



**Reducing Sedentary Behaviour in the Workplace:
A Theory-led Multicomponent Intervention**

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Declaration

This thesis is submitted by the undersigned to Trinity College Dublin for the examination of the degree in Doctor of Philosophy. All work described herein is entirely my own work. Full and informed consent was obtained from all participants involved in the research. I declare that this thesis has not been submitted as an exercise for a degree at this or any other university and it is entirely my own work. I agree to deposit this thesis in the University's open access institutional repository or allow the Library to do so on my behalf, subject to Irish Copyright Legislation and Trinity College Library conditions of use and acknowledgement. I consent to the examiner retaining a copy of the thesis beyond the examining period, should they so wish (EU GDPR May 2018).

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Gail Nicolson

26.02.2021

Summary

There is strong evidence demonstrating that there is a relationship between greater time spent in sedentary behaviour (SB) and greater all-cause mortality, cardiovascular disease mortality and incidence, type 2 diabetes incidence, and incidence of colon, endometrial, and lung cancer. The use of multi-level interventions developed using participative approaches targeted at specific at-risk subgroups can be helpful in reducing SB.

Objectives and methods

The aim of this PhD research was to develop, implement and evaluate an evidence-based pilot intervention to reduce SB in an adult male population, guided by the socio-ecological model throughout. A multiphase mixed method design was applied to achieve four objectives. The first was to describe the prevalence and correlates of domain-specific prolonged SB using secondary analysis of an Irish cohort dataset. The second objective was to explore the barriers and facilitators to reducing SB in the workplace setting in which most SB occurs using a qualitative approach. The third objective was to adopt a qualitative participatory approach in the development of a workplace pilot intervention to reduce SB in two worksites, with managers and employees. The fourth objective was to test the acceptability and feasibility of a small-scale theory-based intervention to reduce SB in a workplace population using mixed methodology to collect objective and subjective data. The primary outcomes of the study were acceptability and feasibility of assessments, study procedures and processes from an employee and management perspective, recruitment and retention, and a qualitative evaluation of participants' perspectives of the intervention overall.

Main findings

The results of Study 1 revealed that Irish adults (n= 7,328) self-reported a median daily sitting time of 450 minutes/day (7.5 hours), and the workplace was the context in which most sitting occurred (>3 hours/day). Males, with third level educational attainment, with professional occupations, and who lived in an urban location reported the longest sitting times (mean 497.6 mins/day; SD 192). The findings informed the choice of the target population and setting of Study 2, which explored professional men's perceptions of the barriers and facilitators to reducing workplace SB.

Study 2 demonstrated that the primary barrier to reducing workplace SB in professional men (n=23) was the primacy of work, *“we have to get through the day’s work so that’s the reality at the end of the day”*. The main facilitating factor was the motivation to break up prolonged sedentary behaviour as a result of the increased awareness of the dangers garnered from the education session, and the level of PA needed to attenuate the risks, *“that you have to do 70-90 minutes a day of exercise to offset 6 hours of sitting down, I mean that’s pretty stark”*. Ensuring minimal impact on work productivity and capacity was an important facilitator to employees and managers, *“as long as we can fit in that and everyone is still as productive as they are today, or more in some ways hopefully, I don’t have an issue”*.

Flexible and supportive management staff was a key facilitator for employees to reduce their SB at an organisational level. Employees acknowledged, *“[managers] encourage us to do various things to achieve that and make us happier, if you’re happier, you’re healthier”*. At an environmental level, the restrictive traditional work desk was a barrier to movement, and an *“an alternative as opposed to sitting”* was sought by participants to aid the reduction of occupational SB. Active sitting as opposed to reduced sitting was favoured by the participants, *“[if] there’s things you can do while you’re at your desk, while still getting through your work, [I’d be] 100% behind it”*.

The results of the participative approach in Study 2 confirmed that participants were supportive of each proposed intervention component, and of the study overall. Participants confirmed the appropriateness of the pedal device, *“It’s a very good idea. It’s very subtle”*. The mHealth component using a physical activity tracker watch and its associated platform to target behaviour change techniques was of interest and deemed acceptable to the participants in both worksites. The study design and measures overall were concluded as acceptable, context-appropriate and suitable to the target users in both worksites, *“they’re not invasive in your life or in your working day so I can’t see any barriers, I can only see benefits to be honest”*.

The pilot feasibility study was developed using the socio-ecological model. The results of Study 3 showed that the intervention, as well as the trial processes were somewhat acceptable and feasible to conduct (n=21). Trial-related accelerometry outcome measures were collected from 85.5% of participants. Recruitment rate was 40% at cluster level, and at an individual level 73.3% of target sample were recruited. Retention was 95% from baseline to post-intervention (8-weeks). The main intervention benefit was an increase of the awareness of the dangers of SB, at both management and employee level, *“definitely think because we were doing the study it would make you think about moving”*. Minimal impact on productivity from pedalling

was observed from a management perspective, *“is it disrupting their productivity? I have to say they were doing it as they were working”*. The main intervention barriers were time priorities and the sometimes uncomfortable ergonomic set up of the pedal machine, with some participants expressing that this was *“too difficult to overcome”* at times and would require assistance in future studies. Mean cycling time was 27 minutes/day (SD 10.23) in the intervention period. Workplace SB was reduced by 20.4 minutes/day, and total weekday SB reduced by 45.7 minutes/day in the intervention period compared to the control period.

Conclusion

This intervention was the first of its kind to specifically target this at-risk sub-group population and address the main influences of workplace SB pertinent to them. This PhD research presents a formative, iterative, participatory, and evidence-based multicomponent approach that was guided by the socio-ecological model at all stages of the research design, development, and evaluation. The study has demonstrated the acceptability of a multicomponent intervention to reduce workplace SB in professional men. However, considerable assistance with the ergonomic set-up of the pedal device, and automatic recording of pedalling bouts are required before future implementation as an initiative to reduce workplace SB. This thesis provides important exploratory findings, and key considerations for researchers to utilise in behaviour change interventions to reduce occupational SB, detailing barriers and issues that should be attended to in future evaluations.

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List of Abbreviations

AEE: Actual energy expenditure
AIM: Acceptability of Intervention Measure
AUDIT-C: Alcohol Use Disorders Identification Test
BCT(s): Behaviour Change Technique(s)
BEE: Base energy expenditure
BMI: Body mass index
BMR: Basal metabolic rate
CI: Confidence interval
COM-B: Capability- Opportunity – Motivation -Behaviour
CONSORT: Consolidated Standards of Reporting Trials
COREQ: Consolidated criteria for reporting qualitative research
CVD: Cardiovascular disease
DEDIPAC: DEterminants of DIet and Physical Activity
DLW: Doubly Labelled Water
EE: Energy expenditure
EMA: Ecological Momentary Assessment
FIM: Feasibility of Intervention Measure
GAPPA: Global Action Plan Physical Activity
HR: Hazard ratio
HRM: Heart rate monitor
IAM: Appropriateness of Intervention Measure
IPAQ: International Physical Activity Questionnaire
IQR: Interquartile range
ISPAH: International Society Physical Activity & Health
Kcal: Kilocalories
LPA: Light physical activity
MET(s): Metabolic equivalent(s)
mHealth: Mobile health
MOST: Multiphase Optimisation Strategies
MPA: Moderate physical activity

MVPA: Moderate-vigorous physical activity
NCD(s): Non-communicable disease(s)
NHANES: National Health and Nutrition Examination Survey
NPAP: National Physical Activity Plan
OR: Odds ratio
OSPAQ: Occupational Sitting Physical Activity Questionnaire
PA: Physical activity
PAQ: Physical activity questionnaire
PARQ: Physical Activity Readiness Questionnaire
PIL: Participant Information Leaflet
QoL: Quality of Life
SB: Sedentary behaviour
SCT: Social Cognitive Theory
SD: Standard deviation
SEC: Socioeconomic classification
SEM: Socio-ecological model
TEE: Total energy expenditure
TIDieR: Template for Intervention Description and Replication
TILDA: The Irish Longitudinal Study of Ageing
TPB: Theory Planned Behaviour
TRA: Theory of Reasoned Action
UWES: Utrecht Work Engagement Score
VPA: Vigorous physical activity
WHO: World Health Organisation

Dissemination of Findings

Peer-reviewed Publications

Nicolson G, Hayes C, Darker C. Examining total and domain-specific sedentary behaviour using the socio-ecological model – a cross-sectional study of Irish adults. *BMC Public Health*. 2019 Aug 22;19(1):1155. (Appendix A)

Nicolson, G.H., Hayes, C. & Darker C. A theory-based multicomponent intervention to reduce occupational sedentary behaviour in professional male employees: protocol for a cluster randomised crossover pilot feasibility study. *Pilot Feasibility Stud* 6, 175 (2020). (Appendix B)

Nicolson G, Hayes C, Darker C. A randomised feasibility study to investigate the acceptability and feasibility of a multicomponent intervention to reduce the sedentary behaviour of professional male office employees. *International Journal of Environmental Research and Public Health*, 2021.

Poster Presentations

Nicolson G, Hayes C, Darker C. Examining total and domain-specific sedentary behaviour using the socio-ecological model – a cross-sectional study of Irish adults, *Sphere Conference*, Dublin, Ireland, February, 2019.

Nicolson G, Hayes C, Darker C. Examining total and domain-specific sedentary behaviour using the socio-ecological model – a cross-sectional study of Irish adults. *International Society for Behavioural Nutrition and Physical Activity*, 18th Annual Meeting, Prague, Czech Republic, June, 2019.

Oral Presentations

Nicolson G, Hayes C, Darker C. A theory-based multicomponent intervention to reduce occupational sedentary behaviour in professional male workers: a cluster randomised crossover pilot feasibility study. *International Society for Behavioural Nutrition and Physical Activity*, 19th Annual Meeting, Online, June, 2021.

Nicolson G, Hayes C, Darker C. Reducing workplace sedentary behaviour: An exploration of professional men's facilitators and barriers to reducing prolonged sedentary behaviour, *An Ecosystem Approach to Health Enhancing Physical Activity Promotion*, 11th Annual Conference, August/September, 2022* (*Postponed from September 2020 due to Covid-19)

Chapter 1 Introduction

1.1 Non-communicable disease

Worldwide, forty-one million people die per year from non-communicable diseases (NCDs), equivalent to 71% of all deaths (1). In Ireland, NCDs account for 76% of total deaths, and three quarters are due to four main conditions – cardiovascular disease (CVD), cancer, type 2 diabetes and respiratory disease (2). NCDs are extremely costly in terms of population health and to the economy, and are largely preventable (2). One of the main contributors to NCDs is physical inactivity (3). The physical, economic and social environments in which modern humans operate within the contexts of their daily lives have been rapidly changing, and particularly so since the middle of the last century (4). Over time, quantum advances in technology and agriculture have systematically reduced demands for physical activity (PA) and energy expenditure (EE) (5). In modern times, societies have constructed an ecological niche in which sedentariness and unhealthy eating are now a reference of living (4).

1.2 Physical Activity

Physical activity is defined as any bodily movement produced by skeletal muscle that requires EE (6). Figures show that 31% of the population worldwide do not engage in sufficient activity needed to balance calorific intake with EE (7). In Ireland, 54% of adults do not comply with the National Guidelines on Physical Activity for Ireland, and so are ‘physically inactive’ (8,9). Physical inactivity is defined as failing to achieve 150 minutes of moderate-intensity physical activity (MPA), or 75 minutes of vigorous-intensity physical activity (VPA) per week, or equivalent (10).

The 2018 Physical Activity Guidelines Advisory Committee Scientific Report (11) synthesises the available literature and concludes that there is strong evidence of a clear inverse dose-response relationship between regular physical activity and all-cause mortality. Reduced PA is causative in the development of major modern chronic metabolic diseases, including obesity, insulin resistance, dyslipidemia, type 2 diabetes, hypertension, and others (11). Apart from activity, or lack thereof, over the last two decades, time spent sitting (sedentary) has become a matter of concern in public health. It is noteworthy that the recent 2018 Physical Activity Guidelines Advisory Committee Scientific Report (11) systematically assessed the effects of a health risk behaviour not previously examined in the 2008 Report (12), and expanded the list of contributory health behaviour to include ‘sedentary behaviour’.

1.3 Sedentary Behaviour

The last decade has seen an exponential growth in research concerned with sedentary behaviour (SB). Although often conceptualised as reflecting the lower end of the physical activity spectrum, sedentary behaviour can be seen as distinct from a lack of PA (13).

Independent and qualitatively different health effects of prolonged SB on human metabolism, physical function, and health outcomes have been found; concluding that SB should be treated as a separate and unique construct (13,14). As behaviours move along the physical activity continuum they may provoke different physiological responses (13). Alterations in metabolic pathways resulting in metabolic inflexibility occur independently of measurable changes in EE when individuals engage in prolonged SB (15). These changes include a reduced capacity to use fat as substrate, muscle atrophy, a resistance to the effect of insulin, and hypertriglyceridemia together with ectopic fat storage (15,16).

To define this relatively recent ubiquitous behaviour, clearer delineations of sedentary behaviour and physical inactivity have been accepted. Physical inactivity is an insufficient PA level to meet present PA recommendations (17). The term sedentary behaviour refers to sitting-lying behaviours rather than a simple absence of PA (18). Tremblay et al. (19) have described SB as a lack of ambulatory movement in any posture, and is defined as behaviour while awake and in a sitting, reclining or lying posture, and is characterised by an EE of ≤ 1.5 metabolic equivalents (METs) (17).

In some of the original epidemiological studies concerned with too much sitting and its associations with cardiometabolic outcomes, TV viewing was examined as a marker for SB (20–22). Since then a large body of evidence has been generated by examining links between SB and negative health outcomes (23,24), interventions to reduce SB (25), and its correlates and determinants (26,27). A key outcome being that while moderate to vigorous physical activity (MVPA) had been the primary target for public health guidelines for decades (28,29), the deleterious health effects of prolonged SB were reported as independent of MVPA. Stamatakis et al. (30) have highlighted that the issue stemmed from two coinciding publications – one being the Science Advisory from the American Heart Association stating that ‘it is likely that sedentary behaviour influences risk in part through some distinct mechanisms that act independently of MVPA’ (pg. 8) (31). At the same time, a second study (n= 1,005,791 for all-cause mortality) reported on pooled individual participant meta-analysis of self-reported sitting studies as part of the Lancet Series on Physical Activity (32). This study found no evidence for an association between sitting time and CVD mortality risk in those in the top PA quartile. Similar results for cancer and all-cause mortality were found. Figure 1 is a conceptual

diagram of how SB associations with long-term health effects may be dependent on PA. SB significantly increases cardiometabolic and mortality outcomes, however, the associations are dose-dependent, and PA is likely to alleviate the adverse associations (33).

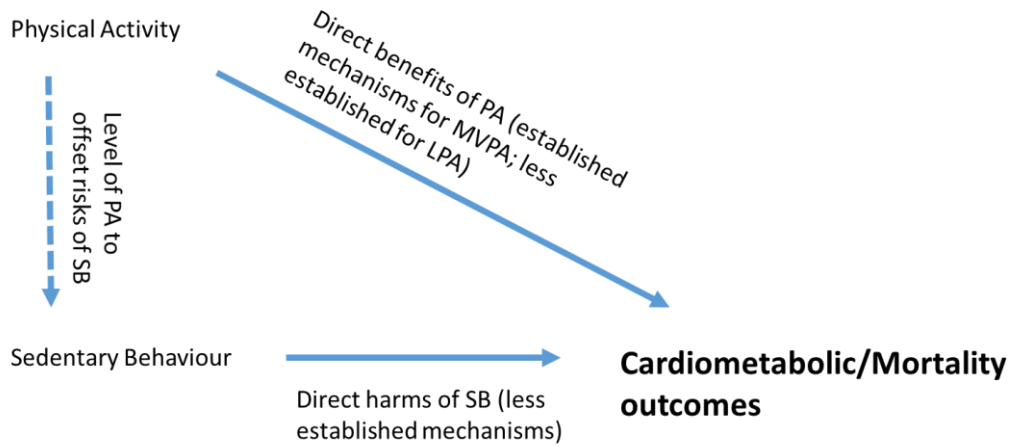


Figure 1 Conceptualisation of the associations between SB and cardiometabolic/mortality outcomes and PA as a moderator of effect (30)

Biological mechanisms used to explain this suggest that unique molecular, physiologic, and clinical effects of too much SB (inactivity physiology) come into effect that are separate from the responses caused by structured exercise (exercise physiology) (13,34,35). The amount of PA needed to mitigate the risks associated with prolonged SB is equivalent to 3.5 times the World Health Organisation (WHO) recommendations (36). As many currently struggle to meet the minimum guidelines, the reduction of risk may apply to a small proportion of the population. Importantly, adults can meet public health guidelines on PA, but if they sit for prolonged periods, they risk metabolic-related disorders because of the unhealthy molecular signals causing metabolic diseases during long periods of SB. This underlines the importance of attempting to reduce SB at a population level.

1.4 Public Health

From a public health perspective, the evidence base is incomplete and insufficiently developed to provide quantitative guidance on recommendations on levels at which risks associated with SB may occur (37). However, prospective studies have generally indicated that overall time spent in SB is associated with all-cause mortality and cardiovascular disease mortality (38–40). The recent WHO ‘Guidelines on Physical Activity and Sedentary Behaviour’ (41), for the first

time provided recommendations on the associations between SB and health outcomes. The guidelines strongly recommend that for health benefits, adults should limit their sedentary time, and replace it with PA of any intensity, including light intensity PA. It is imperative for public health, however, that this rapidly accumulating evidence is gathered and synthesised so that quantitative guidelines and recommendations are produced and disseminated to the public, and importantly, so that researchers can utilise evidence based guidelines in the design of interventions that provide the most benefits to health.

1.5 Workplace sedentary behaviour

As far back as the 1950s, SB in the workplace has been mooted as a potential risk factor for cardiovascular health. Morris and colleagues (42) reported that employees in occupations requiring primarily sitting (bus drivers), had a higher incidence of coronary heart disease than employees who were required to walk about in their daily work (conductors). For many full-time employed adults, the majority of their sedentary time occurs at work, where typically they spend on average more than eight hours of their weekdays (43,44). Although there may be large individual variability, with some individuals sitting for <25% of their workday, others spend the vast majority (>85%) of their day in work being sedentary (45–47). Furthermore, a considerable proportion of workplace SB is accrued in long unbroken bouts of >30 minutes (43,48), which is negatively associated with cardiometabolic health biomarkers (49,50).

Given that 64.7% of Irish adults are in employment (51), the workplace is a key setting in which to introduce strategies to reduce SB (52). Findings from studies using hip-worn accelerometer data suggest that the occupational categories with the highest proportion of time spent sedentary in an average day – including both work and non-work time – are engineers, scientists, architects (65.0% of their day sitting), and management-related occupations (60.3%), while the lowest are waiting employees (39.8%) and cleaners (42.4%) (53,54). Office employees are one of the largest occupational groups in high-income countries (55), and are sedentary for a majority of their day. Reducing this population's SB, by replacing it with PA, could have important public health implications in terms of the associated with chronic disease and mortality (52).

1.6 Socio-Ecological Conceptual framework

Socio-ecological models (SEM) of SB have been used to depict behaviours at an individual level, such as lifestyle and biological factors that determine health status, as operating within

social networks, working, domestic environments, and the socio-political environment (56). Advocates of SEMs particularly emphasise the behaviour settings approach (57). The model highlights that context-specific influencing factors are of particular relevance to behaviour change (56–58). The SEM allows the recognition of the complexity of health behaviours and these complex behaviours are unlikely to have simple cause and effect pathways (58). Single-lens approaches fail to consider the broader social and environmental context in which the behaviours occur, therefore cannot sufficiently achieve changes that are of public health significance. The SEM approach to behaviour expects that all levels of influence must be recognised and targeted to achieve successful behaviour change (Figure 2).

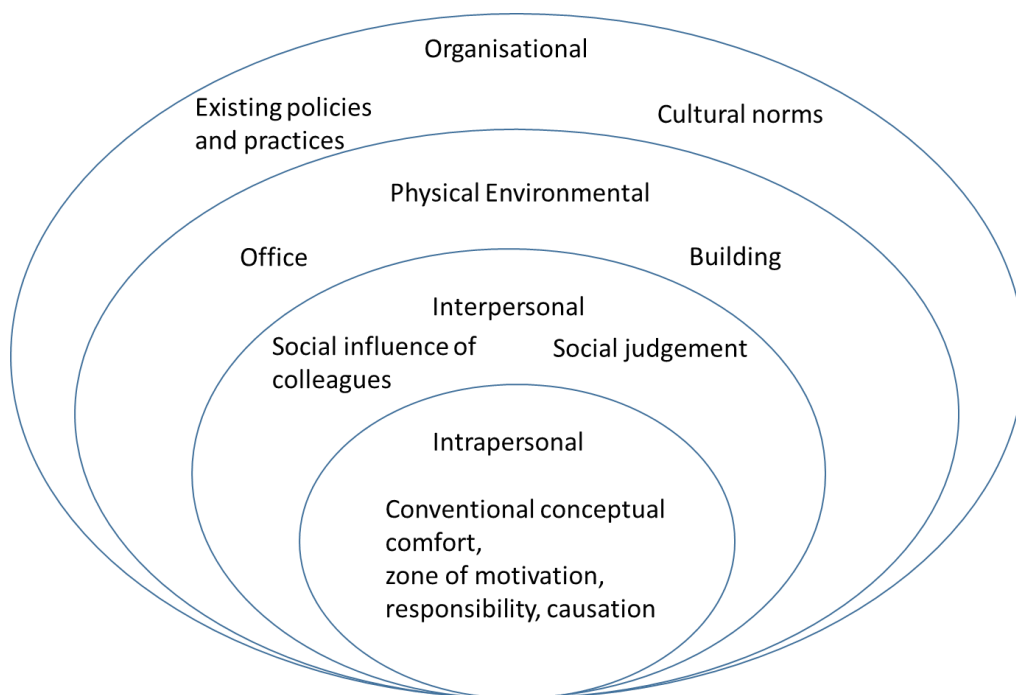


Figure 2 Socio-ecological of health behaviour in the workplace (58)

These influencing factors are context-specific, interacting, and multi-level (56,59). For example, in terms of influencing behaviour change of workplace SB, as well as motivation, self-efficacy, and amenability to change at an individual level, is the physical environment (e.g. traditional work stations set up for sitting), and the social climate, which can evoke strong perceptions and beliefs regarding social norms and expected behaviours. At an organisational level, support or lack thereof from management employees to employees' intervention participation and engagement can be a major influencing factor in reducing workplace SB (60,61).

Socio-ecological perspectives of health behaviours have 5 key principles (58):

1. health behaviours are influenced by multiple levels of factors
2. significant determinants of health behaviours operate in environmental contexts
3. there is an interaction of influences on behaviours across levels
4. SEMs should be behaviour specific
5. to change behaviours, multi-level interventions are most effective

Importantly, the SEM has much in common with best practice in promoting health behaviours. For example, the Ottawa Charter for Health Promotion emphasises the importance of a multi-faceted approach (62). The Charter recommends that as well as supporting and educating individuals, the provision of a supportive environment and sufficient resources are ideal conditions to encourage healthy behaviours. Furthermore, the WHO's 'Healthy Workplaces Model' (63) highlights four areas to include in strategies to improve workplace health: the physical workplace environment; psychosocial work environment; personal health resources; and enterprise community involvement. In order to successfully target such a ubiquitous and prevalent behaviour at a population level, it is necessary to incorporate the various and interacting factors across settings (58).

In a recent review focusing on factors important in developing, implementing and evaluating workplace interventions to reduce SB, a key point highlighted was how crucial it is to explore the context-specific barriers and facilitators as the first step in the development of successful interventions (64). This important phase attempts to understand the previous experience of the intervention's target population with a view to anticipating beforehand the issues that may arise, and resolving them prior to commencement of the intervention, and is in line with guidance from the Medical Research Council (MRC) on intervention development (65). Formative research assesses the beliefs, attitudes, needs and situations of the people who will be using the intervention (66). Consulting with, and involving all stakeholders, both employees and managers, in the planning of an intervention provides an understanding of salient factors that are different within each group with regard to the different elements of the intervention (67).

The challenge now is to use a rigorous and relevant research agenda, utilising the socio-ecological framework, to develop and test a multi-level intervention in the key setting of the workplace, and in the target population most at risk.

1.7 Outline of Thesis

This thesis comprises six chapters describing the background to and stages of development of a theory-led intervention to reduce workplace SB, and the acceptability and feasibility testing of the resulting multicomponent intervention. The combined findings from Chapters 3 and 4 informed the development of the intervention to reduce workplace SB, which then underwent acceptability and feasibility pilot testing (Chapter 5). The following is an outline of the structure of the thesis:

- The current chapter (Chapter 1) details the background to and rationale for this PhD research
- Chapter 2 describes a review of the literature, and explores the effectiveness of behaviour change interventions to reduce workplace SB. This chapter also outlines theories used in interventions to change behaviour, as well as a description of the methodology (mixed methods) that was employed in this research
- Chapter 3 presents quantitative results of secondary analysis of the Healthy Ireland (2016) survey on the sedentary behaviour of adults living in Ireland
- Chapter 4 presents qualitative research with professional desk-based employees and their managers
- Chapter 5 describes the design, development and testing of the acceptability and feasibility of a multicomponent intervention to reduce workplace SB
- Chapter 6 provides the discussion, which summarises and integrates the overall findings from this research, and from each stage of the work and its contribution to the literature. It highlights the strengths and limitations of this thesis and potential implications for further research, practice, and policy.

Chapter 2 Literature Review

2.1 Scope of the Literature Review

The scope of this literature review centres on chronic disease prevalence and risks; how the contemporary risk factor sedentary behaviour (SB) is associated with detrimental health outcomes; as well as the known benefits of physical activity (PA) to population health.

Recommended guidelines for SB and PA health behaviours, methods of measurement, the associated correlates and determinants of PA and SB, and the domains and settings in which SB is most likely to occur, are described in detail. An outline is provided of behaviour change theories, how they can be used to inform the design of complex interventions, as well as the rationale for a pragmatic approach to this pilot feasibility study using mixed methodology.

2.2 Non-Communicable Disease – Definition and Global Prevalence

For much of the human population, medicine, public health, the pharmaceutical industry and education systems have greatly reduced infectious diseases and early life mortality, resulting in record average life spans (68). In place of infectious diseases, most people now die from chronic diseases (69). Chronic disease or non-communicable disease, is defined as a disease slow in its progress (possibly decades) and long in its continuance, as opposed to acute disease, which is characterised by a swift onset and short course (68). Non-communicable diseases (NCDs) are the result of a combination of genetic, physiological, environmental and behavioural factors (69). The World Health Organisation (WHO) has reported that 41 million people die each year as a result of NCDs, equivalent to 71% of all global deaths (69). Fifteen million premature deaths (i.e. 38%), defined as those that occur between the ages of 30 and 69 years each year, are attributable to NCDs (70). The four main NCDs are cardiovascular diseases, which accounts for the majority of NCD deaths, or 17.9 million deaths a year, followed by cancer – 9 million; respiratory diseases – 3.9 million; and diabetes – 1.6 million deaths per year worldwide (69).

Forces that drive these diseases are the globalisation of unhealthy lifestyles and population ageing (71). Modifiable behaviours such as: tobacco use, unhealthy diet, harmful use of alcohol, a lack of PA and increased SB; all significantly increase the risk of NCDs (11,72). In addition, people are living longer, and by the year 2050 it is projected that the population of those aged 60 years and older will be two billion (73). Sedentary behaviour and a lack of PA may present in populations as metabolic risk factors that increase the chance of developing NCDs, i.e. raised blood pressure, increased blood glucose, elevated blood lipids and obesity

(74,75). One health risk behaviour that annually attributes to 1.6 million deaths is insufficient physical activity (1).

2.3 Non-Communicable Disease in Ireland

2.3.1 Mortality rates due to non-communicable disease in Ireland

In Ireland, NCDs account for 76% of all deaths (2). Three quarters of the 31,134 deaths (16,268 male; 14,866 female) in 2019 in Ireland were due to the four main NCDs (76). Of note, 71% of premature deaths in Ireland are due to these conditions, which are largely preventable. Population ageing means an increase in those with NCDs and likewise increased multi-morbidities (coexistence of two or more chronic conditions). This has profound implications for healthcare systems in terms of the complex clinical care and costs required to care for these patients (77).

2.3.2 Ageing population

The population of Ireland is both growing and ageing. It is now at its largest since the 1860s (4.76 million people) and has been getting steadily older since the 1980s (78). In Census 2016 (78), 37.2% of the population were aged 45 and over, compared with 34.4% in 2011 and 27.6% in 1986. An ageing population means an increase of individuals with chronic diseases and it is projected that this will grow by 20% by the year 2022 (79). Data from the Irish Longitudinal Study of Ageing (TILDA) demonstrated an increased prevalence of hypertension (35% to 38%), diabetes (8% to 11%), heart attack (4% to 6%), stroke (1% to 2%) and transient ischaemic attack (2% to 4%) between Waves 1 (2009) and 4 (2016) of data collection (79). Nearly three quarters (73.25%) of Irish adults aged 50+ years may now live with multimorbidity (80).

2.3.3 Burden to individuals and their families

NCDs represent devastating social, economic and public health impacts (81). The four largest contributors to NCD-related morbidity and mortality can lead to impairments such as amputations, blindness, mobility issues and impacts on speech (82). Such disabilities can reduce productivity, increase demand on the social and healthcare systems and impoverish families (83). NCDs and multimorbidity are known to have a negative effect on quality of life (QoL), a subjective concept with a multidimensional perspective including physical, emotional, and social functioning (84). In Ireland, findings from the TILDA Study found that NCDs affect

QoL through increased deficits in physical body function and activity levels (85). The broad range of NCDs included in the study were associated with a reduced positive affect, reduced control/autonomy, and less enjoyment and fulfilment in life. Reduced QoL has been associated with poorer health and social outcomes (86), and may contribute to the worsening of the trajectory of the conditions (84). It is therefore of utmost importance to prevent NCDs and reduce this burden to individuals and families.

2.3.4 Economic burden of non-communicable disease in Ireland

Due to the four main NCDs, 19% of hospitalisations are as a direct result, and 22% are a contributing factor of these diseases; an equivalent of two out of five hospitalisations (2). As reported by Jennings and colleagues (2), 76%, or 1.8 million of all bed days are used either directly (46%), or as a contributory factor (30%) by these patients (2). Of the total health sector budget, 12.5% was spent on acute hospital care for patients with NCDs in 2011. Healthcare utilisation and costs in primary and secondary care are significantly increased among patients with multimorbidity, and this increases as the number of chronic conditions increase (80,87,88).

In terms of the costs associated with multimorbidity, the addition of each chronic condition leads to significant increases in primary care consultations, hospital outpatients visits and hospital admissions (87). Furthermore, the associated total healthcare costs are €4,096.86 versus €760.20 for those with more than four NCDs versus those with no conditions (87). As outlined in Section 2.3.2, the estimated lifetime prevalence of multimorbidity for older Irish adults is 73.25% (80). Many chronic conditions such as CVD and related comorbidities such as diabetes and obesity are highly over-represented by males. Multimorbid associations for angina, heart attacks, heart failure, irregular heart rhythms, diabetes, and obesity are all significantly more prevalent in men (80).

The current and projected impact of NCDs represents a major challenge, not just for the health services - with expenditure on health comprising the second largest facet of Irish public expenditure after social protection - but its associated economic losses (2,89,90).

2.4 Summary of Section 2.3: The Case for Prevention

NCDs are extremely costly in terms of the individual and family burden, as well as in terms of population health and to the economy. We know that NCDs are largely preventable. We also

know that men are more highly represented in the prevalence of chronic conditions and multimorbidity, in particular CVD, type 2 diabetes, and obesity. Modifiable behaviours affect the risk of dying from NCDs and targeting them is of utmost importance to population health and health promotion to reduce incidence and mortality rates.

A lack of PA, and more recently, prolonged SB, are associated with significant increased health risks and have been given close attention as a way of improving the health of populations. However, definitions and meanings of PA and SB have evolved over time. The following section will outline and delineate the concepts of physical activity, physical inactivity, and sedentary behaviour, as they have appeared in the literature.

2.5 Evolution of concepts –From Physical Activity to Sedentary Behaviour

2.5.1 Definition of physical activity

Caspersen et al. (6) defined physical activity as any bodily movement produced by skeletal muscle requiring energy expenditure (EE). Recently the case has been made for a broader conceptualisation of PA that involves ‘people moving, acting and performing within culturally specific spaces and contexts, and influenced by a unique array of interests, emotions, ideas, instructions and relationships’ (pg.1), to include a potentially a more holistic account of PA (91). PA is positively correlated with physical fitness and can be categorised in various ways including type, intensity and purpose (92). Although PA and exercise have previously been used synonymously, exercise is now delineated as a subcategory of PA which is used for the sole purpose of improvement or maintenance of physical fitness (6). Exercise involves repeated behaviour aimed to maintain or improve components of physical fitness in a planned and structured way.

Four dimensions of PA have been outlined: 1) frequency of engagement in the PA, 2) mode of the specific activity (e.g. walking, cycling, gardening), that can also be defined in the context of biomechanical and physiological demands of the PA (e.g. strength or conditioning training or aerobic versus anaerobic PA), 3) intensity or metabolic demand of an activity, and 4) duration of the activity bout in minutes or hours (93). The common domains of PA also occur in a four-classification schema. These are presented with contextual definitions and examples in Table 1 (93).

Table 1 Domains of physical activity (93)

Domain	Contextual definition and example
<i>Occupational</i>	Work-related – involving manual labour, construction, or farming industries
<i>Domestic</i>	Housework, gardening, caring for child(ren), chores
<i>Transportation</i>	Purpose of going a destination: cycling, walking, taking the stairs
<i>Leisure time</i>	Recreational activities: sports, hobbies, exercise, going to the gym

A common measure of interest in terms of PA is the amount of time spent by an individual within a particular PA intensity threshold. Assessments are frequently concerned with whether an individual is meeting the recommended minimum amount of PA per week to achieve health benefits (11). Worldwide recommendations advise that adults engage in a minimum of 150 to 300 minutes of moderate intensity PA per week – in bouts of any duration – to achieve substantial health gains (41). *Physical inactivity* is an insufficient PA level to meet present PA recommendations. Time spent by individuals in a specified PA intensity threshold range can be defined in absolute or relative terms, i.e. determined by the external work performed, or relative to the individual’s level of cardiorespiratory fitness (Vo_2) (93). Engaging in walking at a speed of 3 miles per hour, for example, can be described as moderate PA, however, individual actual intensity may vary. While walking at this speed is equivalent to 3 metabolic equivalents (METs) in absolute terms, fitness levels differ at an individual level. Thus, from a relative standpoint, one person is performing at moderate intensity level while the other is engaging in light intensity PA (LPA). The Adult Compendium of Physical Activities (94,95) is a widely used resource to estimate and classify the energy cost of human PA. The Compendium provides a comprehensive list of the different types and categories of PA and their associated MET(s) value. It is used as a reference for quantifying the types of activity that characterise light, moderate and vigorous intensity physical activities. This quantification of energy expenditure, however, is an *estimation* of EE and it must be noted that EE varies greatly in those who are overweight, and by age and sex. The Compendium does provide consistency in applying intensity levels to PA derived from questionnaires of both estimates and measured METs. Table 2 provides examples of the PA within each intensity category.

Table 2 Physical activity intensity levels and examples (95)

Physical activity intensity	Examples
<i>Light Intensity Activity (1.6- <3 METs)</i>	Slow walking, light effort household chores, standing
<i>Moderate Intensity Activity (3-6 METs)</i>	Brisk walking, jogging, light swimming, stair climbing, stationary bicycling 30-50 watts, very light to light effort
<i>Vigorous Intensity Activity (>6 METs)</i>	Fast running, competitive sports, step aerobics, stationary bicycling 90-100 watts, moderate to vigorous effort

To meet PA recommendations, around 2% of our waking time needs to be spent in moderate to vigorous PA. By definition therefore, the remaining 98% of our waking time is spent in EE of <3 METs. LPA is defined as any activity with an EE between 1.6–3 METs. The lower end of the EE spectrum, or time spent in ≤ 1.5 METs (e.g. stationary sitting), has been investigated and reported as potentially invoking differing physiological outcomes (96).

Until recently, there has been a lack of a widely accepted and consistently applied operational definition of time spent at this end of the activity spectrum (19). Conflicting definitions of a concept lead to confusion in research. Clearly defined terms greatly improve the clarity of research and discussion related to this important health behaviour and can aid researchers searching for studies specific to sedentary behaviour or physical inactivity (18,19).

2.5.2 Definition of sedentary behaviour

The use of terms such as ‘physical inactivity’, ‘sedentarism’, ‘sedentary activity’, and ‘sedentary behaviour’, have been used interchangeably and calls made to refine definitions have resulted in the development of consensus on terminology (19,97–99). The development of sedentary behaviour is a contemporary research field and has been a complex one. Namely because two definitions exist, i.e. one that is used and mainly reported within biology and health literature by those studying the effect of accumulating SB; and a second definition, mainly reported within the sports and exercise literature, used by those who define ‘sedentary behaviour’ as not engaging in recommended levels of PA. Sedentary behaviour is defined as any waking behaviour characterised by an EE ≤ 1.5 METs, while in a sitting, reclining or lying

posture (17). SB, therefore, typically refers to quiet sitting/lying behaviour rather than a simple absence of moderate to vigorous PA (MVPA).

The 2018 PA Guidelines Advisory Committee Scientific report (11) operationalises the definition of a bout of SB as a period of uninterrupted sedentary time. Whereas a break in SB is operationalised as a non-sedentary bout in between two sedentary bouts.

2.5.3 Conceptualising sedentary physiology: the movement continuum

As behaviours move along the PA continuum they may provoke distinct physiological responses (13). Figure 3 illustrates the continuum of intensity of PA from sleep to vigorous PA and illustrates where SB lies within this continuum.

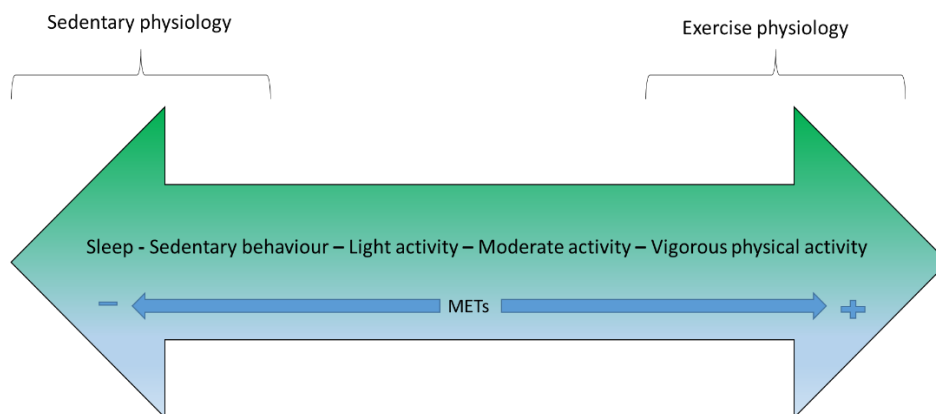


Figure 3 Intensity of activities on the movement continuum from sleep to vigorous activity (13)

Various models and contexts have been used to study the physiological changes that are induced by SB and inactivity. These include animal models, detraining, bed rest, imposed physical inactivity and prolonged sitting time, and provide complementary information that can help build a fuller characterisation of the physiological effects of prolonged SB (100).

Enforced bed rest and spaceflight models impose extreme immobility for extended periods of time, and typically involve healthy young individuals that are unlikely representative of daily living (100). These studies require cautious interpretation as distinct physiological modifications may occur that are different from those while sitting interspersed with incidental movement. However, they can provide mechanistic clues to adaptations and potential mechanisms to immobilisation in the short and longer term. For example, in healthy

populations, evidence was found that 5-10 days bed rest induced dysglycaemia and significant reductions in whole-body, muscle, and vascular insulin sensitivity (101–103). Bed rest also induces a shift in muscle fibre type toward fast-twitch glycolytic type, a resistance to the effect of insulin and a hypertriglyceridemia along with an ectopic fat storage. This mimics the trajectory of pathways observed in the metabolic dysregulation linked with obesity (15).

A recent review outlined the evidence to date on the many physiological responses to immobility such as imposed reductions of ambulatory activity and bed rest studies (104). The transition to reduced activity in laboratory settings resulted in outcomes such as: reduced bone mass density, a reduced capacity to use fat as substrate, muscle atrophy, and differences in adipose tissue adaptation. The key energy and postural features of prolonged SB is that the contractile activity of skeletal muscles, important in supporting upright posture, predominantly ‘flatlines’ while in a sitting, and sedentary posture. This is due to the unloading of the major locomotor muscle groups shown in studies measuring electromyographic activity (105,106).

Metabolic inflexibility is characterised by decreased fat oxidation during fasting and a reduced ability to upregulate carbohydrate oxidation during eating (107). This metabolic dysregulation appears to be a key feature in chronic diseases such as obesity (108,109), insulin resistance (110,111) and type 2 diabetes (112,113). Physical activity is a key predictor of metabolic flexibility (107,114). Prolonged SB triggers a state of metabolic ‘inflexibility’, even among individuals who meet PA recommendations, by disrupting fuel homeostasis and metabolic health. Frequent interruptions to SB with bouts of activity (even 1 minute duration) have been associated with improved metabolic outcomes, including in those who exercise regularly (49,50). Thus, breaking up time in SB is a stimulus for improving metabolic health (flexibility) and has been suggested as a novel and promising strategy in the general population (107). This is particularly relevant in settings where SB is widespread such as office workplaces and may help reduce the risk of and prevent chronic diseases. Furthermore, this research is useful in providing evidence to help refine the guidelines in PA and SB. Regularly breaking prolonged SB with multiple short bouts of PA has an equivalent or favourable impact than continuous PA bouts on the many tenets of metabolic flexibility, which are strongly associated with chronic disease. Therefore, a targeted approach to regularly break SB with any amount of LPA is recommended to produce better outcomes in sedentary individuals (49,115).

The mechanistic evidence base examining metabolic inflexibility and adipose effects, however, remains sparse and it still maturing, and experiments rarely rule out SB as an “innocent bystander” (75). This means that the impacts of SB may simply be part of the physiological

pathways associated with inactivity (116). Furthermore, the current consensus regarding the hypothesised underlying mechanisms of SB and non-communicable disease has been informed by expert opinion, which may be prone to bias. However, sixty years of research investigating metabolic adaptations to bed rest in healthy participants places SB upstream on the list of health risk factors, and as a key determinant involved in metabolic inflexibility (15). The implication of this being the reduction of SB may be of key importance to metabolic disorders such as obesity and type 2 diabetes; and may be a compelling public health strategy to curb the chronic disease epidemic.

2.6 Prevalence of Sedentary Behaviour

As outlined in Chapter 1 of this thesis, we know that 31% of the population worldwide do not engage in sufficient activity (7). In Ireland, the 2019 Healthy Ireland survey reported that 46% of adults achieve the minimum recommendations of PA (8). Just 16% of those over 15 years regularly exercise or play sport (117). More recently, the prevalence of SB among adults and children has been included on the research agenda (118). Similar to PA, SB occurs in various domains and can be categorised into domestic, occupational or school, transport and leisure related (57). Typical SB pursuits include leisure screen-time (i.e. watching television or tablet), using a computer at work, or sitting while taking public transport. It is of interest to understand the associations between patterns of SB, including bouts and breaks, and health outcomes (19). As outlined in the previous section, the effects of prolonged SB may be attenuated by multiple brief bouts of LPA, thus descriptions of total sedentary time, without the provision of information on breaks and bouts does not allow the inference of risk to be correctly estimated (119).

In a nationally representative sample estimating prevalence of the US population from 2001 through 2016, TV viewing SB was reported as at least 2 hours per day (120). The estimated prevalence of total sitting time increased among adolescents and adults, while computer use during leisure-time increased among all age groups. However, SB was measured using self-report measures which is prone to biases including measurement error (described in detail in Section 2.10.5). Furthermore, time spent sitting while using a mobile phone or tablet device was not included in the screen-time sitting measure. This precludes potentially significant sitting time as trends in modes of TV viewing have more recently included mobile devices (121). A final limitation in this study was a lack of differentiation between computer games that are sedentary and those that include a PA element, thereby misclassifying some of the SB

measured, albeit minimal. However, overall, the study provides useful information on sedentary behaviour trends over time in this large generalisable sample and indicates that TV viewing SB has generally remained at a fixed and elevated rate. In a review pooling results of mean sitting times in studies using self-reported and objectively measured methods, Bauman et al. (122) reported that for adults using self-reported measures, estimates of SB were just below 6 hours per day – approximately 2.5 hours less than objectively measured SB (118). Although the data from self-reported studies and objectively measured studies are not directly comparable, the self-reported studies imply that one quarter of adults are sedentary for more than 7 hours/day, whereas the objectively measured studies suggest that three quarters of adults are sedentary for >7 hours/day. This indicates that data significantly differs according to mode of measurement, highlighting the need for objectively measured patterns and the refinement of trends of population estimates. Measurement issues in terms of PA and SB are described in detail in Section 2.8. The risks associated with sedentary behaviour are described in the next section.

2.7 Risks Associated with Sedentary Behaviour

2.7.1 Interaction between sedentary behaviour and MVPA

It has been found that SB and MVPA cause independent cardiometabolic responses which do not align on the PA spectrum (123). For example, Bey and Hamilton (124) reported that, in rats, relative to ambulatory controls, SB was found to decrease lipoprotein lipase (LPL) activity by 55% in oxidative fibres, whereas running caused no increase in relative LPL activity in these fibres. In the linear PA spectrum, the authors expected that the benefits of MVPA would equally and oppositely match the decline in LPL from SB. However, it has been argued that extrapolation of findings from animal studies to the human experience is problematic, and that animal experiments often do not translate into replications in human trials (125,126). Although confirmation of the evidence is required in humans, these findings inform considerations for what may be required to prevent mal-adaptations like these from occurring.

In highlighting this independence between SB and MVPA, Healy et al. (127) found that individuals who met the recommended PA guidelines continued to display associations between increased SB and metabolic risk factors. Therefore, a bi-axial PA spectrum (Figure 4) may be more appropriate in terms of understanding the physiological responses. The y-axis ranges from high SB to low SB and the x-axis ranges from insufficient MVPA to sufficient MVPA. This allows for the recognition of the 'active couch-potato lifestyle'. These individuals

are classified as 'active' under current PA guidelines but spend the majority of their day being sedentary (123,127).

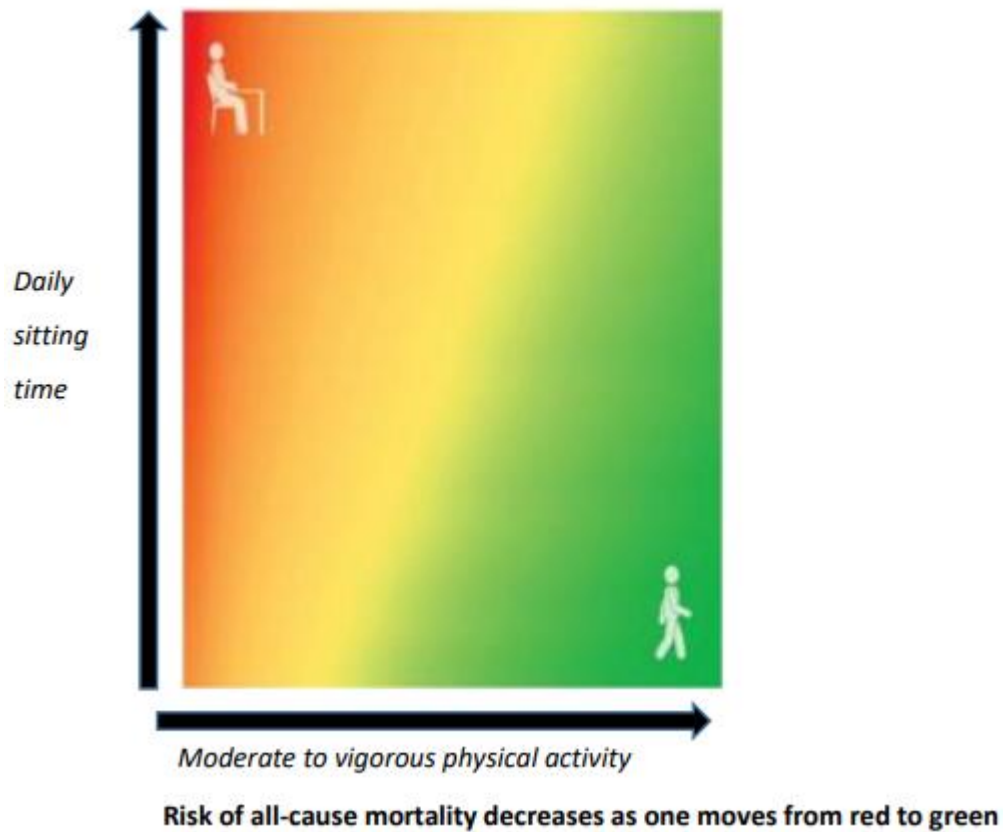


Figure 4 Relationship between sitting and all-cause mortality, stratified by amount of MVPA (11)

Time spent engaged in MVPA has been found to strongly affect the relationship between SB and all-cause mortality (24,128,129). A recent meta-analysis of one million men and women directly compared the joint effects of different specified levels of PA and sitting time in relation of all-cause mortality (32). Increased sitting time was significantly associated with increased all-cause mortality. The magnitude of increased risk with increased sitting time was found to be mitigated only in very physically active people as illustrated in Figure 5.

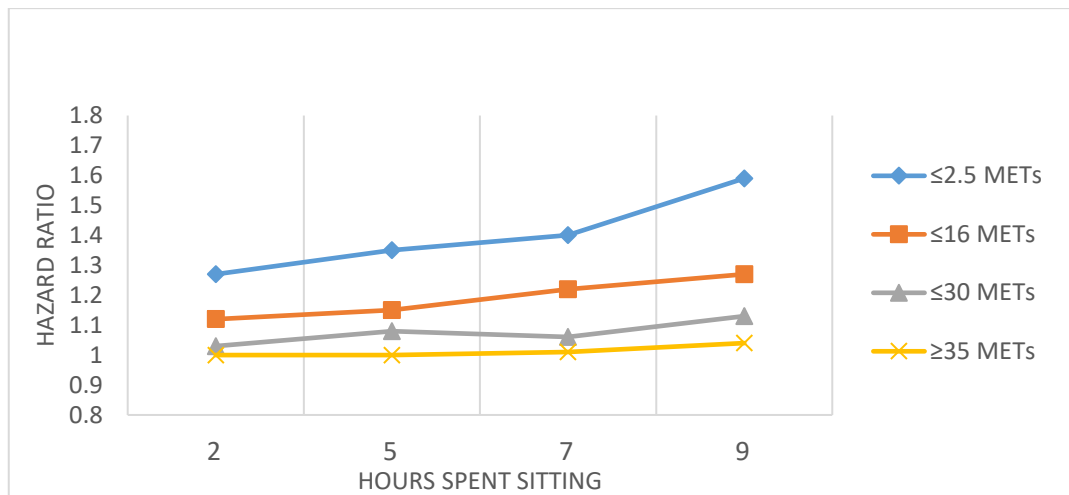


Figure 5 Relationship between sitting and all-cause mortality, stratified by amount of MVPA (Adapted from data in Ekelund et al. 2016 (32))

Those belonging to the most active quartile, i.e. achieving 60-75 min per day of MVPA, but who sit for more than 8 hours per day, seemed to have a significantly reduced risk of mortality. However, the authors of the study acknowledge several limitations in the study; for example, the majority of the data included in the meta-analysis were from participants who were 45+ years old, and male and female data were combined, precluding sub-group analyses from being conducted. These issues reduce the generalisability of the findings. Furthermore, self-report measures were used in the studies included, thereby introducing measurement error as a result of biases such as recall bias and social desirability bias. A strength of the study is that it provides greater levels of detail on SB moving beyond simple 'low vs high' and includes 4 categories of TV and daily sitting times.

In terms of the health risks associated with prolonged SB as a separate risk factor, this area has received an increasing amount of attention as a public health problem because of its prevalence and negative associations with health outcomes (11).

2.7.2 Sedentary behaviour and all-cause mortality

Strong evidence demonstrates a significant relationship between longer time spent in SB and higher all-cause mortality rates, with a direct curvilinear dose-response relationship between SB and all-cause mortality (11). In meta-analysis to quantitatively evaluate the association between sedentary time and health outcomes in adult populations, Biswas et al. (24) reported a significant hazard ratio association between all-cause mortality and high levels of self-

reported SB (1.22 [95% CI: 1.09 to 1.41]). The deleterious outcome effects associated with sedentary time generally decreased in magnitude among those participating in higher levels of PA compared with lower levels. Evidence suggests that this relationship is not affected by age, sex, ethnicity or weight status (11). However, it must be noted that the majority of the studies included in this meta-analysis used self-report questionnaires as measures of SB, thereby introducing measurement error and were vulnerable to biased estimates. The authors also highlighted the marked variations in methodological quality and design across the included studies. The results, interpreted with the aforementioned limitations in mind, indicate significant hazards associated with SB and affirm the need for future research to test effectiveness of interventions to reduce this health risk behaviour.

2.7.3 Sedentary behaviour and cardiovascular incidence and mortality

In 2019, in Ireland, there were close to 9,000 deaths from diseases of the circulatory system, equivalent to 1.8 per 1,000 of the population (130). Strong evidence demonstrates a significant relationship between longer sitting times and higher mortality rates from CVD; and the existence of a direct, positive dose-response between SB and CVD (11). Similar to the HR associated with SB and all-cause mortality, Ekelund et al. (32) demonstrated that those who sit for longest and engage in the lowest levels of PA (MVPA ≤ 2.5 METs per week) have 1.7 times increased risk of CVD mortality compared with those in the most active quartile (HR 1.05). The limitations of this study are highlighted above (Section 2.7.1). Evidence suggests that these relationships do not vary by factors such as age, sex, ethnicity or weight status (11).

Prolonged SB (specifically stationary sitting) has been found to be a critical instigator of leg vascular disease due to the low shear stress to which arteries are subjected to in this position (131). The result of the formation of lesions that largely affect the medium to large sized conduit arteries of the lower limbs is a characterisation of peripheral artery disease, which affects 155 million people worldwide (132). An important and consistent finding is that leg blood flow is markedly reduced while sitting, and some movement (such as pedalling) prevents leg endothelial dysfunction (131). An interesting observation is that the detrimental effects of prolonged sitting on endothelial function appears more profound in men compared with young adult women (133). It is suggested that differences in sex hormones could be a protective factor (pre-pubertal girls are not immune to sitting induced leg vascular dysfunction (134)) from peripheral artery disease, which parallels the lower rates of atherosclerotic disease and leg peripheral artery disease in women (135). This finding of higher levels of vascular

responses to prolonged SB in men may have important implications in the design of health promotion interventions. As CVD is the leading cause of death from NCDs, it may be more important to reduce men's SB to prevent disease and improve cardiovascular health.

2.7.4 Sedentary behaviour and cancers

In Ireland, in 2019, 10,000 deaths from malignant neoplasms (cancers) equivalent to 1.9 per 1,000 of the population were reported (130). Cancer was the leading cause of death among individuals aged 35-74 years. The association between SB and cancer is plausible at a biological level. Immune function, chronic inflammation, metabolic function and body composition (research mostly relates to adiposity) are mechanisms that underlie this assumption (136). Cancer is a heterogeneous disease and the major risk factors differ by cancer site, however, some evidence, although preliminary, has demonstrated a relationship between SB and cancers (11). For example, Biswas et al. (24) reported a summary HR of 1.13 (95% CI: 1.05-1.21) and cancer incidence, and HR 1.17 (95% CI: 1.11 to 1.24) for cancer mortality and SB. In meta-analysis of 25 studies, Lynch et al. (137) found that SB increases the risk for endometrial (36%) and ovarian cancers (32%). The limitations of above studies lie in the self-reported nature of the majority of the studies included in these systematic reviews, thereby introducing measurement error and bias inherent in these types of measures of SB.

Ihira et al. (138) evaluated 33,307 participants, aged 50-79 years, over 10.2 years of follow up. In men only, occupational sitting time was associated with total cancer, with multivariable HRs for the ≥ 7 hours/day vs 1 to < 3 hours/day category of 1.12 (95% CI: 0.99-1.26). Among the findings for cancers at specific sites, in men prolonged occupational sitting time was associated with increased risk of pancreatic cancer, with multivariable HRs for the ≥ 7 hours/day vs 1 to < 3 hours/day category of 2.25 (95% CI: 1.17-4.34). In women, occupational sitting times were associated with an increased risk of lung cancer, with multivariable HRs for the ≥ 7 hours/day vs 1 to < 3 hours/day category of 2.80 (95% CI: 1.33-5.90). However, the study used self-report measures for occupational SB, and this also included transportation SB, therefore it cannot be ruled out that the results were affected by misclassification of exposure. Furthermore, the content of the SB was not available in terms of breaks and interruptions to participants' sitting behaviour and could therefore not be evaluated. Johnsson et al. (139) found that women with working history of occupational sedentariness ($n = 29,524$) over a 2 year period had a significantly increased risk of breast cancer (HR 1.20 [95% CI: 1.05-1.37]) compared to those with non-sedentary occupations. Among women younger than 55 years (adjusted HR 1.54

[95% CI: 1.20-1.96]), a stronger association was found, although no association was observed in women 55 years or older. The association did not change after adjustment for participation in competitive sports. Some limitations of this study included sedentary behaviour was not distinguished from time spent engaged in light physical activity. Secondly, the study would have been strengthened with the inclusion of leisure time physical activity in the analyses, however, only participation in competitive sports was included in the study. This effectively rules out a significant proportion of PA that adults generally engage in, as engagement in competitive sports is low in the general population, and this is particularly pertinent in women (140).

Overall, although modest, there is a statistically significant 12% increased risk of dying from cancer in those in the highest versus the lowest categories of SB (137), and occupational sitting is the domain in which the highest risk of cancer incidence is associated.

2.7.5 Sedentary behaviour and brain health

Across lifespan, maintaining and improving brain health is a universal goal. Brain health can be conceptualised as the functioning of the brain in terms of structural and biological markers which have subjective manifestations that include mood, perceptions of quality of life, cognitive function and sleep (11). The 2018 Physical Activity Advisory Scientific Committee report (11) does not include a section on brain health and SB, perhaps indicating insufficient or limited research had been conducted on this health risk at the time of publication. Recently, attention has turned to examining the effects of SB on mental health and the body of evidence is accumulating.

A review examining SB and cognitive function in adults found that high levels of SB are associated with lower cognitive performance in those aged ≥ 40 years, although the attributable risk of sedentary time to all-cause dementia incidence is unclear (141).

Experimental studies manipulating SB have used the exercise withdrawal paradigm, where the experimental condition involved regular exercisers being asked to replace this regular PA with SB for two weeks (142). On average, SB was increased by 32 minutes per day during the experimental condition. Sedentary behaviour caused an increase in mood disturbances; and in those with higher mood disturbances, higher inflammatory responses to mental stress were observed. Using this paradigm, further studies induced an increase of negative mood following several weeks of exercise withdrawal (143,144). However, the explanation for the mood disturbance could be explained by confounding factors not controlled for in these studies.

Both studies recruited previously active adults and the findings may not generalise to the general population. Furthermore, Poole et al. (143) highlight that objective data was not collected regarding diet or perceived distress associated with abstaining from a pleasurable activity, and relied on self-report measures which may have introduced biases in terms of social-desirability or recall bias.

In an overview of systematic reviews, Saunders et al. (145) found that lower levels of SB were associated with higher physical health-related quality of life ($r = -0.15$ [95% CI: -0.21 to -0.10]). All six studies included in the review observed significant associations between higher SB and decreased cognitive function. However, the systematic reviews included in this overview predominantly included studies where the SB was self-reported, which has increased potential for bias when compared with device-based measures. Secondly, the majority of the evidence was based on cross-sectional studies which limits the quality of the evidence in comparison with prospective or intervention studies. In examining the impact of occupational SB and cognition, the authors concluded that overall, replacing seated with nonseated workstations did not negatively impact cognitive function, while 14/38 studies reported that non-seated workstations were associated with a significant improvement in cognitive performance (146).

Using analysis that accounts for the interplay between time spent in PA and sleep (compositional analysis), longer time in SB has been found to be negatively associated with depression symptoms (147). Changes in depression symptoms were moderated by PA and sleep duration, indicating that all 24-hour lifestyle behaviours may be important for health. The authors suggest that more holistic interventions that target a balance between SB, PA and sleep are needed to improve mental health in the general population.

In summary, findings suggest that, in general, high levels of SB are unfavourably associated with cognitive function, depression, disability and PA levels in adults. Furthermore, all-cause mortality, CVD, cardiovascular incidence, and cancers are positively associated with high levels of SB. Occupational SB is particularly associated with cancer incidence and mortality, and these may differ by gender. Notwithstanding the limitations of the studies included in this section for example self-reported measures of SB, which introduces measurement error and risk of bias, the evidence of the health risks associated with prolonged SB is steadily accumulating, however, the benefits of engaging in PA are well established and are outlined in the following section.

2.8 Health Benefits of Physical Activity

2.8.1 Physical activity and all-cause mortality

In Ireland, 14.2% of all deaths are due to physical inactivity, compared with 9% worldwide (148). A reason for the disparity may be the inclusion of mortality data from low income countries in the worldwide figure (3). However, when mortality rates from a lack of PA, are classified in income levels for low, lower-middle, upper-middle, and high-income countries, scores are 4%, 8%, 10% and 11% respectively, Ireland scores high in comparison with other high-income countries. Ireland does, however, score favourably in comparison to the UK in terms of mortality due to physical inactivity (16.9%).

In terms of those most at risk, important evidence demonstrates that inactive individuals may benefit from even modest amounts of activity which provides substantial benefit for postponing mortality.

2.8.2 Physical activity and cardiovascular disease incidence and mortality

Physical activity prevents both the onset and development of cardiovascular disease and is an important therapeutic tool to improve outcomes for individuals with CVD (149). Sustained PA is associated with decreased markers of inflammation, improved metabolic health, decreased risk of heart failure and improved overall survival (150,151). Strong evidence demonstrates that a significant inverse dose-response relationship exists between the amount of MVPA and CVD incidence and mortality (11). The shape of the curve for both is non-linear with the greatest benefit observed early in the dose-response relationship (152). This may be due to replacement of SB with any intensity of PA induces the largest benefits for adults in the low-active group, whereas little additional benefit is noted for adults who are highly active (153). There is no lower limit in the relationship between CVD mortality risk reduction and MVPA, and risk continues to decrease with exposure to 3 to 5 times the recommended MVPA.

The implications of this being, for those engaging in prolonged SB, such as in a workplace setting where work tasks take precedence, compared with continuous bouts of PA, multiple short bouts accumulated across the day are potentially more practical and acceptable, and evidence suggests, may be more beneficial to health.

2.8.2.1 Light intensity physical activity and cardiovascular disease incidence and mortality

The benefits of MVPA are well-documented and strong, however, the benefit of light intensity PA (LPA) in health risk reduction is more recently becoming the focus of research. Calls have been made to explore the role of LPA in the reduction of health risks (11). It has been hypothesised that compared to muscular inertia (sedentary), there may be substantial increases in lipoprotein lipase activity during LPA, suggesting improved metabolism of circulating lipids (124). The origins of the field can be traced to high-profile research carried out at the turn of the century by Levine and others (154,155), who proposed the term 'non-exercise activity thermogenesis' (NEAT). NEAT describes the incidental movement and non-structured light or low-intensity PA (LPA) such as fidgeting, ambulating, and light intensity incidental walking associated with the routines of daily life. This idea posited that obesity could be tackled by energy expenditure increases through this incidental movement, as structured exercise comprises only a very small proportion of daily PA expenditure. In a large epidemiologic study using accelerometry to measure PA, LaMonte et al. (156) found that LPA contributes to better CVD risk factor levels in addition to, and independent of, MVPA in older women.

In a recent review assessing the relationship between time spent in LPA and cardiometabolic health and mortality in adults, Chastin et al. (157) reported that LPA is associated with acute positive effects on glucose and insulin, and potentially all-cause mortality risk reduction. This is in congruence with findings that accelerometer-measured total PA volume, irrespective of intensity, is associated in a significantly reduced mortality risk, with maximal risk reductions seen at 375 minutes/day of LPA or 24 minutes per day of MVPA (158). These studies highlight the dose-response manner in which health outcomes such as cardiovascular risk reduction, which are positively affected when individuals accumulate LPA throughout their daily activities. Nishida et al. (159), in a longitudinal study of 1,238 middle-aged adults, reported that substituting 60 minutes per day of SB for LPA was associated with an increase in a key molecular mechanism that reduces inflammation associated with several lifestyle-related diseases including type 2 diabetes, atherosclerosis and cancers (OR 1.17 (95% CI: 1.07-1.27, $P < 0.001$)). LPA has been found to have an inverse relationship with arterial stiffness (160), and even very light intensity PA is associated with a reduction in BMI (161).

This has implications for health promotion and disease prevention. The findings are important to policy makers and can inform future guideline development by recognising the role of LPA (even very light intensity) in reducing disease.

2.8.3 Physical activity and metabolic risk and diabetes

In drawing together the epidemiological studies that assess the independent association between PA levels and both CVD and type 2 diabetes outcomes, Wahid et al. (162) included 36 studies (33 pertaining to CVD and 3 pertaining to type 2 diabetes) to model the effects of three PA categories (low PA, 0.1-11.5 MET-hours per week; medium PA >11.5-29.5 MET-hours per week; and high PA; ≥ 30 MET-hours per week). Their findings suggest that an increase in 11.25 MET h/week for an inactive individual is associated with a reduction of risk for cardiovascular mortality by 23% and diabetes mellitus incidence by 26%, independent of body weight. In examining levels of metabolic syndrome in white-collar employees (n=311), the OR for metabolic syndrome were 2.03 times higher (95% CI, 1.01–4.09) in the low PA group (self-reported) than in the high PA group (163). The prevalence of metabolic syndrome was 25.2% in the low PA group compared with 14.3% in the high PA group. Similar to MVPA as previously outlined, moderate PA (MPA) conducted in continuous bouts and accumulated across the day provides the same health benefits to metabolic outcomes in terms of insulin and glucose (152). Fractionation of a continuous bout of exercise, into shorter bouts of equivalent exercise to the total duration spread over the course of a day, does not alter its potential to provide health benefits, and may even provide greater weight loss benefits (164).

2.8.3.1 Light intensity physical activity and metabolic risk and diabetes

Improvements in metabolic risk factors such as postprandial glycaemia, following light intensity PA, are similar to that observed following MVPA (165). In Bailey et al. (166), participants replaced sedentary sitting with LPA (on a motorised treadmill) for 2-minute bout durations before returning to a seated position, and for a total of 28 minutes activity. The authors found that bouts of as little as 2 minutes in duration improved postprandial glycaemia that may reduce the associated risk of cardiometabolic disease (166). None of these benefits, however, were observed in those who replaced SB with standing. The findings suggest that standing needs to be accrued in longer duration bouts or that a minimum threshold increase in EE is required; therefore, standing may not provide the metabolic benefits that LPA does. Bond et al. (167) found that sedentary participants in a workplace setting, not only preferred a goal centring on a 3-minute PA break every 30 minutes, but this group also produced significantly greater reductions in time spent sedentary, compared to the 12-minute PA break condition. Duvivier et al. (168) demonstrated that LPA and MVPA have differential effects on cardiometabolic health suggesting that there may be a need to perform both intensities, as well as reducing SB, for optimum health.

2.8.4 Physical activity and cancer

Although there are several identified genetic causes of cancers, most cancers are as a result of lifestyle factors (169). A summary of the associations between PA and specific cancers, as well as the strength of the evidence is outlined in Table 3, and shows that strong evidence exists that PA acts as a protective factor against cancers such as bladder, breast and colon for example, while less evidence is available for hematologic, brain or thyroid cancers. The effects can be seen across factors such as sex and weight status. The data is derived mostly from studies of white individuals, however, existing data from other racial/ethnicities suggests similar risks (170).

Table 3 Summary of associations of physical activity with specific cancers, with Subcommittee-assigned evidence strength (11)

Cancer	Strength of Evidence
Protection from PA: <i>Bladder, breast, colon, endometrium, oesophagus (adenocarcinoma), renal, gastric Lung</i>	Strong
<i>Hematologic, head & neck, ovary, pancreas, prostate</i>	Moderate
<i>Brain</i>	Limited
No effect of PA: <i>Thyroid</i>	Not Assignable
<i>Rectal</i>	Limited

Moderate- to-vigorous and vigorous-intensity PA had similar associations, with endometrial cancer risk of relative risk 0.83 (95% CI: 0.71-0.96) and 0.80 (95% CI: 0.72-0.90), respectively (171). Household PA was associated with a 30% reduced risk; followed by a 19% risk reduction for occupational PA, and recreational PA was associated with 16% risk reduction for endometrial cancer. Being active across a lifetime and beginning in childhood, has been found to lower the risks associated with the development of obesity-related cancers such as breast cancer, colon cancer and endometrial cancer (172). Collectively, there is consistent, compelling evidence that PA plays a role in preventing many types of cancer and for improving longevity among cancer survivors (173), such as findings by O’Neill and colleagues in oesophagogastric cancer survivors (174).

2.8.4.1 Light intensity physical activity and cancer

Schmid et al. (175) investigated intensity of PA as well as type of activity and found that the greatest reduction in endometrial cancer incidence was associated with LPA for which a relative risk of 0.65 was observed (95% CI: 0.49-0.86). Similar to previous findings highlighting the health benefits of LPA (176), engagement in frequent LPA as a replacement to SB, significantly reduces circulatory inflammatory cytokines (159). One example being the reduction of tumour necrosis factor- α which is associated with the development of cancers, in a longitudinal study of healthy middle-aged men and women (159). Light physical activity is associated with reduced endometrial cancer risk (177). This further highlights the importance of LPA as a meaningful target for public health guidelines to enable significant improvements to cancer risk and survivorship.

2.8.5 Physical activity and brain health

Several decades of evidence shows that regular engagement in PA promotes positive mood states, promotes self-esteem, social support and self-efficacy, has anti-depressive effects, can protect people from developing depression, reduces inflammation and increases resilience to oxidative and physiological stress (178,179). Strong evidence demonstrates that acute bouts of MVPA have a transient benefit for cognition, including attention, memory, crystallized intelligence, processing speed and executive control during the post-recovery period following a bout of exercise (11). Fortune et al. (180) demonstrated a significant negative correlation between VO₂ max and reaction time in healthy males compared to their low fit counterparts. The effects are greatest in pre-adolescent children and older adults, relative to other periods of the lifespan.

2.8.5.1 Light intensity physical activity and brain health

Acute bouts of LPA have a positive effect on cognition (11). Although bouts of LPA of 11 to 20 minutes showed the greatest cognitive benefits, Chang et al. (181) reported that very light-, light- and moderate-intensity exercise benefited cognition immediately following, whereas hard-, very hard- and maximal-intensity exercise intensity demonstrated no immediate benefit. Each extra hour of LPA, but not moderate to vigorous PA, was associated with increase brain volume equivalent to 1.4 to 2.2 years less brain aging (182). This suggests that the potential benefits of PA on brain aging may accrue at lower and more achievable levels of PA intensity or duration.

2.9 Summary of Sections 2.7 and 2.8

Sedentary behaviour is associated with increases in the risk of a large number of diseases and conditions, especially NCDs (11). Scientific evidence demonstrates that more time spent in SB is related to greater all-cause mortality, CVD mortality and incidence, type 2 diabetes incidence, and incidence of colon, endometrial and lung cancers (11). Occupational SB in particular is associated with metabolic disturbances and cancers. Some limitations in the evidence are noted, in particular, as outlined in many studies included in this review, self-report measures to collect data on SB were employed in the majority of studies, increasing the potential for biases and measurement error. However, in terms of the association between SB and all-cause mortality, CVD mortality and incidence, type 2 diabetes incidence - evidence is deemed 'strong' by the PAGAC (11). The evidence in relation to the association between SB and all-cancer mortality, however, is categorised as 'weak' in the PAGAC report, as the results of the studies included in the synthesis of the findings were not always consistent – with one study reporting associations in women only, one in TV viewing but not sitting time, and one in smokers only. Furthermore, cancer screening and treatment availability and efficacy affect associations between specific cancer risk factors and cancer mortality. These were not controlled for or considered in the studies.

Notwithstanding the limitations outlined, evidence in the past decade has greatly expanded the list of diseases and conditions for which greater amounts of PA reduce the risk (11,183). The beneficial effect of MVPA has no lower threshold, with at least 70% of the potential benefit to all-cause mortality reached by achieving the minimum recommendation of 150 minutes per week (11). Importantly, the health benefits accumulate as PA is accumulated.

Although it is widely accepted that MVPA has the most potent effect on many health outcomes, various barriers (such as time constraints and preferences) reportedly prevent the achievement of the minimum recommendations. Recent reviews have found significant evidence that engagement in frequent short bouts of LPA substantially improves cardiometabolic health and all-cause mortality (157,184), and is preferable to sedentary employees. Light intensity activity, and its importance to health outcomes, has been recently cited as an overarching research need in the 2018 PA Guidelines Advisory Committee Scientific Report (11). With few exceptions (11), PA guidelines do not explicitly recommend minimum requirements for LPA (185,186). However, in situations such as workplaces, or particular populations (e.g. elderly, those who are particularly inactive), LPA could be more feasible and acceptable. Lower intensity activity requires less motivation for the majority of the population and is incidental to daily living. LPA could be a pragmatic additional target for future

interventions and public health guidelines for health promotion (157,158). To attenuate the relationship between SB and mortality, the 2018 PA Guidelines Advisory Committee Scientific report (11) recommends that inactive individuals replace SB with LPA. Importantly, the domain in which the SB occurs may have different health outcomes, which may have important implications to intervention development and design in the settings approach (187).

2.10 Measuring Sedentary Behaviour and Physical Activity

It is of utmost importance for public health agencies to monitor the status and prevalence of important health-related behaviours such as PA and SB (188). This is a critical factor in the allocation of public health resources. Large scale epidemiological studies and adequate surveillance systems are required to monitor PA/SB time and evaluate its impact on populations, as well as benchmarking current activity levels and setting targets (189,190). National surveillance also enables participation of countries in worldwide initiatives such as the Global Observatory for PA country cards (191), and large cross-national academic studies (192). Accurate and valid methods to assess the frequency, duration, and volume of exposure to SB and levels of PA, while minimising bias, must be considered by investigators, and are described in the following section.

2.10.1 Energy expenditure

Measuring levels of EE, during volitional and non-volitional human activities, is important in the field of disease prevention and health promotion. Total energy expenditure (TEE) comprises three components: basal metabolic rate (BMR or BEE) \approx 60-75% of TEE, activity EE (AEE) \approx 15-30% of TEE and dietary thermogenesis \approx 10% of TEE (193,194). Over the life course and in different disease states, BEE, AEE and TEE vary. The differences are in terms of age and sex, with older individuals lower than younger people, and males usually higher than females (195). TEE is balanced by energy intake. A fundamental principle of metabolism and nutrition is when energy intake is imbalanced, individuals can become overweight and obese (196). AEE is the most variable part of TEE and is often used to evaluate TEE (197–199).

2.10.2 Metabolic equivalents

To estimate the intensity of PA, application of the metabolic equivalent (MET) is another method used in research and surveillance. One unit of MET represents the resting EE during

quiet sitting and is commonly defined as $3.5 \text{ mL O}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ or $\approx 250 \text{ mL/min}$ of oxygen consumed, which represents the average value for a standard 70 kg person (93). Oxygen consumption increases with the intensity of PA, therefore, a straightforward approach to quantifying the intensity of PA is to use multiples of resting EE. For example, performing an activity requiring an oxygen consumption of $10.5 \text{ mL O}_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ is equivalent to 3 METs (i.e. 3 times the level at rest). Physical activity volume, or total PA level, can therefore be estimated by multiplying the dimensions of intensity, duration, and frequency over a given time period. Physical activity is classified as light-intensity (<3 METs), moderate-intensity (3-6 METs) and vigorous-intensity (>6 METs) (200). PA is commonly estimated by using the MET of the activity. However, the determination of EE in kilocalories is another way to quantify PA.

2.10.3 Kilocalories

Kilocalories are thermal units and since measurement of EE is concerned with the change in energy by measuring heat exchange of the body in its surrounding (201), they can be readily converted to TEE (202). To calculate kilocalories (kcal), one litre of oxygen consumption is approximately equal to 5 kcal of energy (203). For example, a 70 kg person walking for 30 minutes at 4 mph would result in oxygen consumption of 1L/minute, therefore the individual would consume 30 litres of oxygen. This results in a gross EE of ≈ 150 kcal. AEE would be the sum of all the different PA behaviours performed on a given day. EE during AEE directly increases with the mass of the body being moved, therefore it is sometimes expressed relative to body mass as kcal per kg of body mass per minute ($\text{kcal} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) (93). PA results in an increase of EE above resting levels and the rate of EE is directly linked to the intensity of the activity (93). PA related EE is the most variable component of daily TEE; commonly EE is computed by measuring how much time an individual spends in different PA and SB over a given day or week.

2.10.4 Selecting measures of physical activity and sedentary behaviour

2.10.4.1 Validity, reliability, and sensitivity of measures

Several techniques are available to researchers and practitioners when deciding on a measure of PA and SB. While feasibility often drives selection, this depends on the setting, number of participants and cost, as well as the practicality of the measure. Validity, reliability, and sensitivity are methodological effectiveness issues that must be considered. Participant burden and intrusiveness must also be considered in research design. Validity refers to the degree to

which an assessment measures what it intends to measure; while criterion validity is the validation of the measure against the 'gold standard' measure (204). Assurance is provided that the proposed method is an accurate reflection of PA or SB when good agreement between it and the gold standard is achieved. Other forms of validity frequently assessed are concurrent validity (comparison of two measures that give a result that are supposed to be equal), and construct validity (comparison of two measures in the same construct). Reliability refers to the degree to which a measurement produces consistent results on different occasions and there is no evidence of change. Sensitivity is concerned with the extent to which a measure is sensitive to detect true changes in the outcome of interest. Sensitivity to change is not a static attribute and depends on several factors of intervention design: who the results are presented for, which scores are being contrasted, and what type of change is quantified (205). All of these factors require careful consideration prior to selecting methods of PA and SB assessment.

The most common types of measurement used in investigating time in SB/PA are self-reported subjective measures (traditionally includes questionnaires) and device-based objective methods (e.g. motion sensors). The following section will outline the various methods of measurement used in PA and SB research, and a critique of each. It will include laboratory based measures, and the gold standard measure of EE which is considered to be the Doubly Labelled Water technique (206), as well as their strengths and limitations.

2.10.4.2 Measures of energy expenditure

Laboratory-based measures

Measurement of whole-body metabolic rate is performed with direct calorimetry based on the measurement of heat loss from aerobic and anaerobic metabolism, between the body and its environment (207). Indirect calorimetry is based on the measurement of oxygen consumption, carbon dioxide production, and urine-nitrogen loss for energy production from carbohydrate, protein and fat (208). The doubly labelled water method (DLW) is considered the gold standard in the assessment of PA by determining total EE, and was developed in the 1950s by Nathan Lifson and colleagues (202,208). Measurement of EE with DLW is a variation of indirect calorimetry, where EE is derived from the measurement of carbon dioxide production. Due to its invasiveness and relatively high cost, this method is only used in studies with small sample sizes but can provide accurate information about the average level of PA in terms of EE over a 1–3-week period. This technique is useful in PA validation studies.

Direct observation

Direct observation involves a trained observer watching or video recording an individual who is engaging in PA to monitor and record the activity. This method can be used to collect important contextual information which enables the evaluation of the mode, the where and with whom the PA occurs (209). Direct observation requires little inference or interpretation, therefore has high internal validity, or face validity, and is often used as a criterion method for validating other measures of PA, such as self-report or motion sensors (210). However, it must be noted that PA and EE are two distinct constructs: PA refers to observational body movement and the energy expended from PA can only be inferred by observation. This means that the output measure of direct observation is an estimate based on METs (211).

2.10.5 Self-report measures

Self-report measures of physical activity

Total energy expenditure can be determined based on behavioural patterns. Physical activity questionnaires (PAQs) are among the most widely used methods to measure PA. This is due to their ability to collect data from a large number of people at low cost, their convenience, acceptability to participants, and the variability of questionnaires available (85 questionnaires were included in a review of PAQs for adults) (212). The most commonly used PAQs include recall, global, and quantitative history questionnaires (209). Recall questionnaires, such as the IPAQ (short (213) and long (198)), provide accounts of frequency and duration of activities over long periods and are used for surveillance purposes. This type of questionnaire does not alter the behaviour under study, and is possible to assess all dimensions of PA to examine patterns of behaviour (214). Duration of assessment varies from 24 hours to 7 or more days. The main differences between the questionnaires are the amount of supervision required to successfully complete, and the level of detail and length of time assessed. A limitation of PAQs is that although they can encompass longer time frames, this can lead to recall bias. Typically, PAQs are designed to minimise these potential biases as much as possible. For example, the Global PA Questionnaire uses the phrase 'in a typical week' in order to minimise recall bias (215). In some circumstances, very short PA measures are required, some comprising just one question and are used for screening purposes. These global questionnaires, such as the Exercise Vital Sign is a two-item questionnaire and provides a quick overview of a person's activity level (216). They are used to identify whether respondents achieved a specified level of activity for use in clinical practice or to determine their appropriateness for entry to an intervention (217).

The major limitation of questionnaire-based assessments is the ubiquitous overestimation of vigorous PA, and underestimation of daily sedentary living activities (193,218). PAQs may introduce considerable measurement errors, such as response bias (e.g. social desirability), and may have poor validity and reliability (219,220). In terms of validity, previous comparisons of PAQs and DLW highlighted that incorrect reporting of EE by PAQs is common (193). Moreover, a recent review by Sharifzadeh et al. (221) comparing TEE and AEE, estimates from PAQs and DLW found that no PAQ measuring AEE showed an acceptable correlation with DLW. Regarding TEE, only two measures (Active-Q and Three-day PA diaries) had acceptable means and heterogeneity at the population level. In a recent study testing self-report measures of PA in university students (222), the findings showed that the IPAQ-SF was the only measure found to have a significant association with accelerometer derived MVPA and total PA for males ($r = 0.27-0.31$, $p < 0.05$) and females ($r = 0.29-0.33$, $p < 0.01$). However, Kelly et al. (223) argue that a measurement hierarchy has been constructed in relation to various PA measures and how they are validated against DLW – in that objective measures tend to fare better than subjective measures in terms of statistical agreement with the ‘gold standard’. This, they highlight, has resulted in subjective measures considered ‘bad’ and device-based measurement ‘good’. Troiano et al. (224) point out that the low correlations between self-report and accelerometers are as a result of PA assessment methods being distinct and non-equivalent. Kelly et al. (223) highlight that more important validity issues and variability may be introduced via methodological decisions that are made regarding data producing PA and SB outcomes variables. The authors suggest that the validity and reliability of the obtained data, and how the variables are generated are a more appropriate focus rather than the measurement instrument used.

Despite the limitations, PAQs remain the most feasible method of conducting population-level surveillance where the aim is to identify the proportion of a population is meeting a set of parameters such as PA recommendations (225). PA questionnaires are generally easy to administer and are well tolerated by participants (28,226).

Self-reported measures of sedentary behaviour

More recently, and with the exponential growth in SB research attention in the last ten years (30), questionnaires have been designed to measure periods and bouts spent sedentary. SB is difficult to measure (e.g. compared with time spent in MVPA); due to its ubiquitous nature it can be difficult to recall all times spent sedentary. Much of the early (20,22), and more recent

(227) research on SB used TV viewing as a proxy marker for sitting. The problem with TV viewing time is that it is poorly correlated with sitting time. The NHANES study (228) reported weak correlations between TV viewing questions and waist accelerometry. This is also reflected in further studies using waist (229) and thigh-worn devices (230). TV viewing time is also confounded by factors that are strong determinants of poor health outcomes but are not always accounted for such as dietary intake and TV viewing-time snacking (231), socioeconomic status (232,233), and mental health (234).

A recent review of population level questionnaires measuring SB reported on 35 unique SB questionnaires (187). The results indicated reliability and were generally good to excellent for targeting key domains of SB. In the questionnaires used in population studies, low levels of testing for validity were found, whereas questionnaires that had been psychometrically tested have not been employed in larger national/international surveys. As has been described in Section 2.6, some domains or contexts of SB appear to be more consistently associated with indicators of deleterious health outcomes than others. Some types or domains of SB, such as reading and being mentally active while sedentary can be benign, or indeed beneficial (235), and may be associated with a reduction of feelings of depression (236). This multifaceted nature of SB is highlighted by Kelly et al. (223), and the issues with validity and reliability that arise when considering the advantages and disadvantages of objective and subjective measures of SB. In focussing on issues of validity and reliability of SB measures, Kelly et al. (223) argue that this misses the crucial information of what aspects of SB (and PA) the instrument is valid and reliable for. The complexities of behaviours and their domains, dimensions and differing correlates and determinants, may be missed using objective measures, and the identification of 'measurement purpose' has been called for as an important first step in research design decisions. In terms of SB, self-reported measures are low-cost and are valuable to ascertain the types and domains in which the exposure occurs, due to the differing associated health outcomes. This is important to better understand subgroup differences to inform public health strategies to reduce dangerous levels of SB (237,238). The output measures used in PA and SB questionnaires are estimates based on METs (211). One method of self-report employed more frequently in recent years and aims to minimise recall bias, to maximise ecological validity, and allow study of micro processes that influence behaviour in real-world contexts, is the use of ecological momentary assessment (239,240).

Ecological momentary assessment

Shiffman et al. (239) define ecological momentary assessment (EMA) as ‘involving repeated sampling of subjects’ current behaviours and experiences in real time, in subjects’ natural environments’ (pg. 1). EMA has more recently been used in PA and SB research to overcome the challenges of the extensive memory distortion that pervades retrospective self-reported PAQs. Societal changes and advances in electronic technologies have created opportunities to assess PA and SB as they occur in people’s daily lives. The recent use of smartphone applications creates new opportunities for activity monitoring in surveillance and intervention studies (241–243). Understanding more about the contexts of PA and SB can help to address disparities in PA and SB among different populations, such as gender differences (244).

In terms of SB and PA, EMA has been assessed to be a valid and feasible tool to aid the understanding of patterns, as well as the causes and correlates of SB and PA (245,246), and is particularly suitable in workplace settings (241). A limitation however, when measuring PA, is participants not carrying their smartphone when they are engaging in PA, thus resulting in missing data (247). Technological issues such as battery drainage and software malfunctions are further issues that may arise, as well as the potential for participant burden (247).

However, EMA has the potential to generate new insights into the prediction and modelling of PA that build upon, and in some cases, challenge current assumptions that have been garnered from traditional methods.

Self-reported measures of PA and SB remain an active area of research and are now generally considered complementary to objective measures – which are outlined and described in the following section.

2.10.6 Objective measures of physical activity and sedentary behaviour

Pedometers

Objective measures of EE generally comprise pedometers, accelerometers, and heart rate monitors. Pedometers are typically waist-band worn (but can be placed on the ankle or shoe) motion sensors that record movement during gait cycles (248). These devices record steps taken and can estimate the distance travelled if the participant’s stride length is known. This allows the calculation of EE of the PA by estimating the EE associated with walking. Validity assessments have been conducted providing support that pedometers strongly positively correlate with accelerometers in terms of observed time in PA, and negatively in terms of sitting (249).

Accelerometry

Contemporary accelerometers measure movement on three planes (triaxial; X-, Y- and Z-axes), and record activity counts (raw or pure movement data) that are produced by the frequency and intensity of movement, sampled at set intervals (epochs) (250). TEE can be estimated based on individual characteristics such as age, gender, height and body mass (197), and estimated based on the calibration equation (211). Accelerometers have been validated under free-living conditions (251,252). In a recent review of systematic reviews of techniques for PA measurement, criterion validity of the measures was determined by assessing EE via DLW and via direct observation of steps and PA behaviour (253). Accelerometer models have their own algorithms to convert accelerometry counts into kcals or METs, which may lead to different output values depending on the model (254). This may make it difficult to directly compare data from different models.

Accelerometers are non-invasive and useful in laboratory and field settings. They provide indicators of intensity, frequency, duration and minute-by-minute information (255). However, the financial cost may prohibit their use in studies using large numbers of participants. There are limitations with regard to inaccurate classification or assessment of various activities such as upper-body movements, lower-limb and stationary activities such as stationary cycling, and water-based activities (250,254). Investigators are also reliant on participants correctly placing the monitor for accurate readings during long, unobserved periods of data collection.

As triaxial accelerometers use counts per minute as a method of measurement, with a count being the amount of movement and speed in a particular direction, SB was previously defined as <100 counts per minute (256). Lying and sitting positions have been described as sedentary, therefore, a more valid method to measure SB is to use an inclinometer (257). Inclinometers not only discriminate between SB and PA behaviours, but provide information on the position or posture of the participant which is important to allow objective examination of activity behaviours, especially in studies assessing SB in detail (258,259). Both inclinometry and accelerometry are not considered appropriate methods for specific SB modalities such as TV time or reading. To collect this level of detail of SB context, direct observation or detailed diaries/logs are considered more useful measures to examine specific domains of SB (187). Inclinometry is however, considered the gold standard for total SB and sitting time (e.g. activPAL3) (187), and has the highest sensitivity for distinguishing between sitting and standing, although can be expensive (260,261).

Heart rate monitors

Heart rate monitors (HRMs) are a physiological measure and employ the underlying principle that PA is derived from the connection that makes changes in heart rate (HR) indicative of cardiorespiratory stress, during movement of any type, and thus during PA and exercise (93). There are two types of technology used by HRMs, the electrical signal (chest belt) and optical sensor (wristwatch or armband) (262). Chest belts detect the electrical signals (ECG based) from the heart each time it contracts. Optical sensors use LED light sensors to detect HR through the rhythmic changes in blood flow that occur at each blood volume pulse (263). Optical sensors are cheap, discrete and comfortable, and many individuals prefer to wear these devices (e.g. Apple watch, Garmin Forerunner) to estimate EE during activities, which are highly popular and commercially available products (264). However, they are less accurate with some skin textures or due to artefacts because of motion on the wrists or arm (265). Chest straps that use ECG-based technology are more reliable, accurate and consistent in monitoring HR due the positioning of the electrodes close to the heart (266).

2.10.7 Contemporary measurement of physical activity and sedentary behaviour

Consumer wearable devices are a popular and growing market for monitoring PA, sleep, and other behaviours. Smartphones and wearable activity trackers present opportunities for large-scale PA surveillance that overcome some limitations of questionnaires or researcher-administered devices (267). Smartphone penetration in Ireland is projected to reach 73.9% by 2021 (268). Recently, a systematic review examined the reliability and validity of commercial wearable activity trackers in terms of step count, HR and EE in a range of devices (269). Strong inter-device reliability was reported for steps, HR, and calories, although considerable variability was found. No device fell within the acceptable accuracy limits for EE. This outcome is similar across activities such as cycling and resistance exercise. Some activity monitors show validity in terms of the mode of exercise, however, as intensity increased, underestimation of HR was apparent and no device showed valid EE measurement (270).

PA trackers in relation to PA surveillance have been considered in terms of the user representativeness of tracking technology in various countries including the UK (267). Strain et al. (267), in a study to investigate the potential use of smartphone apps and wearable trackers, found smartphone use to be the most prevalent technology outcome, however, owners of smartphones and wearable technology trackers are not representative of the general population. An inverse correlation was found between smartphone use in those aged >65

years compared with 16-44 years, those who are inactive, the male gender, as well as those in the most deprived areas who were less likely to own a smartphone. This is in congruence with studies looking at smartphone use undertaken in Canadian (271), Swiss (272), German (273), and American (274) adult samples. At the moment the population that most frequently uses smartphone apps and personal trackers is young, more active and more affluent, however, this is a fast-moving field and trends indicate that these types of trackers will become more prevalent in the near future (275).

2.11 Summary of Section 2.10

Self-report measures are pragmatic, generally cheaper and are more easily integrated in existing surveillance and epidemiological research (276), whereas the rationale for using objective measures is to reduce the potential for bias due to measurement error in the exposure. In terms of test-retest reliability of self-report measures, trends for recall accuracy reduce as the recall duration increases. Objective measures such as; indirect calorimetry (measures EE) or accelerometers (motion sensors) are highly accurate, valid and reliable measures of PA (277–279). However, they may be expensive, need a high degree of technical expertise and cannot account for all activities such as cycling (280) or stair use (281). Activity monitors have moderate to strong test-retest reliability of free-living PA behaviours. Again, reliability of activity monitors diminish as duration between measurement increases and the intensity of the activities change. In order to obtain timely self-report data, researchers may consider using EMA in their study protocols in addition to objective measures to obtain real time information not detected by objective measures, and for situations when the device has malfunctioned or was not worn (282). Given that PA and SB are multifaceted and complex behaviours, and objective measures may be described as precise and accurate, however, self-report measures are of value as they can capture the intricacies of PA and SB dimensions to provide a more continuous evaluation of free-living activity. Concerns regarding questionnaire validation against device-based instruments, and test re-test administration for reliability have been highlighted, however, these issues remain the methods of testing the psychometric properties of measurement tools until the concerns have been resolved.

2.12 Sedentary Behaviour & Physical Activity Public Health Recommendations

2.12.1 Sedentary behaviour guidelines

Research on SB policies is still in its infancy, but has experienced some positive progress in the last few years (283). In a recent study, Klepac Pogrmilovic et al. (284) collected data from 76 countries, and found that 40% of countries worldwide have SB guidelines, while 62% of countries have PA guidelines. Although calls were made as early as 2008 to introduce guidelines on SB (34), evidence for population level quantitative SB guidance continues and is based on cross-sectional findings. Several countries have responded to the accumulating evidence and included SB-related messages in their public health guidelines on PA. Table 4 outlines some examples of countries with official SB public health messages and guidelines for adults. This highlights the descriptive nature of SB guidelines as opposed to a quantitative SB target for optimum health.

Table 4 Examples of countries with official SB public health guidelines for adults (37)

Country, year, issuing body	SB guideline component 1	SB guideline component 2
UK, 2019, Dept. of Health/The Four Home Countries Chief Medical Officers (186)	All adults should minimise the amount of time spent being sedentary	Break up long periods of inactivity with at least light PA
Norway, 2014, Norwegian Directorate of Health (285)	Sedentary time should be limited	Long periods of SB should be interrupted with activity breaks
Australia, 2014, Department of Health (286)	Minimise the amount of time spent in prolonged sitting	Break up long periods of sitting as often as possible
New Zealand, 2015, New Zealand Ministry of Health (287)	Sit less	Break up long periods of sitting
Germany, 2017, German Federal Ministry of Health (288)	Adults and older adults should avoid long periods of inactivity whenever possible	Adults and older adults should break up sitting time by physical sitting
Canada, 2020, Canadian Society for Exercise Physiology, Public Health Agency of Canada (289)	Replacing SB with additional PA; Limiting sedentary time to 8 hours or less, which includes no more than 3 hours of recreational screen time	Breaking up long periods of sitting as often as possible

The WHO recent 'Guidelines on Physical Activity and Sedentary Behaviour' (41) recommend that 'adults should limit the amount of time spent being sedentary. Replacing sedentary time

with PA of any intensity (including light intensity) provides health benefits', and 'to help reduce the detrimental effects of high levels of SB on health, adults should aim to do more than the recommended levels of moderate - to vigorous - intensity physical activity' (pg.3).

The 'Global Action Plan on Physical Activity 2018-2030' (188) also proposes 'reducing SB through the promotion of incidental PA (for example, standing, climbing stairs, short walks) can support individuals to increase incrementally their levels of PA towards achieving the recommended levels for optimal health' (pg.14), and does not issue specific quantitative targets on SB reduction. Stamatakis et al. (30) acknowledge that public health messages require a strong and consistent evidence base, which is lacking for SB, and advocate that a 'move more at any intensity' message is most prudent until robust and consistent findings are available.

The 2018 PA Guidelines Advisory Committee Scientific report (11) states that the literature is insufficient to recommend a specific target for adults for how often during the day sedentary time should be interrupted with PA. Furthermore, a specific healthy target for total SB time has not been determined. This may be because the risk related to SB is dependent upon the amount of MVPA performed, with higher levels of MVPA negating the deleterious effects of prolonged SB. The current consensus is a reduction of any amount of SB over the course of the day is likely to have beneficial health effects, however, a targeted approach to regularly break SB with any amount of LPA is recommended to produce better outcomes in sedentary individuals.

2.12.2 Sedentary behaviour guidelines in Ireland

Like international guidelines on SB, Ireland has yet to develop national quantitative guidelines on dangerous levels of SB, or set targets to minimise risks associated with prolonged SB. Furthermore, Ireland has yet to publish qualitative guidelines on SB reduction. At present the 'National Physical Activity Plan (NPAP) for Ireland' (185) outlines no guidelines or recommendations on SB other than the aim of the plan being to promote 'less time spent being sedentary' (pg.11), mentioned in the mission statement. Within the National Physical Activity Plan Implementation Summary 2018 (290), Action 28 highlights a plan to 'Develop national guidelines on SB'. Availability of public health SB guidelines are a good indicator of a government's national SB policy, as it shows the government's commitment and intention to support the promotion of a reduction of SB.

Nearly a decade ago, Woods and Mutrie (291) outlined why PA policy was important in terms of promoting population based increases in PA. Now, in congruence with that call, there is a need for policy regarding SB to be included in national guidelines. As highlighted in Woods and Mutrie (291), it is more difficult to convince decision makers of the contribution, need and importance of reducing SB without the support of a national SB policy with clear goals, a strategic plan of action, resource identification, partners, and evaluation mechanisms in place. Across Europe, 46% of countries have some SB guidelines indicating that more investment and attention is needed in the development and implementation of effective SB policies (284).

Of note, in addressing Action 29 of the NPAP (185), centring on guidelines to support mental health service users to engage in PA, recent guidelines advise to sit less, and encourage users to break up SB (i.e. sitting or lying) with replacement of light activity (292). This highlights that recent findings outlining the association between mental health and SB have been incorporated into population guidelines targeting specific individuals, thus translating research into policy (293). Targeting a specific at-risk population regarding the promotion of PA and the reduction of SB is valuable to achieving sustainable reforms in these health behaviours.

2.12.3 Physical activity guidelines

The recent WHO guidelines on PA and SB (294) highlighted the significance of PA on public health, the global imperative for the work carried out by WHO in relation to promotion of PA, its effects on NCD prevention and the limited existence of national guidelines on PA. This report made recommendations to address the questions regarding the frequency, duration, intensity, type, and total amount of PA needed for the prevention of NCDs. The report outlined that for adults aged between from 18-64 years, PA includes 'recreational or leisure-time PA, transportation (e.g. walking or cycling), occupational (i.e. work), household chores, play, games, sports or planned exercise, in the context of daily, family and community activities'. For important improvements in cardiovascular and muscular fitness and the reduction of the risk of NCDs, four principle recommendations were made:

1. Adults aged 18–64 years should achieve at least 150 minutes of moderate-intensity aerobic PA throughout the week, or engage at least 75 minutes of vigorous-intensity aerobic PA throughout the week, or an equivalent combination of moderate- and vigorous-intensity activity
2. Aerobic activity should be performed in bouts of any duration

3. For additional health benefits, adults should increase their MPA to 300 minutes weekly, or engage in 150 minutes of vigorous-intensity aerobic PA weekly, or an equivalent combination of moderate- and vigorous-intensity activity

4. Muscle-strengthening activities should be performed involving major muscle groups on 2 or more days a week

The WHO have reaffirmed the message that some PA is better than none for health benefits (41).

2.12.4 Physical activity guidelines in Ireland

In Ireland, the NPAP (185) describes appropriate levels of health enhancing PA for the Irish population. The recommendations are outlined in Table 5.

Table 5 Physical activity guidelines for Ireland (197)

<i>Population</i>	<i>Physical activity recommendation</i>
<i>Children and young people (aged 2 - 18)</i>	All children and young people should be active, at a moderate to vigorous level, for at least 60 minutes every day. This should include muscle-strengthening, flexibility, and bone-strengthening exercises 3 times a week.
<i>Adults (aged 18 - 64)</i>	Adults should be active for at least 30 minutes a day of moderate activity on 5 days a week (or 150 minutes a week).
<i>Older people (aged 65+)</i>	Older people should be active for at least 30 minutes a day of moderate intensity activity on 5 days a week, or 150 minutes a week with a focus on aerobic activity, muscle strengthening and balance.
<i>Adults with disabilities</i>	People with disabilities should be as active as their ability allows. Aim to meet adult guidelines of at least 30 minutes of moderate-intensity activity on 5 days a week.

These guidelines are in line with recent updated recommendations from the WHO, with the exception of pregnant and postpartum women and those with chronic conditions, also targeted in the new WHO guidelines (294).

‘Healthy Ireland, A Framework for Improved Health and Wellbeing 2013-2025’ (295) is the national framework for the whole of the Irish Government and whole of society action to improve the health and wellbeing of people living in Ireland. As part of the Framework, The NPAP for Ireland (185) set quantitative targets for each population group as shown in Table 6.

Table 6 Targets set for each population group identified in the National Guidelines on physical activity (185)

<i>Population Group</i>	<i>Target</i>	<i>Base*</i>	
<i>Children 0-18 years</i>	Increase by 1% per annum in the proportion of children undertaking at least 60 minutes of moderate to vigorous PA every day	19% (primary aged) 12% (post-primary aged)	
	Decrease by 0.5% per annum in the proportion of children who do not take any weekly PA	11% (primary) 34% (post-primary)	
	<i>Adults 18-64 years</i>	Increase by 1% per annum the number of adults undertaking at least 150 minutes of moderate-intensity PA per week, or 75 minutes of vigorous-intensity activity, or an equivalent combination	31%
		Decrease by 0.5% per annum in the proportion of adults who do not take any weekly PA	12.6%
<i>Older people 65+ years</i>	Increase by 1% per annum the number of older people undertaking at least 150 minutes of moderate-intensity aerobic PA throughout the week or 75 minutes of vigorous-intensity activity throughout the week, or an equivalent combination	33%	
	Decrease by 0.5% per annum in the proportion of older adults who do not take any weekly PA	33%	

*Base figures are derived from the Children’s Sport Participation and physical activity study (296), (297), (298)

The NPAP for Ireland (185) draws heavily on the Toronto Charter for PA (299), with well-established goals on PA for public health. Its principles are consistent with the World Health Organisation's 'Global Strategy on Diet, Physical Activity and Health' (300) as well as other international health promotion charters (301,302).

2.12.5 Composition approach to guidelines

Previously, the majority of studies that have investigated the association between SB/PA behaviours and health outcomes have done so in isolation, without adjusting for time spent in other behaviours (303,304). The outcomes, therefore, may be influenced depending on the patterns of other health behaviours. A single day is finite which means that all behaviours are mutually exclusive, thus an increase in time spent in one behaviour must decrease the amount of time spent in others. Essentially, a single day is a composition of time spent in multiple behaviours. Each behaviour is co-dependent on the amount of time spent in the other behaviours that make up a daily composition, which is constrained by a daily constant sum of 1440 minutes (164). Accordingly, activity data can be considered as 'constrained' or compositional data. Using this statistical approach has some significant advantages in that it acknowledges the interdependence of times spent in different components of the 24-hour continuum to include SB, standing, LPA, MVPA and sleep. Powell et al. (164) used compositional analysis together with thigh-worn accelerometers to investigate changes in cardiometabolic health by replacing SB with LPA. Body mass index (BMI), body mass and fat mass were negatively associated with LPA and positively associated with standing time, while SB was also associated with higher BMI. Replacing 5 to 30 minutes of daily SB with LPA was significantly associated with a reduction of cardiometabolic risk factors.

Decisions have been made in some countries to move away from separate public health guidelines for individual movement behaviours to employment of a single 24-hour movement guideline that encompasses all movements across the whole day (289). Studies investigating the combined effect of 24-hour movement behaviours (i.e. sleep, SB and PA) on health, clearly show that whole 24-hour time use is associated with health outcomes across the lifespan (305,306). Using objective measures for activity and self-reported sleep time (n = 6,322; adults aged 18-64 years), associations were observed in those who engaged in larger proportions of MVPA relative to time in other behaviours and BMI, waist circumference, aerobic fitness, resting heart rate and metabolic markers such as; high-density lipoprotein cholesterol,

triglycerides, blood glucose and insulin levels (305). Relative time spent in LPA was negatively associated with BMI and beneficially with triglycerides and grip strength.

In essence, MVPA is important, but time spent in LPA relative to SB and sleep is a significant factor, and SB relative to sleep is also significant (306). Using this paradigm, the Canadian 24-hour Movement Guidelines for Adults (289) provides recommendations for integrated movement behaviours, which supports the notion that time spent in health risk behaviours, for example, sedentary behaviour, should be reallocated to some LPA, MVPA or sleep time, irrespective of which behaviours are replaced. As Tremblay et al. (307) suggest, it is the balance of sleep (e.g. short sleep is associated with obesity (308,309)), inactivity, and PA that is required for optimal health. This change towards an integrated 24-hour movement paradigm has the benefit of providing an understanding of the (inter)relationships between all health behaviours including sleep and cardiometabolic health markers, and the short and long-term effects of reallocating these on health (164).

2.13 Approaches to Physical Activity Promotion and Sedentary Behaviour Reduction

2.13.1 Public health

Public health is described as the science and art of preventing disease a society undertakes to assure the conditions in which people can achieve a standard of living for the adequate maintenance of health (310). These include organised community efforts to identify, prevent and ultimately counter threats to the health of the public (310). The functions of public health are delivered together with co-operation from healthcare systems and other community sectors to establish effective prevention, control and management of diseases and chronic conditions (311). Over recent years the remit of public health has broadened to include interventions for injury prevention and control, chronic disease prevention and management, public policies prioritising health promotion, environmental supports for behaviour change and public education (312). In a climate of limited resources, calls have been made for public health interventions to be evidence based. A research priority for improving public health and reducing risks of health outcomes is to build the requisite knowledge base for effective interventions (313). To do so requires an understanding of the determinants of the risk factor i.e. sedentary behaviour. It is useful to understand risk factors as inherently context-specific, taking place in domestic environments, during motorised transportation and in the workplace (58).

2.13.2 Settings approach

Adopting a settings approach to health promotion is to direct attention on the contexts within which people live, work, and play and makes these the object of inquiry and intervention (314). Fundamentally, this approach focuses on contexts together with the needs and capacities of people operating in different settings (314). Success of interventions can be increased when they offer opportunities to situate practice in context. Poland and colleagues (314) describe, ‘members of the setting can optimise interventions for specific contextual contingencies, target crucial factors in the organisational context influencing behaviour, and render settings themselves more health promoting’ (pg. 505).

The settings approach, which during the 1980s increasingly emerged as a coherent and balanced framework for new public health, and in which its roots are widely accepted to lie within the WHO ‘Strategy for Health for All’ (315). The Ottawa Charter for Health Promotion in 1986 (316) was a critical point in the development of a settings approach. It reflected a growing consensus that health is not primarily the outcome of medical intervention but is a socio-ecological product that arises from the complex interplay of behavioural, genetic, social, environmental, economic, and political factors. Baric (237) has suggested that the settings-based approach is characterised by three key elements: a healthy working and living environment, integrating health promotion into the daily activities of the setting, and reaching out into the community. Poland et al. (314) describe three important tenets of the settings approach: 1) understanding settings, 2) changing settings and 3) knowledge development and translation.

In 2018, the WHO published a ‘Global Action Plan on Physical Activity 2018–2030: more active people for a healthier world’ (GAPPA) (188). Within this plan are four strategic objectives that form a universally applicable framework, and each have been identified as critical and effective components of a population-based response to increase PA and reduce SB. These objectives seek to incorporate a whole-system-approach and ‘create a society that intrinsically values and prioritises policy investments in physical activity as a regular part of everyday life’ (pg.25) (188). These objectives are briefly described in the following sections.

2.13.2.1 Create Active Societies

Creating active societies involves the implementation of best practice communication campaigns, held at both national and community level, that can increase awareness, knowledge and appreciation for the various and important health benefits associated with

regular PA and less SB (188). By providing free access to enjoyable, affordable, and appropriate experiences of PA, through the implementation of regular mass participation initiatives in public spaces, entire communities could potentially be engaged.

2.13.2.2 Create Active People

The 'Create Active People' objective seeks to achieve lifelong engagement in and enjoyment of PA. In primary and secondary health and social care services, systems of patient assessment and counselling on increasing PA and decreasing SB, by trained providers and as part of a universal health care, is an action to meet this objective, and has been identified as cost-effective (317). It is important to target and engage the least active groups with appropriately tailored programmes to increase opportunities for PA and reducing SB, for example in private and public workplaces. The GAPPA (188) states that PA is important across all ages, and should be integrated into multiple daily settings.

For many adults, the workplace is a key setting to increase PA and reduce SB. Travelling to and from work, activity breaks, workplace programmes and incidental activity all offer opportunities for increased PA throughout the working day, and can contribute to increased productivity and reduction in injuries and absenteeism (318). Development and dissemination of national guidance, together with the promotion and implementation of workplace health programmes, should be aimed at increasing PA, reducing SB, and promoting incidental PA during the working day for employees. These workplace programmes should be implemented in different occupations and settings, and with a priority focus on the least active.

2.13.2.3 Create Active Systems

This objective seeks to create and strengthen leadership, governance, multi-sectoral partnerships, and workforce capabilities. The implementation of actions to increase PA and reduce SB include policy coherence across sectors, guidelines and recommendations on action plans, and monitoring and evaluation of progress to strengthen accountability. GAPPA (188) advocates addressing this objective as a strengthening of national and institutional research and evaluation capacity. It recommends that institutional research should stimulate the application of digital technologies and innovation to accelerate the development and implementation of effective policy solutions targeted at increasing PA and reducing SB. The objective of the enhancement of data systems at national and subnational levels will assist regular surveillance of population level PA and SB. Finally, the rapidly growing practice of mHealth (mobile health) should be used to harness the potential of data to help promote,

support and monitor PA to improve the health and well-being of all individuals (319,320). Digital technologies that allow mass reach communication are well-placed to monitor the socio-cultural and environmental determinants of low levels of PA and prolonged SB in order to inform policy and practice. In settings such as the workplace, there are opportunities for digital innovations to promote and support participation in PA and reduce SB. These can build upon the rapidly growing practice of mHealth (described further in Section 2.22) to harness the potential of data to help promote, support and monitor PA to improve the health and well-being of all individuals (319,320).

2.13.2.4 Create Active Environments

The focus of this objective is to have strong urban and transport planning policies, at all levels of government, to connect neighbourhoods and to enable and promote PA by walking or cycling. This includes good quality open public green spaces, as well as amenities and sports facilities for all age-groups and abilities. Within this objective is a call for improved design and policy guidelines that are adapted to culture and context, to promote PA in schools and workplaces, and to enable individuals to be physically active in and around the buildings. Stakeholders (e.g. employers) should partner with government to develop the evidence base on the effectiveness of fiscal instruments to promote PA (e.g. tax-free salary sacrifice schemes for bicycles, subsidised gym-membership etc.). The workplace as an important setting for health promotion is described in the following section.

2.14 Workplace Setting for Risk Reduction & Health Improvements

For working adults, more than half of daily sitting time on a weekday is accumulated in the workplace (321,322). Desk-based or white collar employees have been found to be the most sedentary in workplace settings (323–325), in particular males (324), and those who are overweight or obese (323,326). The WHO (52) advocates that the workplace offers several advantages as a setting for intervention due to the substantial number of the working population that can be reached, and where multiple levels of influence on behaviour can be targeted. In particular, using the socio-ecological model to target influencing factors at all important levels for workplace health promotion is recommended.

In the WHO 'Best Buys and Other Recommended Interventions for the Prevention and Control of Noncommunicable Diseases' (327), the implementation of multi-component workplace programmes to increase PA is advocated as an overarching and enabling action to tackle

physical inactivity. The WHO (82) 'Action Plan for the Prevention and Control of Noncommunicable Diseases in the WHO European Region', recognises that although some interventions may take some time for the cost effectiveness to be realised, such as those impacting on the risk of obesity; short term effectiveness such as mental health improvements in the workplace can be observed. The Plan advocates the provision of opportunities and counselling for PA at the workplace, and consideration of appropriate measures to enable more PA during the working day and active transport to and from work.

2.14.1 Systems approach

As part of a systems-based approach, the International Society for Physical Activity and Health (ISPAH) have published 'Eight Investments that Work for Physical Activity' (328). This includes the workplace as a key setting for health promotion. The approach includes people, communities, organisations, resources, the physical and social environments, built infrastructure and the broader economy, in which the needs of the system in context are identified and met (329). The workplace is one system within a larger context, and effective approaches to tackling physical inactivity (and SB) require multiple concurrent policies, strategies and actions that are implemented across settings and sectors (328). There is growing consensus that a systems approach to health is key to achieving better outcomes, however, there is less agreement on how to strengthen them (330). Although significant improvement has been made, some of the difficulty has been getting existing and emerging knowledge about more (and less) effective strategies into practice, especially in low-income and middle-income countries (331). However, in terms of the global pandemic of physical inactivity and sedentary behaviour, it is widely acknowledged that a system-based approach is required, as previous individual-level, or single-tier approaches have thus far been unsuccessful in improving this significant public health concern (328,332).

In Ireland, the Healthy Workplace Framework aims to encourage and support the development of health and wellbeing programmes in all places of employment across both public and private sectors (333). This is further strengthened by legislation in the public sector which requires all employers to have in place, and report on a health and wellbeing programme. In the ongoing development of the Framework, policy mechanisms described in the literature (334), and cost benefits (335) are considered. The risk to health of prolonged workplace SB means that there is now an imperative and impetus to develop and test interventions to reduce prolonged bouts of SB, by increasing LPA in the workplace. The resulting evidence-

based effective insight into the roles of individuals, their environment and workplace policy, can be translated into evidence, in a scalable way, to improve population health.

Workplace PA interventions can improve many physical, mental, and social health outcomes. Additionally, employees may experience reduced absenteeism (336) and burnout (337). Systematic reviews of the literature on interventions to reduce SB and increase PA have reported significant reductions in workplace SB, with most effective interventions adopting multi-component interventions targeting the main influences of SB that operate at the individual, social and environmental levels (338–340).

2.15 Socio-Ecological Model Conceptual Framework

Narrowly conceived conceptual models that emphasise individual-focused behaviour change strategies, neglect the environmental influences and determinants of behaviour, thereby fail to recognise that most public health challenges are too complex to be understood adequately from a single-level lens (341). In accordance with the WHO (63), best practice in the design of interventions for health promotion should target not only the individual, but also the work environment and organisational level factors of influence. McLeroy et al. (342) describe an Ecological model in which there are five sources of influence on health behaviours. This model integrates and considers these sources of influence as: intrapersonal, interpersonal and primary groups, organisational or institutional factors, community factors and policy level factors (341). Intrapersonal factors refer to individual characteristics that include knowledge, beliefs, self-concept, and self-efficacy, as well as biological factors such as genetics. Interpersonal processes refer to an individual's social environment such as family, friends, co-employees, and social and cultural factors. Institutional or organisational factors include the formal and informal rules that exist within social organisations such as schools or workplaces. Community factors refer to relationships between organisations and in neighbourhoods, and also refers to community norms. Finally, public policy influencing factors are laws, policies, and regulations at the local, county, or national level.

The main principles of the socio-ecological model for health promotion are (58):

- 1) health behaviour is influenced by multi-faceted factors i.e. physical environment, sociocultural factors, and personal attributes; and are categorised into the five levels described above

2) influences are multidimensional, and variables can work together or interact with each other; these can be social or physical, actual or perceived, discrete attributes (such as spatial arrangements) or constructs (such as social climate); however, these may be intertwined meaning it can be difficult to delineate the most important interactions

3) interventions should be most effective when multiple levels are targeted; single-level interventions are less likely to be successful in the long-term or at a population level; for interventions to be successful or have a sustained effect, policy and environments must support the change in beliefs and behavioural skills

4) interventions must be behaviour specific; environmental and policy variables specific to a particular behaviour must be identified, and form part of the intervention targets

Using this model, research on the prevalence and determinants of PA and SB is essential to monitor population levels, identify at-risk populations, as well as to reveal how these differ in the various domains (workplace, domestic, transport, leisure time). This research informs interventions and public health guidelines (343). Many factors are likely to influence an individual's choice and/or risk of engaging in PA and SB. The socio-ecological model (SEM) of health is a framework used to understand the various influences that interact and overlap to contribute to particular health behaviours (56). This model advocates that it is the dynamic interplay between individual, social, environmental and policy level factors that result in particular health behaviours. Figure 7 illustrates the levels of influence on behaviour. Central to the SEM, is the behaviour settings construct – this construct is described in detail in Section 2.12.2 of this chapter (344). The settings construct emphasises the influence of context on behaviour, and posits that individuals are just one component within larger behavioural systems. Within each setting, behaviours may be restricted by demands and certain actions being prohibited, while others are promoted and encouraged (65). This model is helpful as it highlights how the behavioural settings approach can help provide an understanding of the factors associated with SB in differing contexts.

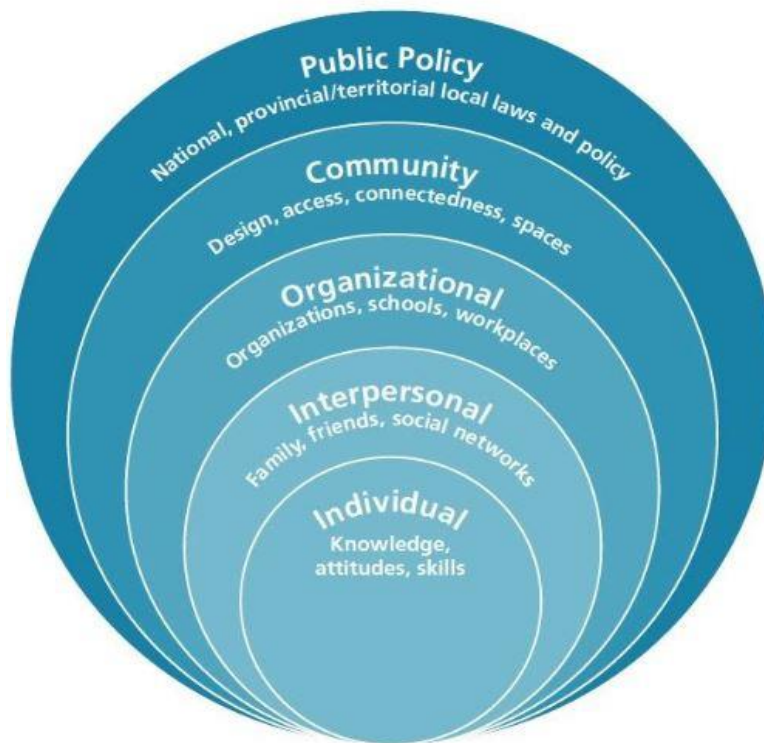


Figure 6 Socio-ecological model of behaviour (46)

Physical and social environmental influences are important determinants of health behaviour, and these must be identified to guide the development of appropriate interventions. The causes of PA and SB behaviour are essential to understand in terms of development and improvement of public health interventions (238). Understanding the determinants (factors with a causal relationship), and correlates (those associated with the activity) could reduce the current global epidemic of inactivity and contribute to effective interventions to prevent NCDs (343). These multiple determinants range from proximal to distal, as identified within the framework of the SEM (345). Determinants and correlates operate at the policy, environmental, inter-individual and intra-individual, as well as the socio-demographic levels. Within these dimensions, positive or negative determinants, may exist. The strengths and critiques of the socio-ecological model are outlined in the following section.

2.15.1 Strengths and limitations of the socio-ecological model

A key strength of SEMs is their attention on targeting of multiple levels of influence that provides broad options for interventions. In particular, the focus on policy and environmental changes in interventions can affect entire populations, not just those who choose to

participate (56). Changes made at this level may persist in sustaining changes to behaviour which may solve the problem of poorly maintained individually directed interventions (346). A major strength of this theory is the integration of strategies of behavioural change *and* environmental enhancement within a broad-systems theoretical framework.

Socio-ecological theory highlights the importance of identifying factors within environments that can affect employee physiological, emotional and/or social well-being (347). From a physiological perspective, changes to the environment such as such as adjustable desks or chairs, or the construction of bright, safe stairwells facilitate and support health improvements. Individuals' perceived predictability, controllability and novelty can influence emotional well-being, while economic stability, structural flexibility and/or provision of opportunities for involvement in supportive interpersonal relationships can strongly affect levels of cohesion and commitment observed at an organisational level. The diversity of intrapersonal factors such as genetic heritage and makeup, personality dispositions and health habits are also considered in the socio-ecological model.

However, the model presents limitations, in particular the lack of specificity in terms of the most prominent hypothesised influences (348). This means that the burden is on the researcher or health promotion professional to identify the most crucial factors to be included in the intervention. Another weakness of the model is the lack of information about how the various outer variables interact or operate across the levels (56). Minimal guidance is provided on exactly *how* to use the model in behaviour change interventions. This contrasts with individual-level psychosocial theories of behaviour change (see Sections 2.20.2 and 2.20.3), which are more likely to stipulate the variables and mechanisms by which behaviour will be influenced. Developing sophisticated operational models that drive testable hypotheses and helpful guidance in interventions is a major challenge when using SEMs.

Some studies have tested the interaction between individual, social and physical environment variables to explain physical activity (349,350). In one of the studies (349), each variable was significantly associated with PA, however, associations were strongest for individual and weakest for environmental, whereas in the other (350), the social and physical environment were related to PA. Increased recognition and understanding of the multi-level and interactive influences on behaviour may lead to more targeted and thus more effective interventions. The principles of SEMs are centred on the many various and interacting characteristics, individual, social, environmental, that are difficult to experimentally manipulate. The aim of experimental designs is to identify change as a result of the intervention in isolation of its context. At a

conceptual level therefore, SEMs, with their whole ecology emphasis may seem to be at odds with controlled experimental design, however, multi-level interventions can be applied successfully using multi-level analytic approaches (351). In Sallis et al. (56), it is highlighted that with sufficient sample sizes, multi-level statistical models 'can yield estimates not only of the contributions of interventions to outcomes but also of the extent to which those contributions are influenced by moderating factors' (pg.481).

The difficulty of implementing multi-level interventions has been acknowledged and should not be underestimated (56). The logistical challenges of developing, collecting measures of influence, and conducting research at multiple levels is significantly more demanding than behaviour change research at an individual level (352). Furthermore, policy level changes require considerable time and are not within the control of many researchers and health professionals. Advocacy in the political process requires skills or partnering with those who have the capability to impact at policy level (56).

Another limitation of SEMs is that they fail to fully acknowledge the role of some social and structural factors that influence behaviours (353). For example, in SEMs, age and gender are categorised as biological rather than social and therefore do not account for the social influences on behaviour that gender and age exert on individuals (354). The incorporation of social structural factors in SEMs as individual-level characteristics, neglects the social nature of gender, age, ethnicity or socio-economic status for example (352). These factors should be more adequately incorporated in SEMs, and in doing so, recognise that individuals are connected to and located within sociocultural structural influences, and address these structural influences in intervention design (354). In the WHO 'Action Plan for the Prevention and Control of Noncommunicable Diseases in the WHO European Region' (82), 'gender responsiveness' in workplace health programmes is recommended in promoting health in specific settings, thereby highlights the social constructed nature of gender in health interventions.

Although the model does have limitations, it is argued that the importance of considering multiple levels of influence to improve health behaviour is an extremely useful tool and framework to adopt and creating supportive environments and policies make it more possible to make healthy choices. There is a rapidly growing body of literature highlighting built environment correlates of PA and SB, in conjunction with, and complementing literature on inter- and intra-personal correlates (64,339,355). Reframing health behaviours to a reciprocal and dynamic perspective, rather than keeping them as the sole responsibility of the individual,

makes it clear that the causation of behaviour is widely distributed. It attempts to tackle the influences to motivate, support and educate to make more healthy choices.

In summary, SEMs of health behaviour assist us in understanding how environments and individuals interact, through multi-level approaches to intervention development. It is a simple premise that asserts that individuals cannot effectively change their behaviour when provided with motivation and skills if the environment and policies are set to make it impossible to change their behaviour. The challenge for researchers is to be creative and persistent in utilising SEMs to generate evidence on the roles of influences of behaviour at multiple levels, and to translate that evidence into health improvements. The following section describes the determinants of SB and PA from a socio-ecological perspective.

2.16 Socio-Ecological Determinants & Correlates of Sedentary Behaviour & Physical Activity

PA and SB determinants vary across the life-course. Recently, the European Commission set in motion an increase in research capacity across member states to investigate all of the possible determinants of PA and SB. This resulted in the creation of the project, DEDIPAC (Knowledge Hub on the DEterminants of Diet and Physical Activity (356)). Using the available literature, this project identified all determinants of PA and SB, across life-course, using the SEM as a framework for investigation.

A number of environmental, social and individual-level determinants of SB appear to be distinct from those associated with PA (11). The presence of unique determinants that influence SB supports the development and testing of specific intervention strategies and approaches to reducing sedentary time—several which may be separate from methods aimed directly at increasing PA. A key principle being that knowledge about the various levels and types of influences and contributors to SB can inform the development of multilevel interventions that offer the optimum level of success (357). Behaviour change is a process rather than an event, with factors that influence behaviour changing over time. The focus to date on factors that influence SB has mostly been on individual level factors such as biological, psychological and behavioural (57,358), or socio-demographic factors in isolation. More distal contextual factors such as the built social and economic environment, are overlooked in many studies (27). The SEM conceptualisation of SB leads to explicit consideration of multiple levels of influence, i.e. intrapersonal (biological, psychological), interpersonal (social, cultural), organisational, community, physical environment and policy, and focuses on the interrelationships between individuals and these multiple environment level factors (57).

Owen et al. (57) not only advocate this model of SB to understand the correlates of time spent in SB across different domains (e.g.. recreation, transportation, occupation), but also recommend the identification and understanding of modifiable factors in these settings, in order to develop effective interventions and appropriate policies.

Systematic reviews have assessed the available evidence on socio-ecological factors influencing SB across the life course; in youth (26), those aged 18-65 (358) and older adults (359,360), as well as more recently to include low- to middle-income countries (361). They provide information to help map the domains of this risk factor, as well as a conceptual approach to understand determinants of prolonged sitting time. Correlates and determinants of PA are also described in the following section.

2.16.1 Individual level determinants of sedentary behaviour and physical activity

Psychological correlates and determinants

Out of five studies included in a recent literature review of the correlates of SB in adults aged 18–65 years based on the SEM (358), four reported positive associations between symptoms of depression, anxiety, and tension, and total screen-time SB. Similarly, perceived tiredness (362) and stress levels (363–365) were positively associated with SB (measured by occupational SB, TV and screen watching and total sitting time). People with lower life satisfaction have higher OR of sitting for more than 7.5 hours per day (366). In a non-Western context, a recent study of desk-based Japanese participants using objective measures of activity, reported that feeling stressed in work was associated with longer SB in the workplace in men (367). Feeling motivated to reduce SB and to take SB breaks, was also associated with longer SB in men. This suggests that those who are motivated to reduce SB, may have a larger volume of work to complete, therefore are more sedentary. However, perceived health (368,369), perceived benefits of reducing SB, attitude and intention (370), and habit (371) were negatively correlated with SB. No association with SB was found between perceived control and norm (370), or perception of personal appearance or body image (372). More recently, in meta-analysis, higher levels of self-efficacy were associated with lower levels of SB (373).

In terms of the psychological determinants of PA, Cortis et al. (374), under the DEDIPAC framework, found evidence for self-efficacy (positive association with PA) and stress (negative association with PA) regardless of age (374). Habit strength, self-concordance, self-efficacy, perceived behavioural control, and intention were identified as moderating variables for PA

(375). It may be concluded that the predictive value of psychological determinants of PA may be most informative when several theories and models of behaviour are used to understand and explain behaviours.

Behavioural correlates and determinants

Behavioural factors associated with SB include TV and screen viewing, alcohol consumption, diet, smoking and physical activity. Habits such as TV and screen entertainment, and mobile phone use (gaming and browsing) are positively associated with total SB (371,376–379). Alcohol consumption is associated with increased driving SB (364) and overall weekend SB (365). Snacking behaviour (including high calorie snacking), and food cravings are highly associated with sedentariness (365,369,380,381). Smoking is positively associated with TV and screen viewing SB, driving SB and total SB (364,368,376,382).

PA has been extensively investigated in terms of SB and unsurprisingly, a large body of evidence demonstrates an inverse relationship with SB (368,369,376–378,383–385). Retirement and activity levels in various SB domains (i.e. TV and screen viewing SB, leisure reading, occupational SB and domestic SB) were not correlated in a longitudinal study of older adults (386). In a four-arm RCT, Kozey-Keadle et al. (387) investigated the effects of (i) a traditional exercise intervention with no instruction about PA or SB when not exercising, (ii) an intervention to reduce SB and increase PA, (iii) an intervention receiving exercise training and also targeting reductions in sedentary time and increasing non-exercise PA, and (iv) a control group, to maintain habitual behaviour to reduce SB and increase non-exercise PA. Only the group that received advice to reduce their SB increased their daily PA and significantly reduced their total SB, highlighting the importance of having SB as a primary intervention target.

In terms of the behavioural determinants of PA, the evidence is somewhat limited and inconclusive and it may not be possible to ascertain definite conclusions on whether or not individuals choose to engage in PA (388). Among children and adolescents, probable positive evidence for previous PA and independent mobility and active transport has been found. For the adult population, the transition to university and pregnancy, and/or having a child, showed probable negative associations.

Biological correlates and determinants

Men, and those who are of younger age (18-35 years), and those 65+ years have a higher risk of sitting for more than 7.5 hours per day (389,390). This is in congruence with findings from a study (n=1360) of older adults using objectively measured SB and PA time, where taking more medications, being overweight or obese, and having a slower gait speed were associated with SB (360). However, in terms of the domains of SB, women, older people, and people with sufficient levels of PA were more likely to accumulate >4hours/day of occupational sitting. Using self-reported data, men, younger and inactive people were more likely to accumulate >4hours/day of leisure sitting time (390). The evidence regarding biological determinants of PA includes those of younger ages, being male, higher health status and higher physical fitness levels (391). Among adults, convincing strength of evidence shows that normal birth weight is positively associated with PA, while findings among adolescents are inconsistent and with limited strength of evidence.

Socio-economic correlates and determinants

Having a higher education and being in white-collar positions (i.e. office or other administrative setting) are associated with increased leisure SB (358,361), and total SB (>7.5 hours per day) (366). In terms of occupational SB, being in full-time employment, working in a call centre, having a high level of leisure time sitting, attaining a high level of education and a high income were positively associated with occupational SB (392). In a study by Hadgraft et al. (393) using accelerometer data, those with shorter tenure in organisations have lower levels of total and workplace SB. Buck et al. (394) found that occupational level was directly associated with SB for adult populations. SB has often been labelled as a 'white collar' problem. White collar employees, who mostly live in high GDP regions, engage in more desk-based activities throughout the day (395).

In terms of socioeconomic correlates and determinants of PA across life, those in higher socioeconomic groups engaged in more leisure-time PA, and more occupational SB, with more disadvantaged groups engaging in less overall PA (396).

2.16.2 Interpersonal determinants of sedentary behaviour and physical activity

There is evidence that social norms (the informal rules or standards of acceptable behaviour operating within a group, i.e. social group, family, community, or society as a whole), guide or constrain health behaviours (397,398). Social factors in relation to SB are, however, relatively under-examined within the literature. A recent systematic review (399) found that SB norms,

with friends as the referent group, were more consistently associated with SB, although overall, the nature of the relationship between SB norms and SB was mixed. Interpersonal factors such as, marital status (400,401) and family and caring duties (376), may be potential correlates associated with sitting time.

Evidence for interpersonal determinants of PA is also scarce, although socio-cultural PA determinants include receiving encouragement from significant others and having a companion for PA are associated with higher PA in children and adolescents (402). Parental marital status (living with partner) and experiencing parental modelling were not associated with PA in children (402).

2.16.3 Environmental determinants of sedentary behaviour and physical activity

At an environmental level, correlates of SB include physical environment and neighbourhood attributes such as safety and walkability (358). Inconsistent and mixed results are available on associations between SB and perceived neighbourhood attributes such as open spaces (358). Neighbourhood aesthetics are associated with overall sitting times (401), and women in neighbourhoods with high walkability spend less time watching TV (403). A correlation between living in an urban location and longer sitting times has been found in some studies (376,404). In a recent systematic review investigating physical environment and weight status in adults (405), urban sprawl and land use mix (a strategy for integrating complementary functions within an area), were found to influence weight status in the US only. Busschaert et al. (406) used a range of socio-ecological factors related to context-specific sitting times. However, this was a small (n= 301) cohort and the physical environment correlates used in the study focussed particularly on the close environment (e.g. proximal – in one's home). The distal neighbourhood environment access and characteristics as outlined in Owen et al. (57) and the SEM, such as perceived aesthetics and open space availability that may influence SB (407) are also important to understanding SB.

In terms of PA determinants at an environmental level, outdoor toys and equipment, and outside garden space are positively associated with PA in young children (408). The availability of PA programs and equipment within schools, and neighbourhood features such as pedestrian and cyclist safety structures were positively associated with PA in children and adolescents. In adults, negative street characteristics, for example, lack of paths and streetlights, were negatively associated with PA.

2.16.4 Policy determinants of sedentary behaviour and physical activity

A dearth of evidence surrounding policy determinants of SB is available, and many researchers have called for an increase of investigations on this important health threat (27,359). With regards to policy determinants of PA among adults, working hours were negatively associated with PA, though evidence was limited (409). At the population level, community- and street-scale urban design and land use policies were found to positively support PA levels, but evidence was scarce (410).

To address the lack of evidence on the merit, worth or utility of cross-European policy interventions, a joint programming initiative, the Policy Evaluation Network (411), has been formed to provide guidance on how best to evaluate the implementation and impact of diet and activity policies.

2.17 Summary of Section 2.16

The findings emphasise the necessity to focus on separate domains of SB and PA. Socio-economic status is indicated to be the most consistent factor of all of the individual level factors associated with television viewing SB and occupational SB (358). The authors of the DEDIPAC reviews state that despite calls for the use of the SEM approach to look at determinants of SB, intrapersonal factors are the focus in most studies investigating SB. Therefore, it is important when investigating prevalence and patterns of SB to take a multilevel approach to understand all of the varying influences on this behaviour.

2.18 Applying the Socio-Ecological Model in this Research

As the primary strategic goal of research into the determinants of SB is to integrate evidence and promising strategies to reduce this risk behaviour, the SEM approach highlights these multiple factors and contexts as the basis of the investigation. In this PhD, Study 1 (described in detail in Chapter 3), included socio-ecological factors in a broader manner than previous studies, and the domains of sitting incorporated the different contexts in which sitting can accrue across the day. The sample was a large representative sample with a wide age-range and is therefore generalisable. The aims of Study 1 were, in a population level study, to compare overall sitting between different individual, social, and environmental categories, and to identify individual, social, and environmental level correlates associated with sitting time across these domain-specific physical and social contexts where most sitting behaviours occur.

The objective of Study 1 was to apply the socio-ecological model using the 2016 Healthy Ireland dataset, to describe the prevalence of SB across various important domains, as well as the correlates of SB. This provided information on the characteristics of the most at-risk groups of this health behaviour such as age, gender, socioeconomic status, and occupation type. To inform the development of a multicomponent intervention tested in a pilot feasibility trial, the findings of which are described in Chapter 5, the study identified the setting in which most SB occurs.

The development, evaluation and implementation process of a complex intervention is a lengthy process. It has many stages, and importantly, adequate development and piloting work in the exploratory phase must be conducted to test practical issues of implementation thereby resulting in a stronger intervention (412). The following section describes the framework used in this PhD research – the Medical Research Council (MRC) ‘Framework for the Development and Evaluation of RCTs for Complex Interventions’ (413), and how it informed the development of the research.

2.19 Complex Intervention Development

The overall aim of this PhD was to design, implement and evaluate through a pilot test, a novel evidence-based complex intervention to reduce SB. An intervention is defined as complex when it involves several interacting components (413). The number and difficulty of behaviours required by those receiving or delivering the intervention, or the number of target levels of the intervention add further complexity (413). Adopting an evidence-based framework to develop and test interventions to improve health provides a structural approach that is more likely to lead to successful implementation and evaluation of the intervention in question (62). Approaches such as Intervention Mapping (414) and the PRECEDE-PROCEED model (415) are complex frameworks that are highly prescriptive and labour intensive and may be restrictive in terms of time and cost. The focus of other models such as the RE-AIM framework (416) is heavily weighted towards the evaluation of interventions rather than their development. The MRC Framework in Craig et al. (413) builds on the Campbell et al. (412) ‘Framework for the Development and Evaluation of RCTs for Complex Interventions to Improve Health’ by extending guidance on complex interventions implemented outside of the health service. This updated iteration provides a flexible, less linear framework to assist researchers to recognise and employ appropriate methods in the development of complex health behaviour change interventions.

The phases targeted in this PhD research are highlighted in blue in Figure 7, illustrating Campbell and colleagues' framework. The first preclinical stage was a literature review of workplace interventions to reduce SB and the identification and application of socio-ecological theory to the design of the current intervention. The key benefit of the SEM, as described previously, is it allows intervention designers to consider all influences on health behaviours, and thus intervene at these important levels that are most appropriate in the context (57).

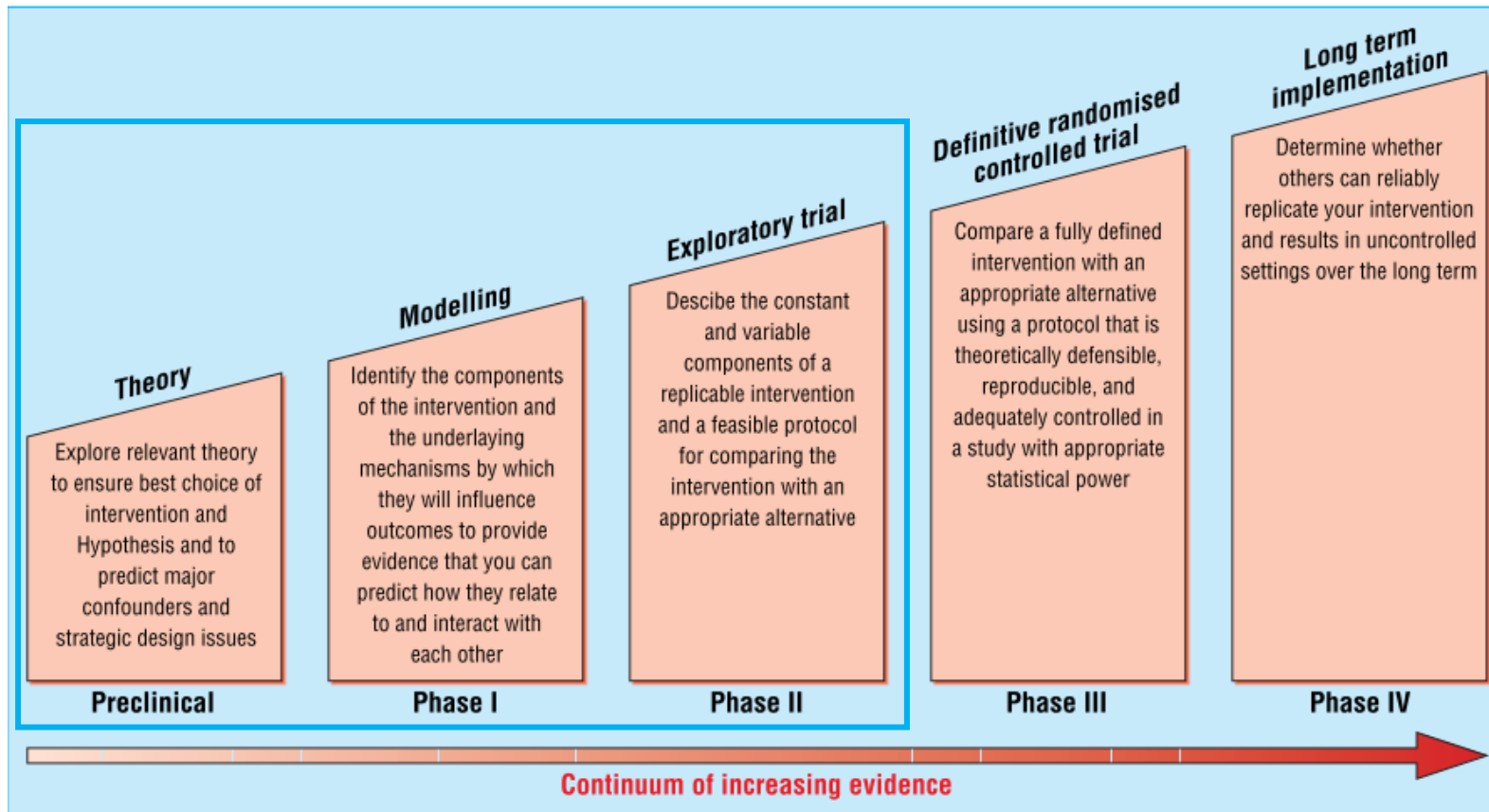


Figure 7 Sequential phases of developing randomised controlled trials of complex interventions (412)

This MRC framework aligns with the pragmatic epistemological stance taken in this PhD as the mixing of qualitative with quantitative methods to understand barriers to participation, providing important insights into processes of change and involving users of the intervention are recommended. The MRC framework and the socio-ecological model can be used together in a complementary approach as each serve different purposes in the development and conducting of complex interventions. The MRC framework (412,413) provides guidelines for best practice by developing an intervention systematically using the best available evidence and appropriate theory (Figure 8). A series of carefully phased pilot studies are recommended to target key uncertainties in the design, before moving on to exploratory and definitive evaluations. This approach, taken in the development of the intervention in this PhD research, is theory and evidence based, which combines published research evidence and existing theories (417).

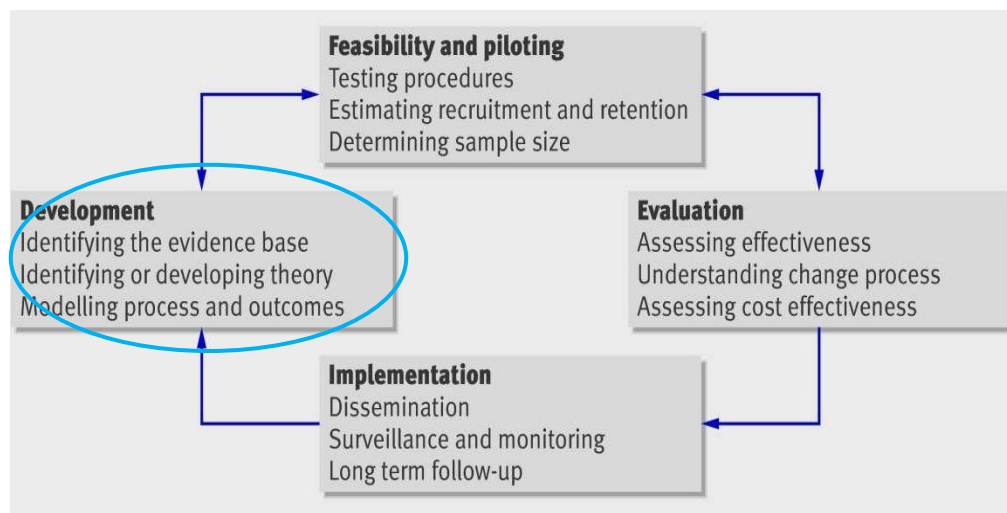


Figure 8 Key elements of the development and evaluation process from the MRC guidance: Development stage (38)

The process began with the primary step in the development phase, a review of the literature was conducted methodically to identify important research gaps (Chapter 2), and refinement of the research questions. A systematic review was not conducted as three systematic reviews and a Cochrane review on workplace interventions to reduce sedentary behaviour had recently been published (338,355,418,419). The review of the literature informed the development of the multicomponent intervention designed to answer the research question.

The aim of Study 1 was to provide the evidence base for the target population and setting for the intervention. Study 2 explored the barriers and facilitators of change. According to the

MRC Framework, those targeted by the intervention should be involved during the development stage to ensure relevance and appropriateness of the intervention. The context-specific barriers and facilitators salient to important stakeholders, as well as views of the intervention components, pilot measures and processes were discussed with the various stakeholders in the development stage.

Following the development stage, the MRC framework advocates testing the feasibility and piloting of the intervention (highlighted in Figure 9). The aim of Study 3 was to test the acceptability and feasibility of a multi-component intervention. This stage is conducted to test procedures for their acceptability, and to test the likely rates of recruitment and retention of participants. Craig et al. (413) contend that use of mixed methods is useful here to understand the barriers to participation, and to estimate response rates.

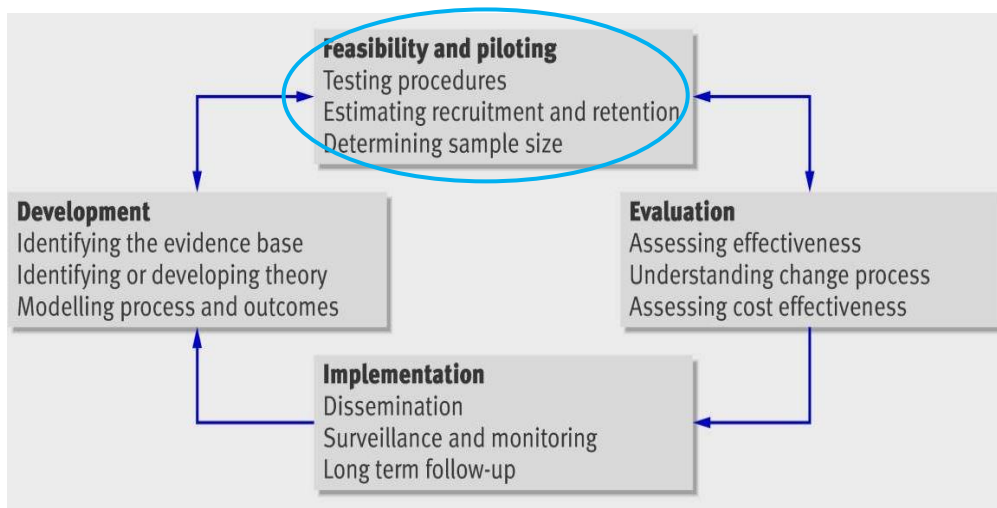


Figure 9 Key elements of the development and evaluation process from the MRC guidance: Feasibility and piloting stage (38)

This preparatory work is vital to prevent problems of acceptability, compliance, intervention delivery, recruitment and retention that often undermine complex intervention evaluations. The following section describes pilot and feasibility studies and their value in the exploratory phase of the design and evaluation of complex interventions.

2.20 Pilot and Feasibility Studies

Cluster randomised trials, as opposed to individually randomised participants, can minimise the potential for contamination between groups when participants are recruited within the same setting (420). However, they are often larger and more expensive than individually randomised trials. Given the resources associated with delivering such interventions, it is important to optimise interventions prior to expensive evaluation, through rigorous assessment of their feasibility (421). Exploratory work (described in Phase II in the original MRC Framework illustrated in Figure 7 (412)), aims to optimise and assess the feasibility of an intervention and/or the design of a full-scale effectiveness evaluation (421). It has been stated that there remains significant lack of guidance in the literature concerning exploratory studies (67). Inconsistencies in the use of terms 'pilot' and 'feasibility', and what constitutes each, have incited calls for formal guidance on terminology (422).

Eldridge et al. (423) have produced a conceptual framework for definitions of pilot and feasibility studies. Feasibility is defined as an overarching concept for interventions that assess whether a future RCT is viable. Within this concept are three subsets of studies: randomised pilot studies, non-randomised pilot studies and feasibility studies that are not pilot studies. Therefore, pilot studies are one type of feasibility study. Figure 10 shows in diagrammatic form when there is uncertainty about a future RCT feasibility, a feasibility study is appropriate.

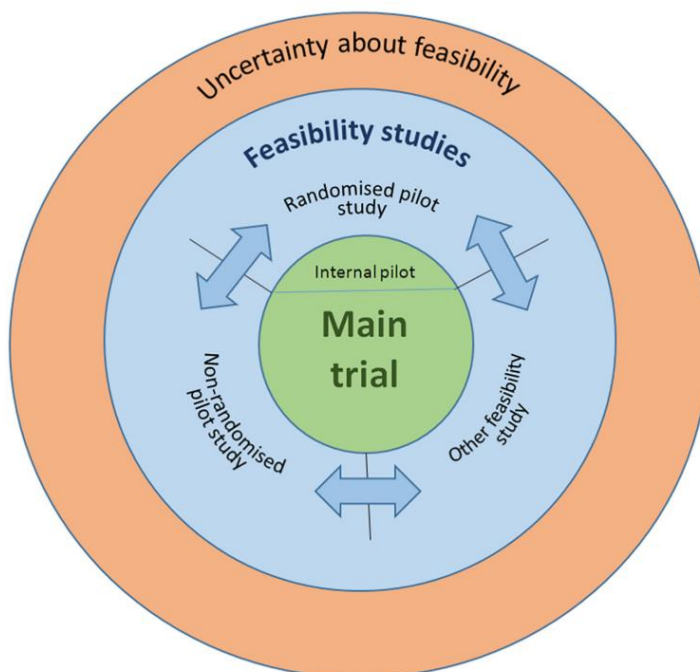


Figure 10 Pilot and feasibility conceptual framework (423)

Non-randomised pilot studies aim to evaluate all or part of the intervention, as well as other processes of the future trial, but without the randomisation of participants. These studies may be very similar to a randomised pilot study except the control and intervention groups are not randomised. They may centre on testing the intervention, without examining trial processes.

Feasibility studies that are not pilot studies do not pilot-test the intervention or the trial processes but may test one aspect of the intervention to inform intervention development. The majority of studies testing interventions, however, employ a randomised pilot study design (423), as was employed in this PhD research. This type of pilot feasibility study aims to conduct the intervention of a future RCT on a smaller scale, including the randomisation process (423). These studies are valuable to inform on key uncertainties in the future trial design, as well as testing the intervention strategies in a real-world setting. The MRC guidance on complex interventions suggests a 'feasibility and piloting' phase as part of early work to be carried out to inform confidence that an intervention can be delivered as intended, and the Eldridge et al. (423) conceptual framework is in keeping with this guidance (413).

A recent review of published guidance by Hallingberg et al. (67) identified pre-requisite activities for pilot feasibility studies. These include determination of the evidence base, establishment of a theoretical framework for the intervention (described in section 2.20), identification of intervention components and understanding how intervention components may interact and impact on the outcomes (described in section 2.21). It is important to understand how the intervention interacts with the various contextual settings, as well as identification of unintended harms (424) and implementation issues (67,425).

The use of mixed methods to assess processes such as feasibility of recruitment, consent to randomisation, retention, randomisation procedures and whether all components of a protocol can operate together, as well as participant burden of outcome assessments, has been endorsed (67,426). The inclusion of stakeholder involvement and the use of qualitative methodology is widely recommended in the planning, running and evaluation of pilot studies to ensure the realities of the setting are reflected in the findings (66). Finally, it is important to report intervention studies using an agreed and recommended format, such as the new Consolidated Standards of Reporting Trials (CONSORT), by Eldridge and colleagues that includes an extension for randomised pilot and feasibility trials (Appendix Q) (426). A range of acceptability and feasibility studies is warranted to test interventions to reduce SB, particularly in a workplace setting (57). An understanding of the conditions under which approaches to SB reduction are likely to be feasible and acceptable will assist with tailoring programmes to suit

organisational needs (427). A cluster-randomised crossover pilot feasibility study will be used in this PhD research to test a set of feasibility objectives to ascertain if a future randomised controlled trial is viable in terms of recruitment and retention.

Identifying and using one or more behaviour change theoretical models is widely reported to be an important first step in the development of intervention strategies (348). The following section will outline the importance of theory as a framework to design successful interventions and describe some of the most commonly used theories in SB and PA interventions, concluding with the rationale for the theoretical choice for this PhD research.

2.21 Behaviour Change Theories

2.21.1 The importance of theory in behaviour change

In the case of public health promotion and interventions to improve health, for them to be effective it is helpful to understand the theories surrounding health behaviour, health promotion and public health (348). A theory is defined as an explanatory framework which helps us understand and predict the ways in which individuals or societies operate (428). Kerlinger et al. (429) suggest that a theory is a completely closed set of interrelated concepts (i.e. the major components of a theory), that attempt to explain and predict phenomena by presenting a systematic view of specific relations among variables of that phenomenon. These are, in essence, abstract and symbolic representations of a conceived reality. They are more of an ideal than a reality and represent an integrated summary of the hypothesised causal processes involved in behaviour change (357). Theories of behaviour suggest and explain ways to achieve behaviour change and are useful in predicting behaviours under certain conditions. They also guide and direct the search for modifiable factors such as knowledge, self-efficacy, social support, and attitudes. The relationship between theory, research and practice occurs on a continuum, and an understanding of theory provides a guide for effective practice and programming. In the development and evaluation of complex interventions (413), emphasis is placed on the use of theory as evidence suggests that theoretically-informed interventions lead to better outcomes (430).

Michie and Prestwich (430) highlight the following benefits of incorporating theory into complex intervention design and evaluations:

1. appropriate intervention targets can be informed by theory by identifying key constructs that are hypothesised to be causally related to behaviour

2. potentially stronger effects may be conferred by changing constructs that cause behaviour that theoretically lead to behaviour change
3. theory provides a means for selecting intervention techniques by initially identifying theoretical constructs to target, and to refine and tailor intervention techniques or strategies if required
4. accumulating empirical evidence of the effectiveness of interventions across various populations, contexts and behaviours within a theoretical framework facilitates a broader understanding of behavioural interventions
5. theory-based interventions can help provide a greater understanding of why interventions are effective or not, by providing information on the mechanisms of change thereby aiding the refinement and development of better theory.

Essentially, theories assist researchers to make sense of complex phenomena by providing tentative explanations for how and under what circumstances behaviours occur. These factors can then be targeted by interventions. By using behaviour change theory in the development of interventions provides a way of understanding the effectiveness, or lack thereof, of a particular intervention (413).

The MRC's published strategy (413) incorporates a development phase, within which is an 'identifying and developing theory' stage before moving on to modelling process and outcomes. Although there is increasing recognition that interventions to reduce SB and increase PA should use theories of behaviour change in their development (431), many published interventions do not mention theory in their development (432). Michie et al. (431) outline three important reasons for using theory as a basis for developing interventions. The first is, if the causal determinants of behaviour, i.e. theoretical mechanisms of change, and behaviour change are targeted, interventions are more likely to be effective. Second, if interventions are theoretically informed, the theory itself can be developed and evaluated. Third, with regard to developing theory across different populations, contexts and behaviours, a theoretically informed intervention allows and supports understanding of what is effective.

Two theoretical paradigms are contended in the field of health promotion; that is the dualism between individualistic and structuralist approaches to health behaviour (428). Promoters of individualist theories argue that it is the individual's own responsibility to maintain good health, and people exercise control over the various aspects pertaining to their health. Whereas advocates of a structuralist viewpoint take a stance whereby individuals have little

control. Structuralists argue that the individual's health cannot be extricated from their social, environmental, political and economic systems (433).

Reviews of theory-based interventions have demonstrated effectiveness in PA promotion in workplace settings (434), however, in the field of SB, theory-based research is lacking (432). Just 14% of worksite-based interventions to reduce SB mentioned theory (432).

The focus of the following section is to critically examine a selected individual focussed theory of behaviour change, Theory of Planned Behaviour, and a socially focussed model, Social Cognitive Theory, in order to briefly outline how the theories may be useful in providing a model of understanding the causal determinants of behaviour and behaviour change, and may be applicable to SB in a workplace setting. A critique of each theory is also provided.

2.21.2 Theory of Planned Behaviour

The individual level theory most commonly used in interventions, either in isolation or together with another framework to reduce workplace SB, is the Theory of Planned Behaviour (TPB) (432,435). TPB is an extension of Theory of Reasoned Action (TRA), which assumes for the most part human behaviour is controllable and rational (436). Attitudes and subjective norms predicate behaviour and behavioural intention. TPB expands TRA to include situations where an individual does not have total control over the behaviour in question, and while behavioural intention is of central importance, an individual's perceived control over said behaviour also influences it. TPB is guided by three main considerations: beliefs about the likely outcomes of the behaviour and the evaluation of the outcomes (behavioural beliefs), beliefs about the normative expectations of others and an individual's motivation to adhere to these expectations (normative beliefs), and perceived barriers and facilitators that may be present, as well as their power (control beliefs) (437).

Studies that used TPB in their design reported varying outcomes with regards to sitting time. Van Berkel (2014) found no change in outcome measures using this model; while DeCocker (2016) reported reductions in self-reported SB and increases in objectively measured breaks in workplace sitting. However, even where individual behaviour is required, such as PA, the social and policy context strongly affects the ability of an individual to engage in the behaviour. In developing an intervention, the higher-level behaviours, not included in individual-level theory such as TPB, should not be ignored, and the evidence is clear that an exclusive reliance on individually oriented interventions would be inadequate to achieve our pressing population health and healthcare goals (348).

In the last 40 years, the limited reach and staying power of even the most effective individual focused behaviour change interventions have led to a fundamental ‘paradigm shift’ in our understanding of what the targets of effective interventions need to be (348). Models and theories themselves have evolved away from individuals in isolation, towards the broader and multi-level behaviour and social-change models that look at the contexts in which people live and work. The Social Cognitive Theory, outlined and critiqued in the next section, addresses the tension between two deterministic ideas that have characterised human behaviours: individuals versus the environment.

2.21.3 Social Cognitive Theory

Social Cognitive Theory (SCT) was first known as Social Learning Theory based on the operation of principles of learning by humans within their social context (438). SCT emphasises reciprocal determinism, which is the dynamic interplay between individuals and their environments, unlike most behavioural and social theories which focus on how individual, social and environmental factors influence individual or group behaviour (439). The key concepts of SCT are outlined in Table 7.

Table 7 Social Cognitive Model Key concepts

RECIPROCAL DETERMINISM	INDIVIDUALS AND GROUPS ARE INFLUENCED BY ENVIRONMENTAL FACTORS, AND VICE VERSA, BUT INDIVIDUALS AND GROUPS CAN REGULATE THEIR OWN BEHAVIOUR
OUTCOME EXPECTATIONS	Beliefs about the value and the likelihood of the consequences of the behavioural choices
SELF-EFFICACY	Beliefs that a person holds of their ability to engage in a behaviour that brings the desired outcome
COLLECTIVE EFFICACY	Beliefs about the ability or the group to engage in a joined action to bring about the desired outcome
OBSERVATIONAL LEARNING	By exposure to interpersonal or media displays of them, through peer modelling, facilitates learning of the new behaviour
INCENTIVE MOTIVATION	Behaviour is modified by incentives or rewards, or punishment
FACILITATION	Making behaviours easier to perform by providing equipment and tools, and by making environmental changes
SELF-REGULATION	Regulation of oneself via self-monitoring, goal setting, feedback and engaging with social support

MORAL DISENGAGEMENT

Thinking about harmful behaviours and those who are harmed in a way that makes the damage acceptable through a disengagement of self-regulatory moral standards

SCT provides a comprehensive and well-supported conceptual framework to understand the influences on individuals and the processes through which learning occurs and can provide health-related solutions. Basic and effective methods that SCT advocates for successful health interventions, is to ensure relevance and individualisation. The fundamental determinants of health behaviour in SCT are: knowledge of health risks, perceived self-efficacy, outcome expectations, health goals, perceived facilitators and barriers, and social and structural impediments to change (440). Although SCT has been widely and successfully used in PA intervention studies (441), evidence on social-cognitive determinants as predictors of SB remains limited.

Gordon et al. (442) conducted an RCT to reduce workplace sitting in sedentary adults using SCT constructs. Emails with psychosocial information and other available resources relating to decreasing SB at work (educational info, goal setting, self-regulation, facilitation, reciprocal determinism) in a 10-week complex intervention. The findings showed no significant reduction in workplace SB in the intervention group. It may, therefore, be concluded that individual-level only behaviour change strategies are not sufficient in isolation and without environmental strategies to reduce workplace SB.

It has been agreed that a better approach to address the complexities of health promotion and health behaviour, is a premise of understanding how the 'upstream' factors influence the individual 'downstream' factors. Intervening on multiple levels across the ecological spectrum may be the most effective to change behaviour (188,316,443).

In this PhD research, several constructs used in the intervention closely matched SCT, thus addressing some of the limitations of socio-ecological models outlined in Section 2.14.1 and their lack of guidance with regards to behaviour change mechanisms.

2.22 Workplace Interventions to Reduce Sedentary Behaviour

Several recent reviews examining the effectiveness of workplace interventions to reduce SB have been conducted (339,340,355). In Shrestha et al. (339), only four of the 38 studies included in this Cochrane Systematic Review were judged to have a low risk of bias, with the

remaining studies deemed as high risk of bias and categorised as producing low to very low quality evidence.

These assessments were based on risk of bias in terms of selection bias (i.e. inadequate randomisation (45,46,444–448) and lack of allocation concealment (45,46,453–455,444–447,449–452)), detection bias (lack of blinding of outcome assessors (45)), attrition bias (incomplete outcome data (46,445,459–464,446,447,450,453,455–458)), reporting bias (selective reporting (46,456,459,465,466)), unequal baseline groups/characteristics, and unvalidated measures of SB (446,454,455,462,467,468). Although five of the studies (442,448,460,461,469) used accelerometer/inclinometers to measure the outcomes, which are valid and reliable measures of sitting times, methodological decisions made before and after data collection may have affected the outcomes (i.e. cut-off points, type of accelerometer and wear time definitions). Three of the four RCTs with low risk of biases, and thus providing high quality data, employed the use of sit-stand workstations for participants to reduce their sitting by standing (470–472). Ellegast et al. (471) reported a reduction of sitting in those in the intervention group who received a stand-up desk, a pedometer and face-to-face motivation to walk at lunchtime. Participants increased their PA and reduced their sitting after 12 weeks; however, the sample size was small in this study (n=25), thereby reducing the generalisability of the findings. Danquah et al. (470) reported a reduction of 71 minutes sitting time (replaced by standing) after 3-months in the intervention group (n=141) compared with the control in a study with a larger sample size (n=317). Follow-up measures beyond 3 months were not conducted, and the reduction in sitting times may not have been sustained over time. Healy et al. (472) conducted longer-term follow-up measures at 12 months, and found that those in the intervention group replaced 45 minutes of sitting with standing at this time-point.

It has been posited that the success of sit-stand desks may be due to the desks allowing individuals to continue with their favoured activity, i.e. computer use (473). However, the cost involved with initial investment of sit-stand desks has been cited as a significant barrier to large-scale implementation (474,475). Moreover, standing for long periods may invoke deleterious outcomes for cardiovascular health, and has been associated with an increase in the risk of ischemic heart disease and varicose veins (476). Authors Rempel and Krause (477) warn that advising sedentary employees to increase standing time at work should not be recommended, and maintain that if the basis for a reduction in SB is to improve cardiovascular health, the promotion of standing is misguided.

Although the act of standing up requires some EE, the EE differences between standing quietly and sitting appear to be minimal. In Mansoubi et al. (478), it was reported that typing while sitting resulted in EE of 1.45 METs, whereas the EE while standing equated to 1.59 METs, a level at which minimum, if any, health benefits from a public health perspective would be observed. In line with this, Shrestha et al. (339) observe that, in theory, if an average person spent half of their 8-hour working day standing, they would expend an extra 16 kilocalories. In their meta-analysis, it was shown that an intervention combining a sit-stand desk and counselling increased standing time by 89 minutes per day at three-month follow-up – resulting in negligible additional EE. In contrast, the EE observed while using a desk-bike workstation at light intensity is 2.4 METs (479). The fourth RCT (480) with low risk of bias, and thereby producing high quality data in Shrestha et al. (339) systematic review, tested a multicomponent theory-based intervention including an under-desk pedal device to enable participants to replace SB with light physical activity. Although this was a small sample size (n= 27 intervention; n= 27 control) of mostly female participants, occupational physical activity was increased by 50 minutes per day in the intervention group at 16 weeks follow-up. In terms of public health, this level of increase of LPA replacing SB, may be an important target to improve population health.

Systematic reviews investigating behaviour change interventions have concluded that interventions focussing solely on reducing SB, rather than adopting a dual focus of targeting an increase in MVPA and a reduction in SB concurrently, have seen greater effects in reducing SB (282,432,481). An explanation for this may be that interventions attempting a dual-hinge approach (i.e. substituting SB with MVPA), engage two separate behavioural systems and this has been found to be overly challenging and less successful due to the strong reinforcement and restrictive properties of social and physical environments (473,481). However, while reallocating SB to MVPA yields far greater ‘per-minute’ reductions in risk factors (30 min reallocated to MVPA = 2%–25% improvement in biomarkers of risk); clinically meaningful reductions in metabolic risk can be achieved by replacing just 30 minutes of SB with light PA (2%–4% improvement per 30 minutes of reallocation) (482). This study was a large representative sample of >2,000 participants and employed objective measures of SB. However, it is not without limitations. The accelerometers used were waist-worn devices which do not differentiate between standing and sitting, and the study was cross-sectional in nature thereby limiting causal inferences. However, the evidence showing that replacing 30 minutes of SB with LPA per day was associated with improved biomarkers is an important finding in terms of workplace intervention design. Thus, engaging in light intensity PA, while

also continuing with the chosen activity (computer use), may improve the health and wellbeing of employees and does not require the major behavioural substitution required by individuals attempting to engage in MVPA in the workplace. This may fulfil public health objectives of reducing SB and increasing light intensity PA (LPA), but with greater acceptability and feasibility to participants and potential longer-term effects.

An increase of light to moderate intensity activity, while being able to continue a task, for example, pedalling an under-desk elliptical device has the benefit of (a) allowing the employee to continue to complete computer-based work tasks (483), (b) even very light to light effort while pedalling (30-50 watts) a stationary bike results in a EE of 3.5 METs (95), and (c) the cost outlay may be significantly lower than sit-stand desks (484). A current gap in the literature exists with regard to testing interventions that enable sedentary employees to reduce their SB by replacing it with LPA using an under-desk pedal device, in order to induce an increase in EE which may provide improved health outcomes. Furthermore, following a review of the literature, targeting those most at risk, i.e. professional men using this type of intervention component to ascertain acceptability and feasibility, has previously not been conducted.

2.23 mHealth in Behaviour Change Interventions

mHealth (mobile health) in interventions has rapidly increased in recent years, and the high penetration of mobile devices together with the development of new and powerful smartphone apps (applications), provides opportunities to expand the reach to previously isolated populations (485). The use of mobile apps, text messages, consumer wearables and sensors, interactive websites, and social media has been shown to improve health by supporting behaviours involved in disease prevention (e.g. PA and SB) (486). There are an estimated 97,000 apps available, and more than two-thirds of these are targeted to the health and wellbeing market (487). Individuals can now objectively monitor their own PA and SB levels. In combination with the PA trackers, associated smartphone and computer apps may assist individuals in improving their health behaviours via a range of motivational and tracking tools such as self-monitoring, feedback and goal-setting (488). Most monitors include goal-setting, self-monitoring and feedback content that closely match recommendations from social cognitive theory (488). PA trackers increase PA participation and can be used by researchers as intervention strategies to increase PA (489) and decrease SB (490). Studies have investigated the use of mHealth in a range of settings, including the workplace (491), with reasonable

evidence to support the promotion of workplace PA, while the impact of SB reduction is less clear (492).

Studies applying outcomes such as daily steps (493,494), or reductions in computer-use as a proxy for SB (495), and in studies of women participants using mHealth to promote PA and reduce SB in the workplace have resulted in reductions in SB (496). The findings of these studies must be cautiously interpreted with several limitations noted. The latter (496) was a small (n=20) feasibility study testing an individual level intervention using behavioural counselling sessions and a Fitbit Flex to reduce SB and increase PA in women shift workers. The study was not powered to test for significance, and its main aim was to test a set of feasibility objectives. Participants in the intervention using Fitbit Flex reported positive outcomes in the domains of demand, implementation and acceptability, and the study had no dropouts over 12 weeks. In terms of the secondary outcomes, SB and PA, the measurement device used in the study was the Actigraph, a waist-worn device that does not distinguish between sitting and standing.

Gremaud et al. (493) conducted a larger (n=146) randomised controlled study comparing two groups; participants receiving Fitbit, and participants receiving Fitbit and a gamification platform of the Fitbit data – MapTrek – to target competition as a motivator to increase PA and reduce SB. Participants in the Fitbit + MapTrek intervention group increased their daily steps by >2,000 per day which is clinically meaningful. The strengths of this study included a low (1%) attrition rate, objective measures of SB (albeit Actigraph, limitations of this device previously mentioned), the reduction of risk of bias by employing random sequence allocation, and blinded outcomes assessors to collect baseline measures. However, the participants were mostly white women thereby limiting the generalisability across different sub-group populations. Sedentary behaviour was defined as 0 steps and did not include standing quietly.

In Ganeson et al. (494), an intervention employing a pedometer in conjunction with a mobile app featuring personalised tools for self-monitoring, including personalised exercise logs, PA, and dietary intake was tested a large sample (n≈ 70,000) from around the world. A significant decrease in sitting hours post-Stepathlon participation of 0.74 h (95% CI: 0.78 to 0.71 h; $p < 0.001$) was reported in the study. However, outcomes were measured using self-report questionnaires increasing the risk of biases such as recall and social desirability. A further limitation was the pre-post study design and no randomisation or control groups were included. The authors also reported significant attrition rates (47%) thereby introducing attrition bias to the findings. The evidence demonstrated that mHealth implementation of a

low-cost life-style intervention was associated with short-term, reproducible, large-scale improvements in PA (daily steps), sitting times, and weight, although workplace sitting times were not reported.

Finally, van Dantzig et al. (495) reported a mean between-group difference in reduction in computer activity (a proxy for sedentary time) of 4.1 min, 30 min before and after receiving a persuasive text message. A significantly higher reduction in computer activity was observed in the intervention group compared with control; with an intervention group reduction of 10 min vs. control group reduction of 5.9 min. The intervention comprised timely, persuasive text messages on participants' smartphones during prolonged periods of sitting (detected by computer software installed on their computers). The intervention was based on four of six social influence strategies – authority, commitment, consensus, and scarcity. The strengths of the study were the moderate sample size (n=86), and low attrition rate (1.2%), however, the outcome measurement was collected using unvalidated software, and the participants were not randomised thereby introducing significant biases to the findings.

The evidence supporting the use of mHealth in promoting PA in a workplace context remains in its infancy. Those that have been conducted are of low methodological quality, however, have demonstrated the feasibility, acceptability, and potential effectiveness of interventions based on mHealth in workplace setting. The evidence on the use of mHealth in interventions to reduce SB is even scarcer. An identified gap in the literature is evidence testing the use of mHealth in a professional workplace setting, using a range of behaviour change techniques. A recent review of workplace interventions to reduce SB using mHealth (492) recommended a primary focus on SB in addition to PA in mHealth interventions, and to use experimental design employing mixed methods to explore the feasibility, acceptability and participants' experience of the mHealth component. The research in this PhD seeks to address these gaps in the literature by utilising mHealth to target SB reduction in a randomised controlled pilot feasibility study and using mixed methods to understand how mHealth may be employed in a future RCTs.

2.24 Paradigm Underpinning Research: Pragmatism

Researchers are urged to situate their research in a particular paradigm (497). A paradigm refers a cluster of beliefs about the nature and knowability of the social world. It pertains to a set of ontological and epistemological assumptions that form an overarching worldview and provide a philosophical foundation (498). Put simply, paradigm differences are worldviews that

influence how we know what we know, how we interpret reality and how we study the research questions we ask. Creswell (497) advocates an acknowledgement of how worldviews are shaped by the cultural, socio-political and personal experience of researchers and the influence this has on a research project.

This PhD research is underpinned by the philosophical stance ‘pragmatism’. This is the most commonly stated philosophy supporting mixed methods research (499–503). Pragmatism draws on many ideas including ‘what works’ using diverse approaches, and values both objective and subjective knowledge (6). Pragmatism advances the notion that the consequences are more important than the process in the ‘attempt to gain knowledge in the pursuit of desired ends’ (pg.69) (504). A pragmatic stance is taken in most mixed methods research where truth is what works at the time. Investigators using both quantitative and qualitative data, adopt a postmodern viewpoint and employ the reflective lens of the social, historical, political, and other contexts at play. In this tradition, knowledge is constructed using quantitative and qualitative data through the adoption of an inductive-deductive logic. In this way, each strand can form knowledge that can be compared and combined, thereby increasing the credibility of the study’s findings (505). This PhD research is situated within this meaningful understanding of pragmatism. Figure 11 illustrates the pragmatic stance, conceptual framework, methodological approach, and methods used in this PhD research.

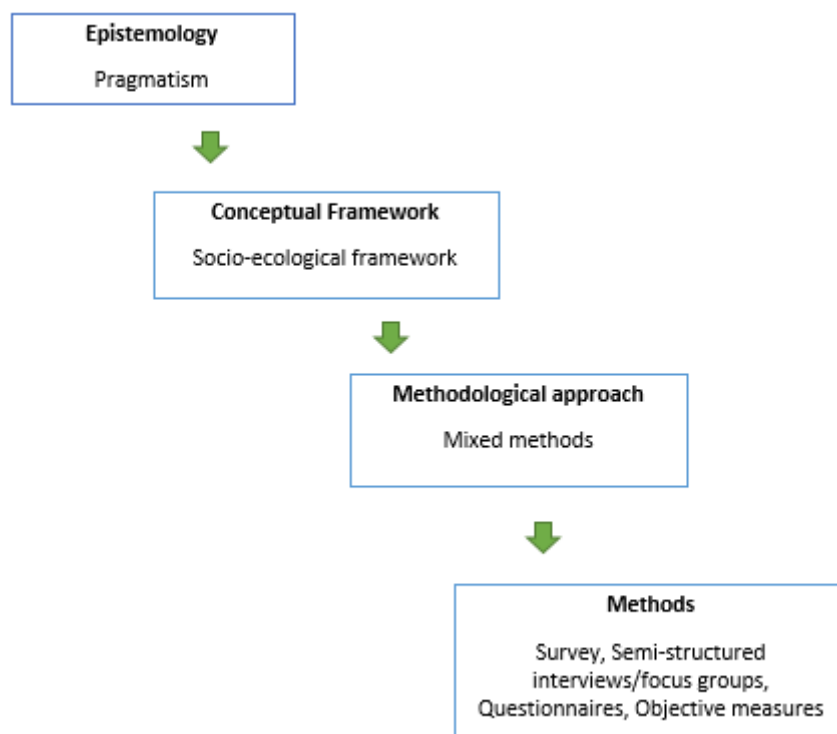


Figure 11 Paradigmatic stance, conceptual framework, methodological approach, and methods of the study (506)

Christ (507) illustrates a worldview matrix of contrasting research paradigms using four main dimensions:

1. Ontology: Reality is what 'exists' and ways in which it can be represented
2. Epistemology: How we gain knowledge of what we know – where the researcher situates themselves in relation to what is being researched
3. Axiology: Values in research - how the role of values influences the way research is conducted
4. Methodology: How the processes of research are used

Each of these tenets are examined in relation to the conduct of this PhD research and its pragmatic underpinning as a means of demonstrating what has been described as a 'coherent philosophy that goes well beyond what works' (pg.1051) (508).

2.24.1 Ontology

Ontology refers to the nature of reality that is assumed when researchers conduct their inquiries. Pragmatists argue for singular and multiple forms of reality (507). By following a Deweyan 'what works' action-oriented view of reality, researchers test hypotheses and provide multiple perspectives (503). Pragmatists deny that truth, regarding reality, can actually be determined. Originally used in the educational context, much of today's use of the pragmatic theory has expanded to conclude that human experience is a transaction between the living organism and its environment (508–510). In short, meaning resides neither exclusively in the objective real world, nor exclusively in the internal mind of the knower, but lies in the interaction or transaction between them, and in which both are affected by the responses of the other (511). This transactional view sees the objects of knowledge as the outcomes of processes of inquiry (511).

Acknowledging this is fundamental to addressing the PhD research objectives ii), iii) and iv) which are concerned with the exploration of the lived experience and differing realities of workplace SB. Objective i) is shaped by this ontological viewpoint of transaction, as the various domains of sitting were acknowledged and investigated in analysing the Healthy Ireland dataset. Together with the qualitative data it 'attempts to say something interesting about the nature' (pg.14) of sedentary behaviour (512).

The epistemological, axiological, and methodological approaches taken in the research are described in the following sections.

2.24.2 Epistemology

Epistemology is a way of understanding and explaining how we know what we know. It is concerned with the relationship between the researcher and the participant. The postpositivist researcher distances her/himself from 'subjects' to gain an 'accurate', 'valid' and 'reliable' representation. The constructivist co-constructs knowledge about events which occur as a result of closeness, i.e. the researcher and participants work together to create or co-construct knowledge and reality (505,507). Pragmatists, however, argue that both etic (objective) and emic (internal) perceptions can co-exist in a single study, and hold that the relationship between the researcher and participants is neither subjective nor objective but lies on a continuum (505). Each strand forms knowledge that can be compared and combined, increasing the credibility of the study's findings (513). On this continuum, there are some points during the research process where a highly interactive relationship may be required to answer complex research questions and at other points, no interaction at all may be needed (509).

Epistemologically, this researcher embraced pragmatism. To address the research questions, a focus on practicality whereby data are collected by a 'what works' approach was adopted (503,514,515). Neither quantitative nor qualitative methods are sufficient by themselves to capture and detail sedentary behaviour and its various influences, contextual factors, and the experience of those most at risk. The researcher sought a balanced view where both objectivity and subjectivity are valued, and where 'bias is not interjected because of a lack of understanding of key viewpoints' (pg. 141) (516). The study design was situated within the paradigm of pragmatism in which to answer the research questions, which epistemologically supports the mixing of methods.

2.24.3 Axiology

Alongside ontological and epistemological issues is the philosophical concept of axiology. According to Hesse-Biber (513), axiology means being conscious of our values, attitudes and biases. Pragmatic researchers contend that values are situational, relative, biased, and unbiased. This is dependent on the research design being used to answer the research question, and can take multiple positions where values are brought to the forefront and recognised as influencing the research process (507). Teddlie and Tashakkori (505) suggest that researchers taking a pragmatic position will ultimately choose what they want to study based on what is important to their own personal value system. The research topic is explored in an

approach that is in line with their own values and includes variables that they believe are most likely to produce interesting data. This description of researcher practice provided by Teddlie and Tashakkori (505) is consistent with the approach taken in which many researchers actually conduct their studies.

This is in accordance with how the current PhD research evolved, stemming from a personal interest in physical activity, and an interest in reducing sedentary behaviour on an individual level in those most at risk, and ultimately from a public health perspective. This process may be observed as a thread throughout this PhD research, asking the questions: 'what is the prevalence of sedentary behaviour?', 'who are those most at risk' and 'what are the experiences of those most at risk of this behaviour?' This led to the development and testing of a pilot intervention to reduce sedentary behaviour in those with the longest sedentary behaviour times. Concerns made by some authors (513,517) regarding the importance of retaining reflexivity in mixed methods approaches are noted in this study. For example, recognising my personal experience as someone who is motivated to be physically active; using my experiences to demonstrate motivation and enthusiasm to promote physical activity and reduce sedentary behaviour, while simultaneously taking care not to allow my personal experiences to unduly influence data collection, analysis and responses within the intervention period (497).

2.24.4 Methodology

The philosophical question of methodology concerns how the processes of research are used (507). Postpositivists take a deductive approach to test and verify *a priori* theories and determine significant differences among groups or strength in relationships among variables. On the other end of the methodological continuum is the constructivists' inductive approach. Researchers taking this worldview use constructivists' grounded data analysis approaches to build patterns, themes, and general concepts. Traditionally, researchers choose between postpositivist and constructivist models with regard to methodology (512). The pragmatist, however, takes a mixed approach, blending various forms of qualitative and quantitative data to derive knowledge about the problem and create a more representative model. The notion of 'utility' perhaps argues for reflexive research practice with any inquiry begging the questions of, 'what is it for?', 'who is it for?' and 'how do researchers' values influence the research?' (510). To adhere to the research objectives of this study, an integration of both quantitative and qualitative methodologies was required.

2.25 Application of Mixed-Methods in the PhD Research

Applying pragmatic philosophy to this research facilitates the selection of research methods emanating from different paradigms, which ultimately allows the research aims and objectives to be met. Research objective i) sought to examine the prevalence and correlates of domain-specific prolonged SB using secondary analysis of an Irish adult cohort dataset (Chapter 3). Quantitative methods were best suited to reach this objective, stemming from the postpositivist paradigm where scientific objectivity, probability, and approximated truth and meaning independent of consciousness and experience, are sought by the development of numeric measures to study the behaviour of individuals (506,515).

Objectives ii) and iii) were concerned with the experiences of those most at-risk of prolonged SB, in particular the barriers and facilitators to reducing SB (Chapter 4). Views, contextual relevance, and appropriateness of the intervention components were sought. Qualitative methods were best suited to meet these objectives. Aligned with the goal of understanding participants' views and subjective constructions of meaning in a constructivist paradigm, the researcher aimed to uncover the reality of participants' experiences in their natural settings, and attempt to make sense of, or interpret phenomena in terms of the meanings people brought to them (509).

A combination of quantitative and qualitative methods aligned well with objective iv) to test the acceptability and feasibility of a randomised pilot study of a small-scale theory-based intervention to reduce SB in a workplace setting (Chapter 5). This allowed data about the intervention to be collected at various levels, e.g. experiences of stakeholders involved, and objective and subjective SB and PA levels, and with regard to the trial processes (497).

2.25.1 Rationale for multiphase mixed methods evaluation design

As extensively described and outlined in this chapter, SB is a newly recognised health risk, and there is a dearth of research testing multicomponent workplace interventions in the population most at risk – professional males. This behaviour change intervention incorporated multiple components which included mHealth, environmental restructuring using a pedal device, and organisational support. In the design of a mixed methods study, two important considerations must be tackled: 1. what is the relative timing of when each component will be carried out? 2. how exactly will the components of the study be integrated? (515). The next section answers the question on integration, followed by the question of timing of components.

2.25.2 Integration

Integration, or the interaction between the qualitative and quantitative components of a study, is an important aspect of mixed methods research, and is indeed, essential in some definitions (518). The core premise of mixed methods research is that through systematic integration of quantitative and qualitative data, a greater insight is provided that neither method alone would yield. In the pursuit of a research question, the complementation of methods ensures that 'the whole is greater than the sum of its parts' (519). Approaches to integration procedures and data can be implemented at three points in a research project; at the design, methods, and interpretation and reporting stages (520). The integration of the qualitative and quantitative data accomplished in this PhD is outlined in the following section.

2.25.3 Integration at study design stage

During conceptualisation of a study, it must be decided how integration will be conducted in a mixed methods design. Two basic designs used in mixed methods studies include an explanatory sequential design and a convergent design. In the former, quantitative data is first collected and analysed, with the findings then informing qualitative data collection and analysis (521). In a convergent (or concurrent) design, quantitative and qualitative data are collected and analysed during a similar timeframe (515). Advanced mixed methods frameworks encompass two or more of these basic components. In this PhD research, a multistage mixed methods framework was used, which employed both an explanatory sequential design (Studies 1 and 2) and a convergent design (Study 3) to address the objectives of the research; all of which are described further in the next section.

2.25.4 Integration at methods level

Integration at the methods stage of this PhD research was intentionally and meaningfully conducted in the following ways:

1. using a connecting approach in the explanatory sequential phase (Studies 1 and 2) where participants were sampled based on the findings from the analysis of the first data
2. through building data from Study 2 to Study 3, where results from one data collection procedure informed the data collection approach, and where the latter builds on the former

3. and the embedding of the qualitative and quantitative data at multiple points within Study 3, where the combination of data was used for clarification of outcome measures and understanding contextual factors that could influence trial results (Figure 12).

The intent of integration of these data was to embed the data to produce integrated results, insights, and interpretations that expand the understanding and provide comprehensive results of the intervention evaluation (522). Integration at the reporting stage is described in the following section.

2.25.5 Integration at reporting stage

Integration at the reporting stage of the qualitative and quantitative data occurred in this thesis through a narrative by using the contiguous approach which involved presentation of the quantitative and qualitative findings (i.e. Studies 1, 2 and 3) in a single report but in separate sections (520). Finally, the 'fit' of data integration which refers to the coherence of the quantitative and qualitative data occurred in this study via expansion. For example, the strength of associations was found in the quantitative Study 1, while the qualitative Study 2 spoke to the nature of those associations. Hesse-Biber (513) argues that weaving of multi-methodology in randomised controlled trials (RCTs) enhances credibility, and the inclusion of subjective meanings 'provides the means to answer a new set of research questions' and expands the 'context of discovery' of RCT mixed methods designs in general, and can provide a 'context of justification' within an RCT.

2.25.6 Timing of components

The data in this PhD study were collected in multiple stages (Figure 12) and included two of the core basic designs of a combination of an explanatory sequential design and a convergent component (520).

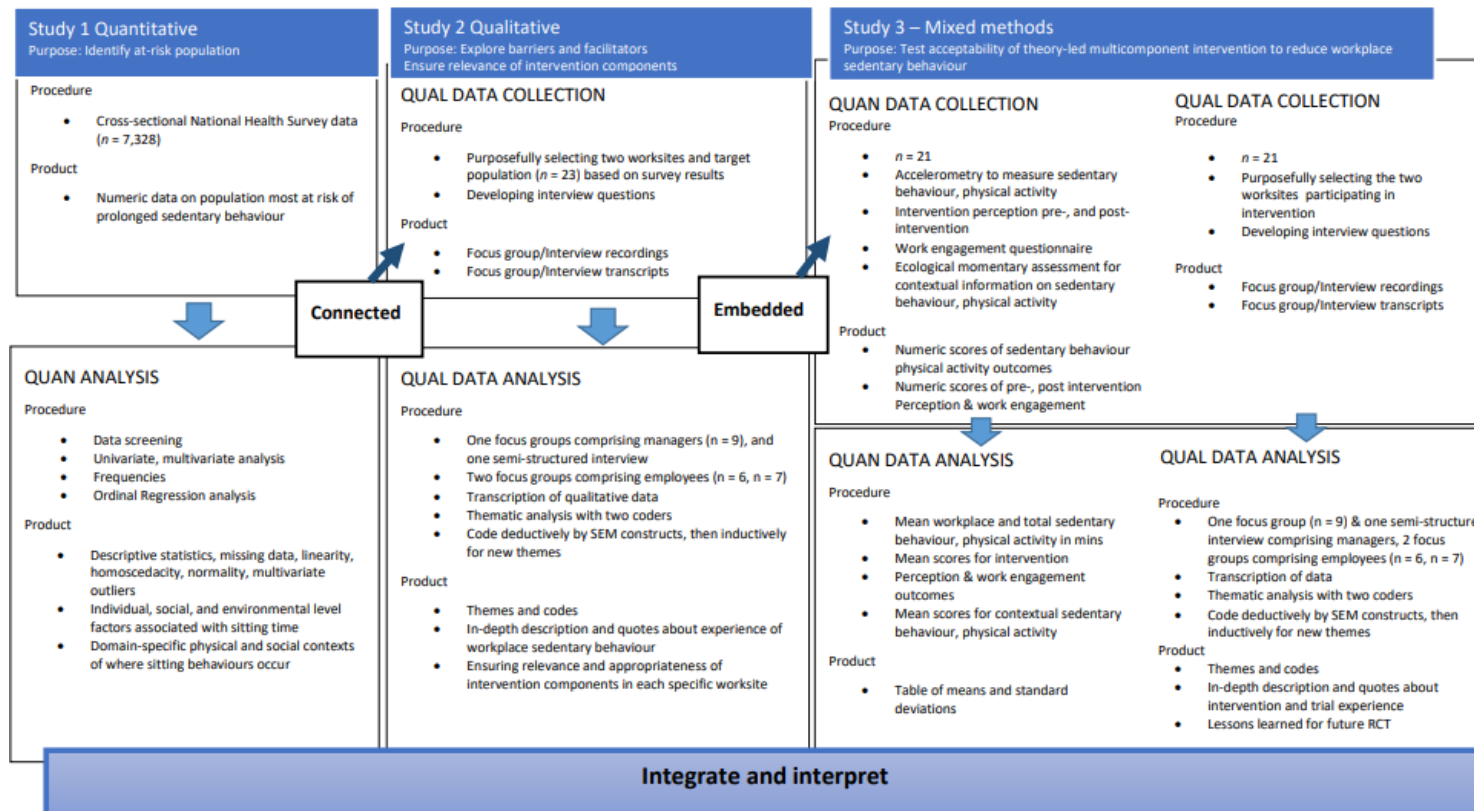


Figure 12 Step-by-step protocol for the multiphase design for the Cycle At Work intervention development and pilot evaluation using explanatory sequential design and concurrent designs with connected and embedded integration

2.26 The Current Study – Scope of the Study

The purpose of this PhD is threefold, that is, to identify those most at risk of prolonged SB, to explore the nature and experience of those most at risk of context specific SB in the domain in which it most occurs, and to design, implement and evaluate a multicomponent intervention to reduce SB. The research questions were:

1. What are the prevalence and correlates of total and domain-specific sedentary behaviour for Irish adults?
2. What are the barriers and facilitators to reducing sedentary behaviour in the context of those most at risk?
3. What are the perceptions and views of the target population of components of a workplace intervention guided by the socio-ecological model of sedentary behaviour? Are the proposed components acceptable and context-appropriate?
4. Is a multi-component theory-led workplace intervention to reduce sedentary behaviour by increasing physical activity acceptable and feasible to professional males?

2.27 Aims and objectives

The overall aims and objectives were described in Chapter 1. Briefly, the aims of the research were to identify the prevalence and correlates of prolonged SB in Ireland, explore the barriers and facilitators to reduce workplace SB, and develop and test the acceptability of a multicomponent intervention to reduce SB in those with longest sitting times.

The research objectives were to identify the prevalence and correlates of domain-specific prolonged SB using secondary analysis of an Irish cohort dataset, to explore the barriers and facilitators to reducing SB in the workplace setting SB occurs using focus groups and semi-structured interviews, to adopt a participatory approach in the development of a workplace pilot intervention to reduce SB using focus groups and a semi-structured interview. Finally, to test the acceptability and feasibility of a small-scale theory-based pilot intervention to reduce SB in a workplace population using mixed methodology.

The first objective was achieved in Study 1, fully described in the following chapter.

Chapter 3 Study 1 Examining the Total and Domain Specific Sitting Times in an Irish Adult Cohort

3.1 Introduction

As discussed in detail in Chapter 2, sedentary behaviour (SB) is a risk factor for a host of deleterious health outcomes, as well as premature death and overall mortality (11). To inform effective interventions and public health guidelines, research into the prevalence and determinants of SB is needed to identify at-risk populations with greater sitting times, and to explore the contexts in which most SB occurs. One of the five research priorities set out in Owen et al. (57) is to build evidence on all of the important factors that influence SB across different countries where environmental, social and cultural attributes may differ. The specificity of contextual and behavioural focus provided by the socio-ecological model (SEM), is helpful to emphasise the key role of contextual correlates and determinants (523).

Varying self-report measures are used in studies interested in SB, and not all studies include important domains and contexts in which SB accumulates (361). Previous studies have used the International Physical Activity Questionnaire (IPAQ) sitting questionnaire, which does not include a breakdown of the separate domains in which sitting occurs, highlighted in the SEM (366). In Loyen et al. (390) only two domains (occupational and leisure-time sitting) were assessed. Measures of total daily SB calculated by including key domains that contribute to total sitting time such as: work, screen-time, leisure time and transportation SB, may be more accurate reflections of overall SB (57,524).

It has been reported that for many adults, television viewing contributes significantly to the total amount of sitting accumulated throughout the day (122). TV viewing has been found to be associated with increased CVD mortality, and cancer mortality (184). Watching TV for 3 hours or more per day is associated with increased mortality regardless of physical activity, except in the most active quartile (32). Recent increased use of smartphones and tablets, together with TV streaming services, have changed the way audiences view programmes (121). In the present study, the inclusion of mobile devices within TV sitting times, may provide a more contemporary and accurate measure of leisure screen-time SB.

In the contexts of TV viewing and sitting during non-work times, which included reading and computer use, Stamatakis et al. (232) assessed self-reported SB. Participants in employment were also assessed on the average daily time spent sitting or standing while at work.

Transportation SB was not investigated as a separate domain. The least amount of daily SB accumulates in the motorised transportation context; 60 minutes per day of transport SB,

compared with 390 minutes and 120 minutes of occupational and TV viewing SB respectively (321). It can be argued that if the objective of interventions is to target the context in which most risk occurs; it may not be necessary to place transportation as a high-risk target for interventions to reduce SB. It is, however, necessary to include transportation SB in overall daily measurements of SB.

In the present study, transportation SB was included together with other leisure contexts of sitting (reading, relaxing, and eating). The data available in the Healthy Ireland dataset can be applied to the socio-ecological model to highlight sitting correlates in a population-level cohort. Figure 13 illustrates how variables available in the Healthy Ireland (2016) dataset can be mapped onto to socio-ecological model of sedentary behaviour (57).

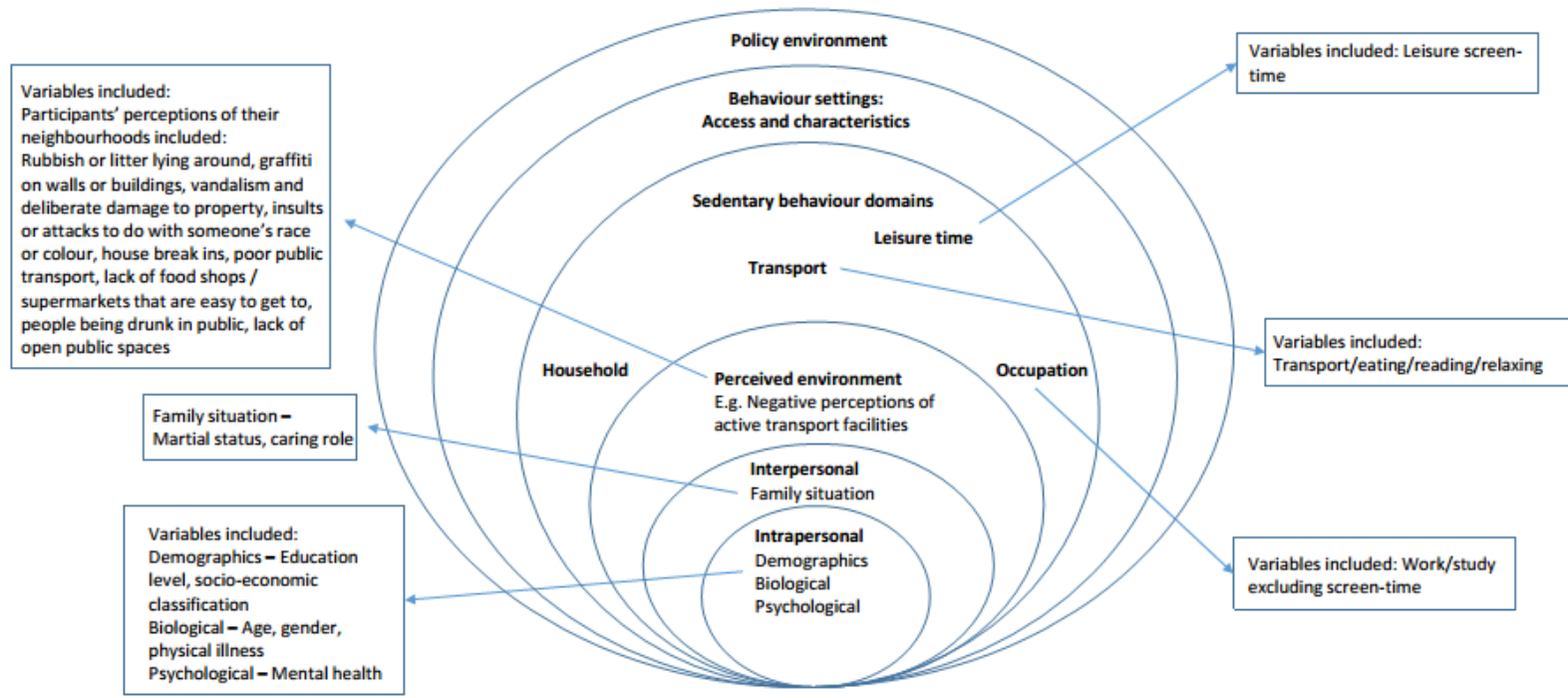


Figure 13 Socio-ecological model of four domains of sedentary behaviour mapped to the Healthy Ireland (2016) dataset (57)

Previous studies have examined some of the correlates outlined in the socio-ecological (SEM) of SB (366,390). One study included socio-demographic variables, dwelling location and life satisfaction in terms of total sitting time (366), while another examined socio-demographic variables, physical activity levels, and BMI in terms of occupational and leisure-time sitting (390). It is valuable to investigate the intrapersonal (psychological factors, risky health behaviours) and environmental factors (neighbourhood and work environment), that are emphasised by the SEM. Thus, investigation of a population level study, using data pertaining to adults with wide ranging ages is of value.

As described in Chapter 2, the primary strategic goal of research into the correlates and determinants of SB is to integrate evidence and promising strategies to reduce this health risk behaviour. Adopting the SEM approach highlights these multiple factors and contexts as the basis for investigation. The current study includes a broader range of socio-ecological factors than assessed in previous studies. It includes all important domains of sitting that incorporates the different contexts in which sitting is accrued across the day. The inclusion of the smartphone and tablet screen-time sitting, ensures a more contemporary measure of leisure screen-time sitting. This provides a comprehensive total sitting time calculation. The sample is a large representative sample, with a wide age-range (18-97 years) and is therefore generalisable.

The aims of this study were, in a population level study, to compare overall sitting between different individual, social and environmental categories, and to also identify individual, social, and environmental level correlates associated with sitting time across these domain-specific physical and social contexts in which sitting behaviour accumulates. To meet this aim, an evidence informed, iterative process was undertaken which is displayed in Figure 14. The pre-clinical phase, and phases 1 and 2 represent the stages of the MRC intervention development guidelines and how this study is mapped onto it. It is important to specifically provide evidence on the prevalence of sitting time and examine potential correlates of sitting as a prerequisite for the development of interventions (57).

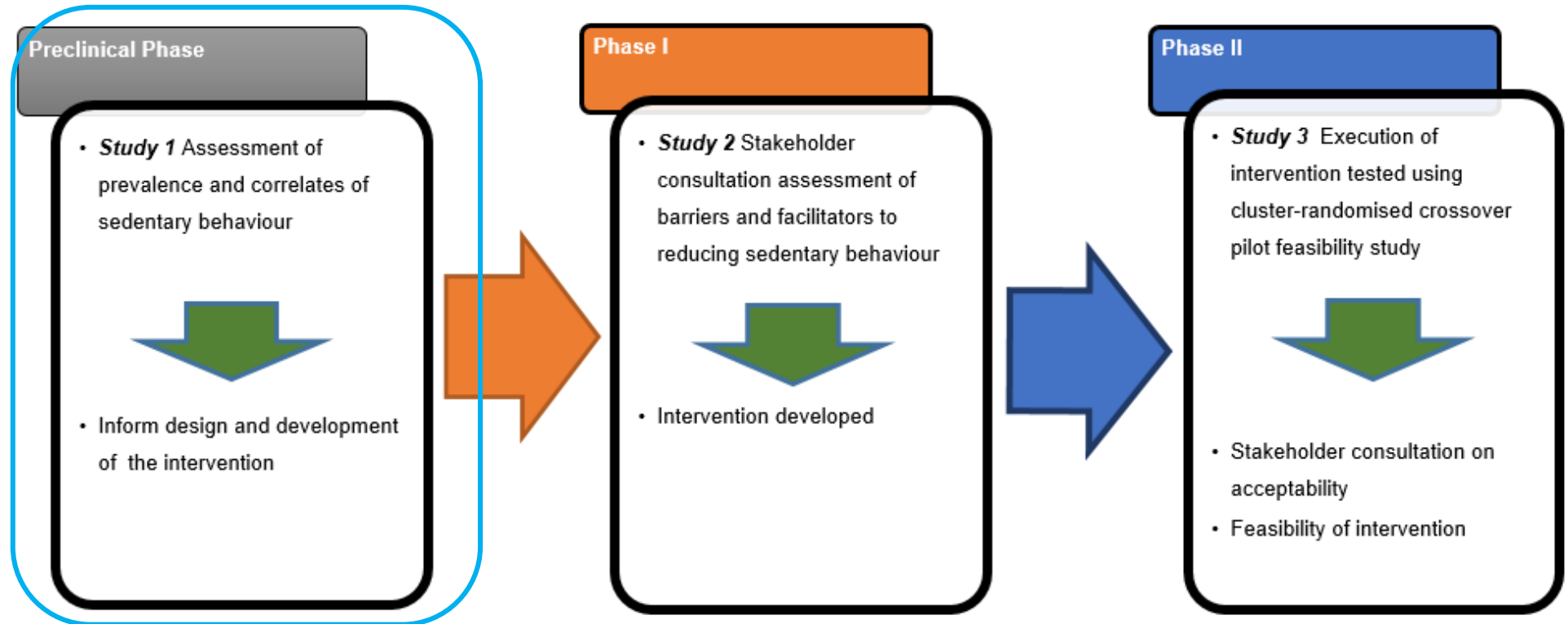


Figure 14 Studies involved in overall PhD research project

As outlined in Chapter 1, the primary objective of this study was to apply the SEM of SB to examine individual, social and environmental level factors associated with sitting time, and to investigate domain-specific physical and social contexts of where sedentary behaviour occurs, using this publicly available dataset.

3.1.1 Healthy Ireland survey

The Healthy Ireland survey is conducted to inform the 'Healthy Ireland Framework 2019-2025' (295), and its key objectives are outlined in Box 1.

Box 1 Key objectives of the Healthy Ireland Survey:

- Provide up-to-date and credible data to inform the monitoring and assessment of the policy initiatives included in the Framework
- Support and enhance Ireland's ability to meet many of its international reporting obligations
- Inform the Outcomes Framework for Healthy Ireland
- Take an outcomes focused approach to targeted monitoring
- Inform policy priorities and engagement and awareness activities of the Department of Health

This study has been published in the BMC Public Health Journal (525) (Appendix A).

Nicolson G, Hayes C, Darker C. Examining total and domain-specific sedentary behaviour using the socio-ecological model – a cross-sectional study of Irish adults. BMC Public Health, 2019 Aug 22;19(1):1155.

3.2 Methods

3.2.1 Study design

The sample comprised 7,328 individuals aged 18 and older participating in the second wave (2016) of the Healthy Ireland survey. This nationally representative survey is carried out on an annual basis to provide a picture of the health and wellbeing of those living in the Republic of Ireland. Data were collected by the market research company Ipsos MRBI. The provision of access to the data lies with the Department of Health and is available to researchers fulfilling assessment criteria. Access to the Research Microdata data for Study 1 of this PhD was granted in accordance with strict guidelines with regards to its use and security.

The primary sampling frame used by Healthy Ireland is An Post/Ordinance Survey Ireland's GeoDirectory (526). This is a complete database of every building in the Republic of Ireland. The sample of addresses was drawn by using two-stage equal-probability process, issued by Electoral Division clusters, and each cluster comprised 20 addresses. The initial stage of the sampling process was to select a representative distribution of sampling points around the country. In adopting the use of a probability sampling approach, every member of the defined population had a calculable chance of being included in the sample. This ensured that the survey sample comprehensively represented the defined population. A Kish Grid was used to randomly select participants (527). This is a selection process for random sampling individuals in each household. Fieldwork was conducted between September 2015 and May 2016. The Research Ethics Committee of the Royal College of Physicians of Ireland granted approval to conduct the original study. Informed consent was electronically recorded and obtained from each participant prior to commencement of the interviews. Trained interviewers conducted data collection, and interviews were completed on a Computer Assisted Personal Interview basis. Sources of the questionnaire instruments, as well as reliability and validity are provided elsewhere (528). Ethical approval for the present study was granted by the Research Ethics Committee, School of Medicine, Trinity College Dublin (ref. 20180517) (Appendix C).

3.2.2 Variables selected for inclusion in this study

Variables for analyses were guided by the SEM and selected a priori. Each variable was classified according to: [intrapersonal] (i) biological and demographic; (ii) psychological and emotional; (iii) behavioural; [interpersonal] (iv) social and cultural and (v) environmental. Potential policy or organisational factors that may influence SB were not available in the dataset.

3.2.2.1 Dependent variable

Sitting time in minutes was assessed using the following measure.

'I would now like to ask you a few questions about how much time you spent sitting down yesterday. It may be the case that yesterday was unusual in some way, but it is very important for this study that you answer these questions about yesterday rather than what you might consider to be a normal day:

(a) Thinking of yesterday, how much time did you spend sitting watching TV or another type of screen such as a computer, tablet, Ipad, smartphone, games console, Kindle etc.? Please do not include any time spent in front of a screen for work or study purposes.

(b) Thinking again of yesterday, how much time did you spend sitting while engaged in driving, eating, drinking, relaxing, reading etc. Please do not include any time that you already mentioned at the previous question.

(c) And again thinking of yesterday, how much time did you spend sitting whilst working or studying. Please do not include any time that you already mentioned at the previous questions.'

For the current study, the values of (a), (b) and (c) were summed to calculate total sitting time. For the occupational sitting time domain, only data pertaining to those who responded 'working' as their current economic status were included in the analyses. Responses such as, 'student/pupil, home duties, unemployed', were removed for this domain prior to analysis.

3.2.2.2 Intrapersonal correlates

Biological and Demographic factors

Information on age, gender and physical health status was provided by respondents. In terms of physical health, participants were asked if they had any long-standing illness or health problem, i.e. problems which have lasted or will last for at least 6 months or more. Responses were a dichotomous 'yes' versus 'no'.

Education level attained and socio-economic classification were included in the analysis as socio-demographic characteristics. Education level was re-classified for the current study into four categories for ease of analysis: early childhood, primary education, lower secondary; upper secondary; tertiary, post-secondary, non-tertiary; bachelors or equivalent, masters or equivalent, doctoral, or equivalent. This variable was dichotomised 'early childhood, primary education, lower secondary, upper secondary' versus 'tertiary, post-secondary, non-tertiary, bachelors or equivalent, masters or equivalent, doctoral or equivalent' in the regression models.

Socio-economic classification was categorised in four levels (not classified; routine and manual occupations; intermediate; administrative, high-managerial professional occupation) for descriptive analysis. This was dichotomised 'not classified; routine and manual occupations;

intermediate' versus 'administrative, high-managerial professional occupation' in the regression models.

Psychological factors

Psychological distress was measured by recording the presence or absence of symptoms such as anxiety or depression using the instrument Mental Health Index-5 (47); a subscale of the Short-Form 36 questionnaire (48). A cut-off point of ≤ 56 predicts disorder, and this was used to dichotomise the variable to 'probable mental health problem' versus 'no mental health problem'.

Behavioural factors

Regarding physical activity, participants were asked, 'do you think you generally do enough physical activity?' Dichotomous responses of 'yes' versus 'no' were used in the analyses.

Smoking behaviour was dichotomised in the present study into 'daily/occasionally' versus 'no'.

Regarding alcohol consumption, the Alcohol Use Disorders Identification Test (AUDIT-C) is an alcohol-screening tool that can help identify individuals who are hazardous drinkers or have active alcohol use disorders (including alcohol abuse or dependence) (49). Dangerous alcohol consumption was measured by using questions on drinking behaviour that were scored on a scale of 0-12 (scores of zero reflect no alcohol use) and ranked on the AUDIT-C scale. This was included as a continuous variable in the regression analyses.

3.2.2.3 *Interpersonal correlates*

Relationship status was re-coded in the present study into two groups 'married or civil partnership' versus 'single, widowed, divorced and separated'.

Participants were asked if they provided regular unpaid personal help for a friend or family member with a long-term illness, health problem or disability. This variable was included as 'caring responsibilities' in the analyses. Dichotomised 'yes' versus 'no' were the response categories.

3.2.2.4 Environmental correlates

Participants' perceptions of their neighbourhoods were derived from questions used in the previous national survey of the lifestyle, attitudes and nutrition of people living in Ireland (SLAN) (530). Questions included whether the following were 'a big problem, a bit of a problem or not a problem':

'Rubbish or litter lying around; graffiti on walls or buildings; vandalism and deliberate damage to property; insults or attacks to do with someone's race or colour; house break ins; poor public transport; lack of food shops/supermarkets that are easy to get to; people being drunk in public; and lack of open public spaces.'

For analyses in this study, all questions were dichotomised as 'a big problem' and 'a bit of a problem' versus 'not a problem'. The variables were used as an interval/ordinal scale ('0 to 9 neighbourhood problems') in correlation and regression analyses.

3.2.3 Statistical analysis

Analyses were conducted using SPSS 25 for Windows (531). Data were weighted by Ipsos MRBI and details about this process are described elsewhere (528). Missing data were very low for all the variables included in the analysis (<5%). Means, standard deviations and medians were calculated for sitting times within the domains. Continuous data were examined for normality by inspection of histograms, QQ plots, and kurtosis and skew statistics. Normality was assessed visually with frequency histograms and statistically with Kolmogorov-Smirnov test suitable for large samples; and this indicated that the data significantly deviated from a normal distribution. Therefore, sitting times in all domains investigated were categorised as ordinal variables, and non-parametric testing was used. The Kruskal-Wallis test examined between group differences in the ordinal variables. Post hoc testing was conducted in analysis involving more than two groups using a Bonferroni adjusted alpha level to control for Type 1 error (532). Data on total sitting times were shown in terms of the various correlates included in the final models, to indicate the characteristics of those who engage in prolonged sitting. Multivariate ordinal regression analyses were executed to investigate associations between all of the (i) biological and demographic; (ii) psychological, (iii) behavioural; (iv) social; and (v) physical environmental correlates with the dependent variables total sitting time, and the three domain-specific contexts of sitting. The level of significance for all statistical tests, other than the post-hoc testing was set to $p = 0.05$.

3.3 Results

3.3.1 Recruitment and response rates

In advance of fieldwork conducted by Ipsos MRBI on behalf of the Department of Health, 13,720 addresses were pre-selected for the Healthy Ireland survey. To maximise the robustness of the probability sampling approach a high response rate must be achieved. A core requirement of the Healthy Ireland survey was to achieve a response rate of 60% amongst all eligible households. The response rate was 59.9%. Details of the characteristics of each sampled household are outlined in Table 8.

Table 8 Details of the response rate for each sampled household ¹

CATEGORY	OUTCOME	CASES	TOTAL
COMPLETE INTERVIEW	Full interview		7498
UNPRODUCTIVE ADDRESS	No reply after five contacts	1,825	
	Address inaccessible/dangerous	250	
	Address not found	86	
	Appointment not maintained by respondent	6	
	Partial interview	4	
	Other reason unproductive	418	
	<i>Subtotal</i>		<i>2,589</i>
			10,087
REFUSAL	Upfront refusal to interviewer	2,204	
	Respondent refusal by contacting head office	218	
	<i>Subtotal</i>		<i>2,422</i>
			12,509
INELIGIBLE	Property vacant	822	
	Occupied but not main residence	163	
	Non-residential address	111	
	Communication difficulties	115	
	<i>Subtotal</i>		<i>1,211</i>
TOTAL			13,720

¹ From the Health Ireland Survey 2016 Technical report

The response rate of 59.9% was calculated by dividing the number of complete interviews by the sum of all addresses minus ineligible addresses (7,498 divided by 12,509). Responses were lower in Dublin compared to other regions (46.5% within Dublin compared to 65.3% outside Dublin). This was addressed through application of the post-survey weighting structure by Ipsos MRBI. Within the dataset, 170 participants under 18 years were removed prior to analysis for this PhD study. The sample used in the analysis of this study thus comprised 7,328 adults who completed the second wave (2016) of the Healthy Ireland survey.

3.3.2 Participant characteristics

The mean age of the participants (n=7,328) was 51 years (SD \pm 17.8). All descriptive characteristics are presented in Table 9 to address the first aim of the study. The total median sitting time of the sample was 450 minutes per day, IQR 290 minutes per day and the total mean sitting time was 473.75 (SD 201.45) minutes per day. In terms of prolonged sitting, i.e. >7 hours per day, 50.6% of respondents engaged in dangerous levels of sedentary behaviour.

Table 9 Mean and SD (Median) for total sitting in min/day, for intrapersonal, interpersonal and environment level influences

	N	Mean \pm SD (Median)
Total sample	7,328	473.75 \pm 201 (450)
Age		
18-24	267	510 \pm 179 (510)
25-34	467	480 \pm 200 (470)
35-44	603	475 \pm 201 (450)
45-54	447	477 \pm 194 (480)
55-64	407	448 \pm 187 (420)
65-74	203	392 \pm 164 (370)
75-84	94	392 \pm 165 (360)
85+	10	437 \pm 140 (420)
Gender		
Female	1,313	456 \pm 193 (420)
Male	1185	477 \pm 193 (480)
Long-standing illness		
No	1,958	463 \pm 194 (425)
Yes	538	477 \pm 190 (450)

Education level		
</= Lower secondary	341	409 ± 185 (375)
Upper secondary	749	439 ± 187 (420)
Post-secondary course	442	458 ± 191 (420)
Bachelor's degree or above	966	510 ± 193 (510)
Socio-economic classification		
Not classified	494	464 ± 185 (425)
Routine/manual	503	400 ± 174 (370)
Intermediate	633	460 ± 199 (420)
Higher managerial/professional	868	509 ± 193 (485)
Probable mental health problem		
No mental health problem	2,310	463 ± 192 (433)
Probable mental health problem	188	506 ± 210 (480)
Physical activity levels		
Insufficient physical activity	1,121	493 ± 200 (480)
Sufficient physical activity	1352	445 ± 185 (420)
Workplace activity		
Sitting	761	613 ± 167 (630)
Standing	281	366 ± 145 (360)
Mostly walking/moderate activity	553	370 ± 150 (360)
Mostly heavy labour/physically demanding	125	330 ± 140 (300)
Tobacco use		
No	2,024	465 ± 193 (450)
Yes	474	472 ± 196 (450)
Audit-C		
1-4	951	465 ± 196 (420)
5-8	275	483 ± 197 (480)
>6	772	490 ± 186 (480)
Marital status		
Married/civil partnership	1,366	456 ± 196 (420)
Not married/or in civil partnership	1,132	478 ± 190 (480)
Caring Role		
No	2,230	468 ± 194 (450)
Yes	268	448 ± 187 (420)
Neighbourhood attributes		
No Problem	893	456 ± 186 (420)
Some problems	1,605	471 ± 197 (450)
Location		

Urban	1,582	494 ± 191 (480)
Rural	916	418 ± 189 (390)

3.3.3 Sitting time by domain specific context

The domain specific average sitting time in minutes per day, by socio-economic classification (SEC) is presented in Figure 15. Sitting times were longest in the work/study domain (195 ± 166), followed by screen-time sitting (184 ± 122) and transportation/leisure sitting (139 ± 95). Those in higher professional occupations had the longest sitting times in terms of both work/studies sitting (230 ± 161) and transportation/leisure sitting (142 ± 78). While those in routine/manual occupations had the longest leisure screen-time sitting (190 ± 107).

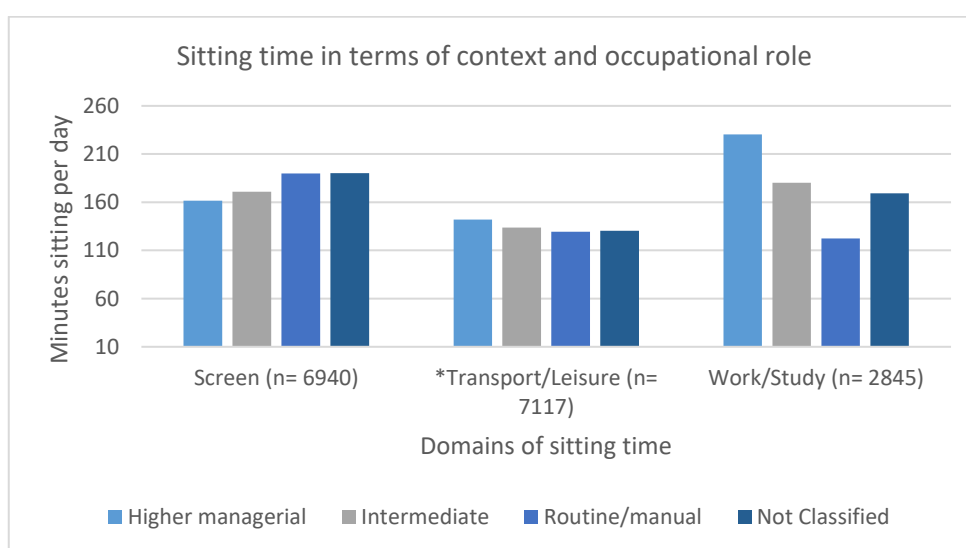


Figure 15 Domain-specific sitting times in terms of socio-economic status

*Full context Driving/leisure/relaxing/eating/reading.

Cumulative odds ordinal logistic regression with proportional odds were run to determine the effect of socio-ecologically informed variables on total, occupational, leisure screen-time and transportation/leisure sitting times. Separate binomial logistic regressions on cumulative dichotomous variables for each independent variable indicated that the assumption of proportional odds appeared tenable. Tests to determine if the data met the assumption of collinearity indicated that multicollinearity was not a concern.

3.3.4 Total sitting time

The strongest predictors of total sitting time were the intrapersonal factors of male gender, younger age, higher socio-economic classification and education levels, low physical activity levels, having a long-term illness and a probable mental health problem (Table 10). Having caring role responsibilities was associated with lower sitting times. Environmental factors including living in an urban dwelling, and higher scores of neighbourhood 'problems' were also associated with longer sitting times.

Table 10 Multivariate ordinal regression on the contribution of various correlates on total sitting

N = 1984	OR	95% CI	p-value
Gender			
Male	1.32	1.11–1.56	< 0.00***
Female	1	Ref.	
Age ^a	0.99	0.98–0.99	< 0.00**
Socio-economic status			
High	1.79	1.5–2.1	< 0.00***
Low	1	Ref.	
Education			
High	1.43	1.21–1.68	< 0.00***
Low	1	Ref.	
Long-term illness			
Yes	1.26	1.01–1.53	0.04*
No	1	Ref.	
PMHP			
No	0.73	0.53–0.99	0.04*
Yes	1	Ref.	
Physical activity			
Not sufficient	1.70	1.46–2.01	< 0.00***
Sufficient	1	Ref.	
Tobacco			
No	0.20	0.93–1.38	0.20
Yes	1	Ref.	
Audit-C ^a	0.99	0.99–1.06	0.18
Marital status			
Married/Cohabiting	0.87	0.72–1.01	0.07
Single/Divorce/Separated/Widow	1	Ref.	
Caring role			
No	1.30	1.01–1.67	0.04*
Yes	1	Ref.	
Location			
Urban	2.03	1.72–2.4	< 0.00***

Rural	1	Ref.	
Neighbourhood ^a	1.05	1.00–1.10	0.04*

^aContinuous variable

* = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$

3.3.5 Occupational sitting time

Results of regression analysis investigating the association between multi-dimensional correlates and occupational time sitting are outlined in Table 11. The strongest predictors of occupational sitting time were male gender, young in age, high socio-economic status and education levels, and low physical activity levels. Urban living was also associated with longer times spent in occupational sitting.

Table 11 Results of multivariate ordinal regression on the contribution of various correlates on occupational sitting

N = 2172	OR	95% CI	p-value
Gender			
Male	1.27	1.08–1.50	0.00**
Female	1	Ref.	
Age ^a	0.98	0.97–0.98	< 0.00***
Socio-economic status			
High	2.20	1.87–2.58	< 0.00***
Low	1	Ref.	
Education			
High	1.57	1.33–1.84	< 0.00***
Low	1	Ref.	
Long-term illness			
Yes	1.15	1.33–1.80	0.16
No	1	Ref.	
PMHP			
No	0.83	0.613–1.13	0.23
Yes	1	Ref.	

Physical activity			
Not sufficient	1.55	1.33–1.80	< 0.00***
Sufficient	1	Ref.	
Tobacco			
No	0.99	0.95–1.04	0.68
Yes	1	Ref.	
Audit-C ^a	0.99	0.96–1.03	0.68
Marital status			
Married/Cohabiting	0.96	0.82–1.13	0.64
Single/Divorce/Separated/Widow	1	Ref.	
Caring role			
No	1.20	0.94–1.53	0.15
Yes	1	Ref.	
Location			
Urban	1.96	1.67–2.30	< 0.00***
Rural	1	Ref.	
Neighbourhood ^a	0.99	0.95–1.04	0.68

^aContinuous variable

* = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.00$

3.3.6 Leisure screen-time sitting

The results of multivariate ordinal regression (Table 12) to investigate the association of multi-dimensional correlates on leisure screen-time sitting showed that male gender, older age, lower socio-economic and education levels were the biological and demographic variables associated with longer leisure screen-time sitting. In terms of health and health behaviours, long-term physical and probable mental health problems, insufficient physical activity, smoking, and alcohol consumption were associated with increased SB in this domain. Being single/separated/divorced/widowed, having no caring responsibility and urban living were associated with increased leisure screen-time sitting.

Table 12 Results of multivariate ordinal regression on the contribution of various correlates on leisure screen-time sitting

N = 5104	OR	95% CI	p-value
Gender			
Male	1.19	1.07–1.33	< 0.00***
Female	1	Ref.	
Age ^a	1.02	1.01–1.02	< 0.00***
Socio-economic status			
High	0.72	0.65–0.80	< 0.00***
Low	1	Ref.	
Education			
High	0.78	0.70–0.87	< 0.00***
Low	1	Ref.	
Long-term illness			
Yes	1.25	1.12–1.41	< 0.00***
No	1	Ref.	
PMHP			
No	0.73	0.61–0.89	0.00**
Yes	1	Ref.	
Physical activity			
Not sufficient	1.47	1.33–1.62	< 0.00***
Sufficient	1	Ref.	
Tobacco			
No	0.81	0.71–0.91	0.00***
Yes	1	Ref.	
Audit-C ^a	1.05	1.03–1.10	< 0.00***
Marital status			
Married/Cohabiting	0.79	0.72–0.88	< 0.00***
Single/Divorce/Separated/Widow	1	Ref.	
Caring role			
No	1.25	1.67–1.47	0.01*
Yes	1	Ref.	

Location			
Urban	1.28	1.16–1.42	< 0.00***
Rural	1	Ref.	
Neighbourhood ^a	1.02	0.10–1.05	0.11

^aContinuous variable

* = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$

3.3.7 Transportation/Leisure

The association of socio-ecological correlates on transportation/leisure sitting behaviour showed that increased sitting times were associated with older age, higher socio-economic and education levels, and physical health problems (Table 13). In terms of health behaviours, insufficient physical activity, being a non-smoker and higher alcohol consumption were associated with increased transportation/leisure sitting. Being single/divorced/separated/widowed, and higher neighbourhood ‘problem’ scores were associated with increased transportation/leisure sitting times.

Table 13 Results of multivariate ordinal regression on the contribution of various correlates on transportation/leisure sitting

N = 5258	OR	95% CI	p-value
Gender			
Male	1.00	0.90–1.12	0.97
Female	1	Ref.	
Age ^a	1.01	1.00–1.01	< 0.00***
Socio-economic status			
High	1.17	1.01–1.30	0.00**
Low	1	Ref.	
Education			
High	1.34	1.21–1.50	< 0.00***
Low	1	Ref.	
Long-term illness			
Yes	1.33	1.18–1.49	< 0.00***
No	1	Ref.	

PMHP			
No	1.10	0.90–1.32	0.39
Yes	1	Ref.	
Physical activity			
Not sufficient	1.12	1.02–2.41	0.02*
Sufficient	1	Ref.	
Tobacco			
No	1.15	1.01–1.30	0.03*
Yes	1	Ref.	
Audit-C ^a	1.03	1.01–1.05	0.01*
Marital status			
Married/Cohabiting	0.90	0.80–0.98	0.02*
Single/Divorce/Separated/Widow	1	Ref.	
Caring role			
No	0.95	0.81–1.11	0.50
Yes	1	Ref.	
Location			
Urban	0.99	0.89–1.10	0.82
Rural	1	Ref.	
Neighbourhood ^a	1.04	1.01–1.07	0.00**

^aContinuous variable

* = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$

3.4 Discussion

The aim of this study, in an adult population-level cohort, was to investigate the factors associated with prolonged sitting times, and the contexts in which this behaviour accumulates. The individual, social, and environmental factors examined were informed by the SEM, as outlined by Owen et al. (57). The results highlight the worryingly long overall sitting times in the Irish population, >7.5 hours per day, given the all-cause mortality risk associated with sitting for >7 hours per day (39). Sitting times reported in this study are significantly higher than previous reports of 5 hours per day (366), and earlier preliminary Healthy Ireland survey (2015) findings reported of 5.3 hours per day (533). Differences in measurement are a possible explanation for the variance. In the present study, total sitting time was calculated by adding together the sitting times of the three domains measured, whereas in previous studies, the

IPAQ short sitting questionnaire was used (366,533). The total sitting time used in Study 1 may have generated a self-reported total sitting time of increased accuracy as it captured SB separately across the most important daily contexts in which the behaviour accumulates (57). An increase in recent decades in desk-based and sedentary occupations has resulted in the workplace being a major contributor to overall sedentariness (43,534). Occupational sitting was the domain in which the highest sitting times were accumulated (>3 hours/day). This is in line with recently reported mean daily occupational sitting times (390), although is lower than some studies that found longer occupational sitting times (321,322). The present study measured worktime sitting across all occupational types and roles, unlike previous studies focusing on the most sedentary occupation, office employees. For working adults, more than half of daily sitting time on a work day is accumulated in the workplace (321,322). Desk-based or white collar employees have been found to be the most sedentary in workplace settings (323–325), in particular males (324), and those who are overweight or obese (323,326). The findings of Study 1 strengthen this evidence, highlighting that males in these types of working roles are most at risk of this health behaviour. Of note is that males were 32% more likely to engage in prolonged total sitting, and 27% more likely to engage in longer occupational sitting times compared with females.

In previous studies including TV/tablet viewing within their screen-time measures, leisure screen-time sitting was lower than found in Study 1 (2.5 hours per day) (406). Transportation/leisure sitting times of 2 hours per day was in agreement with previous reports using this combination of sitting domains (322). Those with insufficient engagement in physical activity were the most sedentary in terms of the sitting contexts investigated in this study. This strengthens previous findings showing an inverse relationship between PA and SB (368,376–378,383).

In terms of intrapersonal or individual factors, higher socio-economic classification and education attainment were associated with longer total sitting times and sitting times in occupational and transportation/leisure contexts. This supports previous findings (377,407). These longer sitting times may be due to the increased likelihood that individuals with higher educational attainment are employed in professional and therefore, more sedentary occupations. A recent review reported (358) that older women had longer overall and leisure sitting times. Contrastingly, the present study provided evidence that males have significantly longer total sitting times, as well as increased sitting times in the contexts of working and leisure screen-time. This strengthens the assertion that males are at increased risk of longer SB

(390,407). Contrary to findings that men have higher transportation sitting times, no association between gender and the context of transportation/leisure was found in Study 1.

In examining computer screen occupational SB, De Cocker et al. (535) reported that being a younger male increased the risk of this type of SB. The present study, in congruence, found that occupational and total sitting reduced as age increased. However, as age increased, leisure screen-time and transportation/leisure sitting also increased. Although higher education levels were predictors of occupational sitting and longer transportation/leisure sitting times, those with lower education attainment had significantly longer leisure screen-time sitting. This inverse relationship between screen-time sitting and education strengthens previous findings (232,536,537). TV viewing has well established links with lower socio-economic positions (232,538–540). These findings highlight the nuances with regard to the correlates and drivers of SB, and the importance of investigating the separate domains of sitting.

Smoking behaviours were a significant predictor of increased leisure screen-time sitting; however, smoking was not associated with total or occupational sitting in this study. Previous studies have reported an association between those who smoke and leisure screen-time sitting (382), while in studies of women, correlations between smoking and increased total sitting times have been found (365,376). Transportation/leisure sitting was associated with being a non-smoker in Study 1. This could be explained by way of smokers may leave their home to smoke outside, thus reducing their leisure-time SB.

Higher levels of alcohol consumption were associated with increased leisure screen-time sitting and transportation/leisure sitting times. Alcohol consumption, in a recent review (358), was found to be unrelated to SB in three of the five studies that examined its correlation as an individual level factor influencing SB (376,404,541). The remaining two studies found increased alcohol consumption to be a predictor of time spent sitting in motorised transportation (364), and to increased total weekend sitting times (365). Relationships between sedentary behaviour and alcohol are complex. The findings may mean that high risk drinkers sit more while in leisure screen-time viewing, possibly reflecting the recent cultural shifts to increased drinking at home (542). Those who consume more alcohol in the transportation/leisure context may reflect a propensity for sedentariness in their leisure activities, which may include consuming alcohol while eating or reading.

Psychological factors associated with SB were investigated in Study 1. Increased total sitting times and leisure screen-time sitting were associated with those who scored as having

presence of symptoms such as anxiety or depression. This strengthens previous findings that participants with major depressive disorders, comorbid depressive and anxiety disorders, spend significantly longer periods sitting in leisure time while using a computer, and sitting while viewing TV (364). Recent reviews found that sitting time is longer in those with increased risk of depression (543), and findings reported positive associations between SB and anxiety risk (544). Evidence in the present study extends the research by investigating psychological wellbeing predictors within broader domains of sitting such as occupational and leisure-time sitting, beyond previously investigated contexts of screen-time sitting and total sitting time. A minority of studies have investigated psychological factors and sitting times, and although previous findings are supported (234,363,545), outcome measures may vary making direct comparisons challenging.

Previous studies investigating TV-related SB and interpersonal factors such as relationship status have reported mixed results. Increased sitting times have been found to be associated with being single (400), contrastingly, Xie et al. (541) found that sitting while viewing TV was increased in those who were married (541). Uijtdewilligen et al. (404) reported that women who were married or living with a partner were significantly more likely to be inactive in comparison with single women. The present study provides evidence of an association between marriage and civil partnership and lower time spent engaged in leisure screen-time sitting or transport/leisure sitting. This strengthens previously reported findings that living alone is associated with longer sitting times (322,400,404).

Mixed results have been reported, depending on the context, in investigations of physical environment factors and sitting times. Longer total sitting times have been associated with urban-living women, compared to their counterparts in rural locations (376,404). Increased sitting times associated with transportation were found in rurally located individuals in two previous studies (377,546). Study 1 strengthens the evidence that living in an urban location is associated with longer total, leisure screen-time and occupational sitting times.

In a systematic review, O'Donoghue et al. (2016) reported conflicting findings with regard to sitting times and attributes at a neighbourhood and community level. Using data from the US, Australia and Belgium, perceived neighbourhood aesthetics and proximity of destinations were associated with longer overall total sitting times (401). Compernelle et al. (547), however, found no association between objectively measured neighbourhood attributes and device-measured total sitting times. The present study examined sitting times within different contexts and self-reported neighbourhood attributes and found lower neighbourhood

attribute scores was a predictor of total and transportation/leisure sitting times. This strengthens evidence of the contention that at least some of the variance in sitting times can be explained by environmental characteristics related to perceived attributes of a neighbourhood setting (401).

The findings of this study highlight the many important correlates of longer sitting times in adults, as well as the physical and social contexts in which daily sitting time accumulates. The socio-ecological model has been useful to aid the identification of the specific and potentially distinct proximal and distal correlates of SB in key settings. By providing factors to target the development of effective behaviour change interventions and strategies, this evidence can help provide strong guidance for researchers and public health policymakers. For example, the findings of this study indicate that males are the most at risk group of prolonged SB and may therefore be at increased risk of the health impacts previously outlined as being associated with long sitting times (Chapter 2, Section 2.7). As highlighted in Chapter 2, Section 2.3.4, many chronic conditions such as CVD and related comorbidities such as diabetes and obesity are highly over-represented by males. Multimorbid associations for conditions such as heart attacks, heart failure, diabetes, and obesity are all significantly more prevalent in men (80). Moreover, men are under-represented in health improving interventions, and health promotion has largely failed to engage and retain male participants (548). Accounting for subgroup characteristics such as gender in approaches to recruit and retain men in interventions recognises gender as a key driver of health behaviours (549). In Ireland, the 'National Men's Health Action Plan: Healthy Ireland –Men, 2017-2021' (550), has highlighted the need for gender-sensitive, or 'men-friendly' approaches to engage men in health promoting behaviour change. Kelly et al. (551) used gender-specific strategies in a community-based PA intervention showing that adopting this approach enabled previously inactive men to improve their aerobic fitness, while Wyke et al. (552) incorporated 'team bonding', and 'banter' in a participative style of delivery in a weight-loss intervention that was attractive to male football fans. Other successful gender-related strategies to influence men's health behaviours include men's preferences for activity-based approaches, self-monitoring, autonomy, friendly competition, and the inclusion of men-only groups have been found to engage men with their health in terms of healthy eating, active living, and social connectedness (553,554). In Ireland, a recent study used a gender-sensitised recruitment strategy that focused on the inclusion of men only was successful in recruiting hard-to-reach and at-risk men (555). It can therefore be postulated that using a gender-sensitised approach

to intervention development, taking account of men's interests and preferences, may improve engagement, retention, and outcomes (553,554).

Furthermore, the findings of Study 1 indicate that the workplace is the context in which most sitting occurs, highlighting the value of focusing on this setting in terms of reducing prolonged sitting times in those most at risk, and also, importantly, in terms of men's health promotion. The 'National Men's Health Policy 2008 – 2013' (556), identified the workplace as a key setting in which to promote men's health, however, little research has been conducted exploring gender-sensitised interventions for men in workplace settings.

The evidence in this study highlighting those most at risk and the setting in which this health risk behaviour occurs provides a valuable contribution in terms of how and in what population to design an intervention that is relevant to them to enable the most success.

3.5 Strengths and Limitations

The large population-representative sample of the Healthy Ireland survey, the results of which can be generalised, enabled the investigation of important correlates of sitting which may operate in distinct ways across different contexts, is a major strength of this study. The novelty of this study lies in the comprehensive measure to calculate total sitting time, enabled by the various contexts of sitting included in the data. The inclusion of smartphone and tablet screen-time sitting in the leisure screen-time SB measure potentially captured more contemporary leisure screen-time sitting habits.

Adopting a socio-ecological approach, the study extends the knowledge on sitting behaviours that are accumulated across multiple and varying domains. This study is one of the few to investigate a broad range of potential factors associated with prolonged sitting time. These include psychological influences, interpersonal factors and neighbourhood factors that may influence SB and have been included in the minority of research to date.

The use of self-reported measures to assess sitting time is a limitation of this study. Although there is consistency between self-reported SB and objective measures for most factors, self-reported measures have limited validity due to issues with recall and social-desirability responses (358). It may be of benefit for future studies to investigate transportation and leisure sitting time separately, as these domains were combined in the present study. The lack of differentiation between weekdays and weekend days in the Healthy Ireland Survey is a further limitation. Sitting patterns and habits are different depending on the time/day of the

week (361). Bout duration of sitting was not captured and is an important characteristic of sitting. Relevant measures such as body mass index, or a more detailed breakdown of physical activity were not included in this wave. This precludes examination of these salient factors and their relationship with and influence on sitting times. An important influence on behaviours highlighted in the outer ring of the socio-ecological model are policy level factors. These were not available in this dataset and could not be investigated. Finally, while the cross-sectional design provides information on factors correlated with sitting, causal inference is limited and is subject to reverse causality.

3.6 Conclusion

Sitting times remain high in the Irish population, with average sitting times reported of >7.5 hours per day. This study provides information on how sitting time is influenced within the contexts in which it accumulates throughout the day, with workplace sitting contributing the greatest amount. Factors have been established that may help predict SB in an adult population and can be used to inform the development of effective interventions. For example, it was identified that males with sedentary occupations, in professional roles and in urban locations were highly likely to be sedentary. The findings provide important information for intervention design and delivery in terms of a gender-specific approach to reduce health risk behaviours in a participant-relevant manner that has informed Studies 2 and 3 in this thesis.

The following chapter describes Study 2, exploring the views and perceptions of reducing SB, in those most at risk, professional males.

Chapter 4 Study 2 Exploring Men's Experience of the Barriers and Facilitators to Reducing Workplace Sedentary Behaviour

4.1 Introduction

As found in Study 1, Irish adults spend an average 7.5 hours per day sitting, most of which occurs in the workplace, and professional males are most at risk of this behaviour (525). As such the workplace has become a priority setting to address this disease risk factor (557). A recent review (64) focused on factors important in developing, implementing and evaluating workplace interventions to reduce SB. A key point highlighted was how crucial it is to explore the context-specific barriers and facilitators as the first step in the development of successful interventions. This important component is employed to understand the previous experience of the intervention's target population with a view to anticipating beforehand the issues that may arise, and is in line with guidance from the Medical Research Council (MRC) (413).

Formative research assesses the beliefs, attitudes, needs and situations of the people who will be using the intervention (66). Consulting with, and involving all stakeholders, both employees and managers, in the planning of an intervention provides an understanding of salient factors that are different within each group with regard to the different elements of the intervention (67). The Person-Based Approach (66) to developing interventions, uses qualitative research at every stage of developing and testing interventions to ensure they are meaningful, useable, and engaging to the people who will use them (558). Intervention development and early evaluation using this approach includes the following activities: 1) intervention planning (e.g. elicit user views of the planned behaviour change), 2) intervention design (e.g. identify key issues, needs and challenges the intervention must address), 3) intervention development and evaluation of acceptability and feasibility, e.g. pilot intervention using mixed methods (66). O'Cathain et al. (417) provide useful guidance on intervention development, acknowledging that insufficient evidence is available to recommend any one set of actions. The value of a flexible and pragmatic approach to intervention design is highlighted, for example, by mixing methods and adopting appropriate frameworks in conjunction with the person-based-approach.

In recent years, a number of systematic reviews have been published on the outcomes of trials examining the effectiveness of approaches to reducing workplace sedentary behaviour (SB) (339,355,418,559). The most common approach has been to change the physical workplace environment through the provision of sit-stand desks (340). Overall, environmental level and multicomponent interventions have resulted in the greatest reduction in workplace SB, with sit-stand work stations potentially leading to the greatest reduction by replacing SB with some

standing (340). However, cost implications of these types of desks may still be a barrier to widespread uptake (60,427). The issue that standing does not induce the metabolic benefits that are elicited by light physical activity (164), and may indeed be detrimental for cardiovascular health (477), as described in Chapter 2, highlights the need for new ways of reducing the metabolic effects of SB in those most at risk.

A limitation to effectiveness studies is they often provide limited insight into the contextual factors that may influence the extent to which behaviour can be changed during interventions (560). Barriers to change prevent, or make it difficult for an individual to adopt a behaviour, and come in many forms such as emotional, societal, structural, environmental, educational, and familial (561). To inform real world implementation of approaches to reduce workplace SB, it is important to understand all involved stakeholders' perceptions of the conditions that encourage SB. It is crucial to know what prevents or encourages the priority audience to practice the desired behaviour, so that this can be incorporated and targeted in the design of the intervention (413). Qualitative research, which seeks to explore questions relating to how or why a phenomenon occurs, can be informative for supplementing findings gained through quantitative methods (e.g. how much behaviour or health-related change has occurred), or for understanding people's experiences and perceptions about a particular phenomenon (562). In particular, stakeholders may have conflicting values or goals, thus facilitating collaborative decision-making using focus groups, by stimulating discussion among a group of fairly homogenous people (similar job roles, socioeconomic status etc.) can ascertain important underlying opinions and attitudes related to the problem (563).

A number of Australian qualitative studies investigating barriers and facilitators to reducing workplace SB have found that a crucial enabling factor to intervention success was manager support of employees in reducing their SB (427,564,565). Team leader engagement in the intervention by fostering a sense of joint responsibility for change was also highlighted. Workplace cultures, however, differ across global regions, and although several studies have been carried out in the UK (566,567), and some European countries (568), management practices, regulations, and in particular the case that SB is relatively unknown to the general public in Europe compared with Australia are relevant issues. Important early research and development of SB and workplace interventions focussing on SB, was conducted by researchers in this region (57,60,569,570). Senior managers' and executives' perspectives have been incorporated in the minority of studies to date, and are necessary to understand acceptability and appropriateness of potential intervention strategies to influence occupational SB. In a recent review (64), just two papers (570,571) reported the use of

collaborative approaches where both managers and employees were involved in intervention implementation. Addressing organisational structures and group dynamics through a participative approach and visible management support has been advocated in effective workplace health promotion interventions (572,573).

Varying social and political contexts within workplaces create different climates of workload pressures that create significant barriers to being less sedentary (566). The target population of this study, professional males, has not previously been investigated as a specific target group in workplace SB interventions. Research suggests that males are under-represented in intervention studies despite the lower life expectancy and premature mortality of men (574,575). Historically, gender-focused health policy initiatives, and gender-mainstreaming approaches to health have, in most cases, been aimed at improving women's health (576–579). This has been attributed, in part, to the significant impact gender inequalities have on women's health, and the fact that gender equality has so far not been attained in any country in the world (580). This in turn is reflected in research questions and priorities. As described in detail in Chapter 2, SB is associated with a significant increased risk of non-communicable diseases, such as cardiovascular disease (184,581). Occupational sitting time is associated with total cancer risk, and for pancreatic cancer, the multivariable hazard ratio for sitting for ≥ 7 hours per day is 2.25 in men, but not women (138). Evidence exists of increased symptoms of depression and anxiety in those who engage in prolonged workplace SB (582). Although the overall picture over recent decades has been more positive, with life expectancy of men steadily increasing in the WHO European Region, the gender mortality gap remains, and cardiovascular diseases and mental health conditions are responsible for the burden of disease for men (583). The WHO has issued a strategy report advocating a gender-responsive approach to men's health to address the high levels of premature mortality in men (583).

A second issue is that men are notoriously difficult to recruit to health promotion interventions (554). As Bottorf et al. (554) state, 'health professionals routinely point to males as a 'hard-to-reach' population wherein unique challenges reside for implementing illness prevention and health promotion initiatives such as physical activity' (pg.776). There is evidence that aspects of adhering to traditional masculinity norms are linked to fewer health promotion behaviours, such as help-seeking in terms of psychological health (584) and physical health (548). It is recommended that researchers and practitioners continue to improve their understanding of the factors that might motivate and encourage men's participation in intervention studies by incorporating their expressed preferences into intervention design and planning (574,585). Including sex- or gender-related factors to inform intervention design has demonstrated a

significant increase in participants' PA or other substantive improvement (e.g. weight loss) (551,552,586). Five themes outlined by Robertson (587) for success and sustainability in men's health promotion are included in many of the gender-sensitive programmes included in the review. The themes include: (a) contexts and settings that include men's engagement (i.e. workplace or sports clubs); (b) incorporating a gender-sensitive approach; (c) including men in the design of the intervention; (d) providing adequate training and ongoing support; (e) partnering with trusted community groups or workplace champions. Engaging men in professional sports with other men was found to be an effective strategy to increasing PA, and team sports participation has increased adherence and enhanced motivation (554). Drawing upon as well as providing opportunities to garner masculine capital by affirming competitiveness and/or striving for physical prowess are strategies to engage men in PA (588). However, only three of the studies included in this review were in a workplace, and none of the studies targeted SB, or an increase in workplace physical activity. Kelly et al. (551) used goal-setting in a gender-specific approach that was successful in improving PA in a community-based intervention, while Wyke et al. (552) adopted the behaviour change techniques self-monitoring, specific goal setting, implementation intentions, feedback on behaviour and promoted social support. This approach has yet to be tested in a professional workplace with sedentary males.

Taking into consideration the high levels of SB, a gender-based approach advocated internationally by the WHO 'Action plan for the prevention and control of noncommunicable diseases in the WHO European Region' (82), and in Ireland in the 'National Men's Health Action Plan: Healthy Ireland –Men, 2017-2021' (550), is required to develop an intervention targeted at males in the workplace specifically to reduce SB. Study 2 seeks to address the gaps in the evidence by exploring the perceptions of professional male employees and managers of the barriers and facilitators to reducing workplace SB, and their views on the proposed intervention components. Using the socio-ecological model to group themes under individual-level (e.g. personal preferences, health), work-related (e.g. work load), environmental (e.g. physical office layout), and organisational and social-level factors (e.g. social and managerial support), has been shown as an appropriate and effective way understanding the most salient factors in terms of barriers and facilitators to reducing workplace SB (560,566).

4.2 Intervention Design and Development

The proposed intervention components targeted the main influences of workplace SB as outlined in the socio-ecological model of SB (57). The full description of the development and design of the intervention, as well as measures used are described in Chapter 5. Briefly, at an individual level, behaviour change techniques targeted goal-setting, self-monitoring, and social comparison using a Garmin physical activity tracker watch and its associated website/smartphone application incorporating mHealth (mobile health). The use of 'gadgets', feedback, goal-setting, and social support has been successfully used in an Irish context testing a community-based gender-specific intervention to increase PA in at-risk men (589).

Harnessing mHealth has been found to be acceptable and effective in workplace interventions to reduce SB (490). At an environmental level, a pedal device restructures the environment to allow LPA. Although SB and PA are conceptually discrete, the replacement of SB with LPA attenuates the risks associated with prolonged SB (164). Social Cognitive Theory (440) stresses the importance of social support for successfully improving individual health behaviour. Social and organisational support to colleagues and employees can be targeted through recruitment of management employees, and the incorporation of teams, to foster a sense of togetherness in reducing SB. Raising awareness of the adverse health effects of prolonged sitting is important for improving individual-level and organisational-level motivation for change (60,61,565). Messages in education given to participants can be both positively framed in terms of strategies to reducing occupational SB by replacing with LPA, and negatively in terms of the dangers for health and outlining the amount of SB to be reduced to reduce risks. Positively framed PA messages have been found to be particularly effective in males (590–592).

As recommended in the Medical Research Council's 'Framework for design and evaluation of complex interventions to improve health' (412), Study 2 of this PhD is phase two of three phases (Figure 16). The first preclinical phase included a literature review and theoretical grounding and Study 1 to investigate the prevalence and correlates of SB; this, Study 2 was *formative research (with the target group)*; and Study 3 comprised pilot testing of the acceptability and feasibility and potential efficacy of the integrated multiple components relative to a control group. The pilot feasibility study, fully described in Chapter 5, was a cluster randomised crossover design using objective (activPAL3) and subjective (Ecological momentary assessment (EMA)) as secondary trial-related outcomes. A description of the study overall, the intervention components, and the outcome measures were presented to the participants in the second part of the focus groups.

The research questions addressed in this study were: 1) what are the barriers and facilitators to reducing sedentary behaviour in the context of those most at risk? 2) what are the perceptions and views of the target population of components of a workplace intervention guided by the socio-ecological model of sedentary behaviour? Are the proposed components acceptable and context-appropriate?

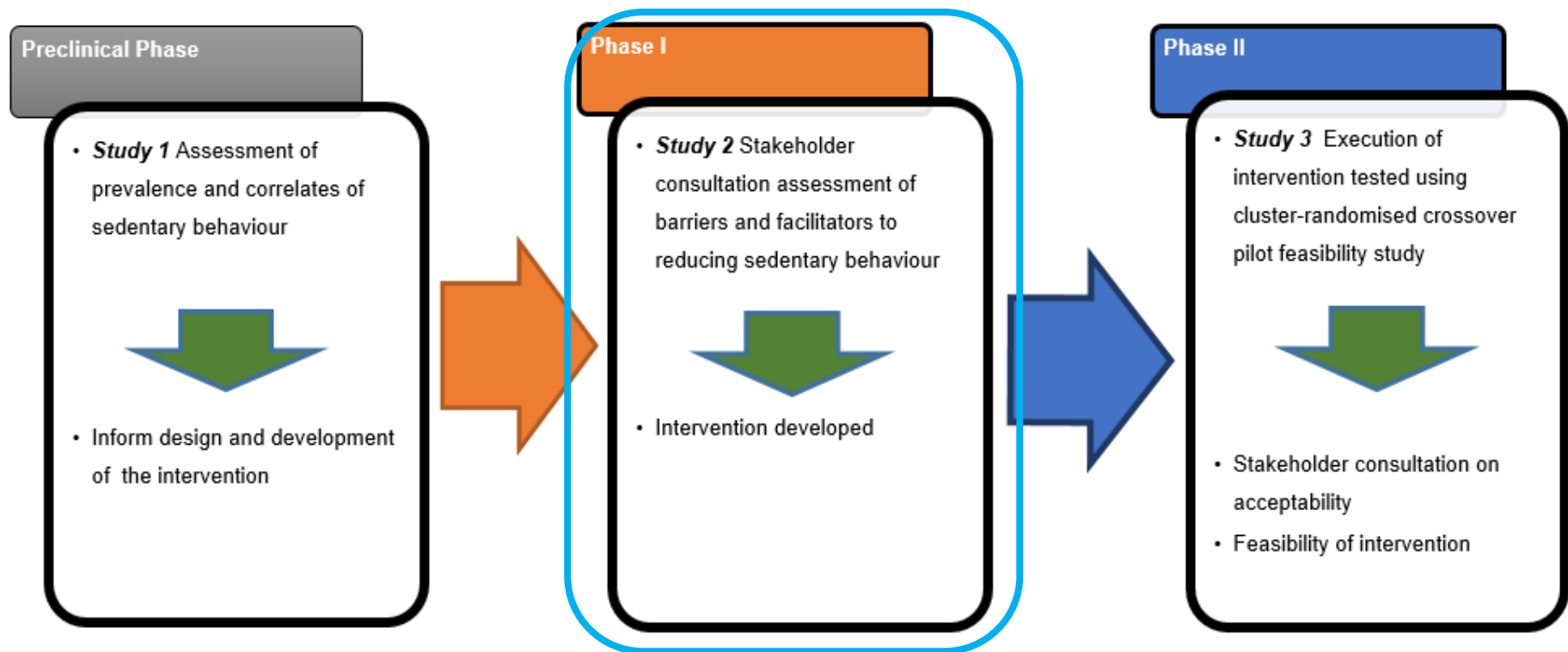


Figure 16 Studies involved in overall PhD research project

4.3 Aims and Objectives

The aims of this study were to: (1) understand the barriers and facilitators to reducing workplace SB relevant to a professional male population; (2) explore the perspectives and opinions of participants on the practicalities of a proposed intervention to reduce SB in a local context to inform the development of a future pilot worksite intervention to reduce SB (Study 3). The objectives were to use focus groups and a semi-structured interview to explore the narratives of employees and management employees of their experience and perspectives of prolonged SB.

4.4 Methods

To address the aims of this study, a qualitative study design was adopted. Thematic analysis was used in the study (593) as it offers an accessible and theoretically flexible approach to analysing qualitative data. This approach allowed for: an in-depth exploration of barriers and enablers to reducing SB at work; the emergence of new themes or ideas which have not been previously identified in the literature; and an in-depth understanding of how these barriers and facilitators may differ within organisations and what the reasons for this may be.

Ethical approval for the present study was granted by the Research Ethics Committee, School of Medicine, Trinity College Dublin (ref. 20190205) (Appendix D).

4.4.1 Sampling

Organisations

The companies were recruited to the study using convenience sampling. Invitation emails (Appendix E) and a flyer (Appendix F) were sent to four private companies in Dublin, Ireland explaining the study and its aims. The companies were identified based on the researchers' networks. A manager from one worksite was approached face-to-face by the researcher. That the study was evidence-based, i.e. targeting men who are at most risk of prolonged SB was explained at this stage. In each organisation a contact person assisted with recruitment of the worksite to the study. Management employees of companies were asked to agree to the participation of employees to the study. Inclusion criteria were professional companies, in Dublin city or immediate surrounding areas, with male employees in sedentary roles. Exclusion criterion was the implementation of any formalised programme to reduce workplace SB. Two organisations agreed to participate, and two cited time constraints as a reason to decline to participate.

Individuals

Purposive sampling targeting individuals who met pre-identified criteria was used. Inclusion criteria were professional males in sedentary and permanent occupations. In each company, 4-7 participants were asked by workplace champions (one was a manager and one was a corporate social responsible manager) to join a focus group comprising employees, and a separate one comprising managers. This is in line with the convention in qualitative research, whereby smaller sample sizes have the aim of achieving an in-depth understanding of the phenomenon being studied, and a variety of stakeholder groups may be more important to provide a greater breadth of understanding of a topic (594). In the case where the requisite number of managers were not available (i.e. in worksite A), a one-to-one semi-structured interview was conducted with the manager. Data saturation is a criterion used in qualitative research that is useful to help decide when to stop data collection, where no new themes arise and collection of more data is unnecessary (595). Data saturation is a widely accepted approach viewed as the gold standard for determining sample size, particularly in qualitative health research, and is one of the most frequently provided guarantees for rigour in qualitative work (596,597). During the interviews and focus groups and preliminary analyses, data saturation was applied in Study 2, it was decided that both stakeholder groups provided the requisite understanding of the topic within each worksite, and nothing new could be added to the existing data by further data collection (595).

4.4.2 Procedure

Prior to commencement of the focus groups, all participants received a participant information leaflet (PIL) (Appendix G) and consent form (Appendix H) to read and consider for at least 24 hours. The researcher then met with participants and written informed consent was obtained. Data collection was conducted in July 2019 in participants' workplaces by the researcher (GN). No prior relationship was established prior to the study commencement. The PhD candidate (MSc) had previous experience of conducting focus groups and conducted the data collection. Employee and manager discussions were conducted separately to avoid group hierarchies. Only the researcher and participants were present during the focus groups/interview. At the beginning of the focus groups, participants completed a short questionnaire on demographic variables including age and education level. To provide information on participants' workplace sitting habits, the Occupational Sitting and Physical Activity Questionnaire (OSPAQ) (Appendix I) measures the self-reported proportion of time spent sitting, standing, walking and doing

more physically demanding tasks at work on a typical day in the last seven days. The OSPAQ has demonstrated excellent test-retest reliability for assessing sitting, standing, walking and doing physically demanding tasks at work (ICC = 0.54-0.89) (598). Validity correlations for occupational sitting, standing and walking measures were 0.52, 0.49 and 0.27, respectively, against Actigraph accelerometers (598). This instrument has been used in many previous RCTs and intervention studies (427,449,475,599).

The focus groups began with an introduction of the concept and presentation educating the participants on the known health consequences of SB. The framing and guidelines of the focus groups were outlined. The duration of the focus groups/interview was 30 to 40 minutes. Field notes were taken during and after the focus groups and interview sessions. After each focus group session, participants were debriefed by the researcher. An operational issue prevented one of the focus groups (focus group one, comprising employees) from being recorded. Field notes were written immediately afterwards to capture the sentiments of the participants in the focus group. A discussion of the main findings occurred with the research team (primary supervisor CD) and included global impressions and differences between the focus groups. The focus groups took place at the participants' convenience and location of their choosing, usually their workplace. They were recorded using a digital audio-recorder, and they were transcribed verbatim by a professional transcriber. Transcripts were not returned to participants.

4.4.3 Interview topic guide

A semi-structured interview schedule was developed using three key questions in part one, with sub-questions to follow up each point. The questions were generated based on themes used in previous studies investigating the topic (60,427,566). The key themes based on the literature review were organised around 1) general perceptions about occupational SB and its detrimental effects; 2) current barriers to reducing SB in the workplace; and 3) current enablers to reducing SB in the workplace. Themes 2 and 3 of the topic guide were shaped by the socio-ecological model (56). Part two of the schedule centred on the intervention development questions, and focussed on participants' thoughts, perceptions, and feedback with regard to the various proposed intervention strategies. Prompts were used to keep the flow of conversation going if needed, or if it did not happen spontaneously. The questioning route was similar for employees and managers except for when the questioning specifically asked about the other group. The order of the questions was changed as required and depending on how the discussion proceeded. See Appendix J for the definitive question

schedule. This was pilot tested in a convenience sample of research colleagues and was adapted where necessary.

4.4.4 Data analyses

Thematic analysis was employed in this study (593) and no software package was used to organise or analyse the data. Focus group field notes and transcripts were analysed in an iterative process during and after the data collection period to identify the main concepts and themes. A-priori themes were used to guide the analysis towards the research questions. A recent qualitative review identified themes such as: the nature of the work, workload, time pressures, and individual preferences on working-style; feelings of self-consciousness or being a distraction to others; physical health effects, stress and impact on productivity; peer and management support and presence of social norms; the existing work environment and the cost of the intervention (64). Each transcript was read independently several times by two members of the research team (GN and CD) to undergo the process of familiarisation with the data, and to enable the creation of a set of preliminary codes. Line-by-line coding was then independently undertaken by GN and CD to assign the initial a-priori themes and relevant excerpts. The codes were re-named according to the data collected. After both researchers separately identified initial codes and applied them to the data, any doubts or disagreements were discussed until consensus was reached. Inductive thematic analysis was also carried out which allowed for the emergence of additional themes. From the pre-defined and emergent themes, higher order themes were determined, forming a hierarchical structure. A process of moving back and forward between the entire dataset and the themes being produced, allowed iterative refining of the final higher order themes and subthemes. Direct quotations were used to describe and characterise the themes, enhancing credibility of the analysis. The men's own words are presented in italics. To uphold anonymity, only the participant's role and focus group number have been used in these findings.

The findings of the study were reported using the Consolidated Criteria for Reporting Qualitative Research (Appendix K) (600). The use of this checklist allows for critical appraisal of qualitative research by promoting explicit and comprehensive reporting of the important components of the study design.

4.5 Results

4.5.1 Demographic information

Participant demographic information is presented in Table 14. Two focus groups were conducted with employees (n=14 participants, 6 and 8 participants in each focus group, mean age 41.1 (SD 4.1) years). One focus group and one semi-structured one-to-one interview were conducted with managers (9 participants in the focus group, mean age 42.9 (SD 11.8) years). All participants in the study had third level educational attainment. A range of different organisational roles were represented including IT specialists, software developers, engineers, legal professionals and managing partners. The companies involved were a corporate legal firm (n=17) and an online medical training company (n=7). Neither of the companies had implemented any formalised programmes to reducing workplace SB. Data collected using the OSPAQ revealed that participants reported spending a median self-reported sitting time of 80% (range 40-95%) of their working day, 5% (1-40%) of their working day was spent standing, 10% (2-20%) of their working days spent walking, and 0% in physically demanding tasks. The focus groups and interview ranged in length from 24 minutes to 41 minutes (mean length 36 minutes). All participants contributed to the discussions.

Table 14 Participants demographic information

Characteristic	Workplace 1	Workplace 2	Total
Type of company	Online training	Legal firm	
Location	Dublin suburb	Dublin city	
Total no. of participants	7	17	24
Total no. of focus groups	1	2	3
Total no. of semi-structured interviews	1	0	1
Total no. of managers	1	9	10
Total no. of employees	6	8	14
Mean age (years)	41.1	42.9	42.0
Highest educational attainment			
Third level or equivalent/or higher (n)	7	17	

Median % workday (range)			
- sitting time	80 (80-95)	82 (40-95)	80 (40-95)
- standing	5 (3-10)	5 (1-40)	5 (1-40)
- walking	10 (2-10)	10 (4-20)	10 (2-20)
- physically demanding tasks	0	0 (0-2)	0 (0-2)

4.5.2 Reflections on health effects of sedentary behaviour, expected and perceived benefits of reducing sedentary behaviour

Knowledge of the general risks associated with prolonged SB

In terms of knowledge of the risks associated with prolonged SB, participants spoke about some awareness of the ideas presented in the media such as ‘sitting the new smoking’. There was a feeling that people were gradually becoming aware of the dangers of prolonged SB.

“I think that’s very much in its infancy though, people wouldn’t be as conscious of the fact that sitting down is going to be as detrimental as say smoking or things like that. But it has started.”

Focus group 3, employee.

There was a sense of concern at the perceived detrimental effects that participants had read about as a result of prolonged SB.

“I read that it can take 20 years of quality of life off your life, I read that somewhere. It’s quite worrying!” Focus group 3, employee.

There was also some insight into the case for SB to be a target for improving health and reducing negative health risks associated with this behaviour.

“I think just in general awareness is a bit better than it used to be like they talk about sitting is the new smoking so it seems like this is going to be the next domain in which there is going to be a health drive to try and get people to move more in work..” Focus group 3, employee.

A sense of shock from some participants was displayed as a result of the education piece received at the introductory session in terms of the amount of moderate PA required to mitigate the risks associated with prolonged SB.

“Most people don’t know that you have to do 70-90 minutes a day of exercise to offset 6 hours of sitting down, I mean that’s pretty stark.” Focus group 2, manager.

In conjunction with the lack of knowledge regarding the dangers associated with prolonged SB, false beliefs were held by some participants with regard to the level of PA required to mitigate the risks associated with daily SB.

“You don’t realise how permanent the damage could be and that you know just a bit of activity every day could offset that.” Focus group 3, employee.

Knowledge of physical and mental health effects of prolonged sedentary behaviour

Participants acknowledged some vague and minimal knowledge of the negative physical health consequences of prolonged SB, such as cardiovascular risk and poor circulation, but lacked good insight.

“The only thing would be where I’ve heard that it can have em it can cause issues with your heart and so that would be about it that I’d know, I just know that it can have a negative effect.” Focus group 3, employee.

“It’s the standpoint of being at your desk all day long, you’re not, your blood isn’t really circulating, it’s just pooling in your legs and static and you’re just sitting there.” Focus group 3, employee.

There was limited insight into the risk of weight gain and prolonged sedentary behaviour.

“Just the fact that when you’re sitting or sedentary it is harder to be active the longer that you do it, you’re going to put on weight when you’re just sitting down.” Focus group 3, employee

Musculoskeletal effects

The vast majority of participants' knowledge of musculoskeletal effects of prolonged SB was informed by their own experiences of discomfort and pain induced by their occupational sitting habits.

"Sitting causes me problems with my back eh from a pure sedentary perspective..."

"Definitely sitting around in the course of the day does cause me some back issues." Interview 1, manager.

Musculoskeletal discomfort, such as delayed onset muscle soreness (DOMS) which can occur in the days post exercise was felt to be exacerbated from prolonged SB, and was a facilitator to reducing prolonged SB.

"I suppose just personally I notice you can get very stiff if you're doing sport or something after work and you've been sitting for a while... there's an increased chance of an injury because you are stiff and you know if you're walking around the body is moving there isn't that same stiffness, you don't have to stretch for as long, personally I've just noticed that." Focus group 3, employee.

Mental health effects

There was a distinct lack of knowledge expressed within the focus groups of the mental health risks associated with SB. This is reflected in the fact that only one quote was available in the data on this important topic.

"Whether it's a mental issue I don't have an opinion on that." Focus group 2, manager.

4.5.3 Current sedentary behaviour and physical activity levels

The overwhelming consensus was that the vast majority of participants' working day was spent sitting down and being sedentary.

"The majority of work is at your computer, it's at your desk so you have to be at that desk for the majority of the day." Focus group 3, employee

It was acknowledged that participants would move about during the working day for tea and coffee breaks, and some participants habitually engaged in walking at lunchtimes.

“I’d never let lunchtime go without leaving the building, so I’ll get a daily habit in every day because you know to avoid that sort of 3 o’clock flat you get.” Focus group 3, manager

4.5.4 Ideas or strategies to reduce sedentary behaviour

Participants had some knowledge and insight of various strategies to reduce workplace SB. The majority of the strategies mentioned and suggested were technology based, and primarily involved the use of prompts. These included regular electronic prompts to remind individuals to engage in PA to break prolonged SB.

“You’d be getting an electronic prompt at [your] desk to get up and walk every hour within the hour. You’d be getting a move bar on your watch to give you a prompt if you don’t know what to do.” Focus group 2, manager

“I suppose some people are a little bit conscious of getting up once in a while, you know the watches and things like that, it beeps when to go for a walk and they might go for a little walk down the corridor or get the lift down and walk up the stairs or do a lap of the block or something like that so there’s a little bit of that going on.” Focus group 2 manager

Participants were interested in a competition element where employees would compete with each other in their PA throughout the working day.

*“They have this kind of a Fitbit competition where all the employees were given a Fitbit type device and there’s a competition around how many steps you get to do during the day and that kind of stuff. **Interviewer: And do you like the sound of that?** Yeah it sounded like a good idea”*
Focus group 2, manager

Increased behavioural prompts, such as motivational point-of-decision prompts situated at key locations, to promote the use of the stairs was a strategy suggested by participants to increase daily PA and reduce SB.

“When I suggested it to the powers that be, we should have sandwich boards on every floor, basement including sorry not basement, ground floor included, saying you know ‘going one or two floors? Try the stairs’. I think it would be good for everyone.” Focus group 2, manager

“A few of those posters around tea stations wouldn’t go amiss you know, it’s in their face or you could even put it as a screen saver do you know what I mean.” Focus group 2, manager

Highlighting the dangers associated with prolonged SB via the use of scare tactics, was suggested as a way to promote and encourage employees to break up SB.

“If you scare people with some of the science that you mentioned at the start of the session that would get people going.” Focus group 2, manager

The education received by the participants on the risks associated with prolonged SB resonated with this participant as being a motivating factor to improve this health behaviour.

Managers suggested a removal of choice and personal responsibility from the employees by forcing individuals to take the stairs through ‘disabling’ the lifts and preventing their use, or by activating the fire alarm to impose upon the employees to take the stairs.

“Could you disable lifts between certain floors? You have to have special authorisation to be able to walk or to take a lift between floors 3/4/5/6, you have to walk it.” Focus group 2, manager

“You could set the fire alarm off every hour.” Focus group 2, manager

Taking a walking break by changing working habits was mentioned as a strategy. Face-to-face interactions instead of using the telephone in particular were suggested as a facilitator to reducing prolonged SB.

“There’s certain things you can do, for example you can pick up the phone to speak to a colleague across the other side of the corridor or even you know I’ve probably never done this but if I needed to talk to somebody for 5 minutes and say look let’s take a quick walk around the block and talking rather than sitting or standing when on the phone so things like that.”

Focus group 2, manager

Increasing water consumption to induce more toilet breaks was suggested as a helpful way to break up prolonged SB.

“That’s what people do like if you have water on your desk and you drink a lot of water, not only do you have to go up and refill the water but you also have to get up to go to the bathroom more. So, it’s kind of like a double thing. So, I don’t know like if you had a big glass of water on your desk it would be quite helpful!” Focus group 3, employee

Using high shelves in order to read work material was suggested to facilitate some standing or posture change while working.

“I see people like em standing like there’s certain shelves that are neck height or maybe not even that high and people would put stuff down there and review it and pore over it in detail, it’s something to do with maybe a change of a stance or something that helps you concentrate or something like that to break it up.” Focus group 3, employee

There were suggestions by participants in Focus group 1 however, that standing for long periods was uncomfortable and induced its own musculoskeletal issues.

4.5.5 Strategies to reduce workplace sedentary behaviour

Participants reported to be already engaging in some strategies to reduce their daily SB. Again, these strategies were predominantly technology based. The use of mHealth, and in particular the use of smart watches had already been adopted and enjoyed by many participants in terms of increasing daily physical activity. Goals to achieve a particular step count per day, or a number of minutes of activity per day had been undertaken by some participants.

“The Fitbit tells you to walk 250 steps an hour, and that 250 steps is more or less from my office to the coffee dock and back and it tells you every hour to walk 250 steps and it also then gives you reports and tells you how well you’ve done and in a performance type of environment I think it’s a real benefit because you kind of feel oh Janey I’ve only got 1000 steps to do today, I’ll go and do them because then you get a green tick or whatever.” Focus group 2, manager

Smartphone applications (apps) to increase PA and reduce SB were suggested by participants as a useful and enjoyable way to engage in PA while remaining at the desk in the workplace.

“A lot of the apps em say I’m using an app called ‘Zworkit’ and it’s about you can do 10 minutes, 20 minutes or 30 minutes workout but they have exercises for working and sitting at the desk as well right and it’s actually quite good.” Focus group 2, manager

A further strategy previously adopted by some participants was to take active breaks by taking phone-calls using earphones, to enable the continuation of work-tasks while moving away from the desk.

“If I’m on a call I will put my earphones on and walk up and down the office for 5 minutes. If it’s a simple call and it’s not confidential or whatever right. Em or going around the block or going over to the [shopping centre] and get something or just break up your day a little bit.”

Interview, manager

A strategy used by a participant in one of the worksites was walking to speak with work colleagues to engage in regular breaks from prolonged SB in order to reduce musculoskeletal discomfort.

“Yes I think that suggestion I mean I just thought a particular, we’re all involved with people who’ve had back and neck problems and sitting too much and sitting badly so in fact I try to go and see most of the people I talk to, not everybody so I spend a lot of time on my feet and it definitely helps me.” Focus group 2, manager.

There was, however, a feeling that previous strategies and/or programmes adopted within the workplace to increase PA were short-lived and did not change the habits previously held with regard to workplace PA/SB.

“I think what we tend to do is we’ll do tactical campaigns that will either endure or they don’t with individuals just we’ll do awareness things that will have a spike and there will be some good initiatives going on around the canteen for example you know on an ongoing basis but em from a sustainable perspective on the exercise in the workplace front, anything that we do around that tends to hinge on an event so for example the Calcutta Run we’ll try and get some

fitness awareness around but again it's about spikes in the year as opposed to a daily mind-set and you know that's kind of what's missing today." Focus group 2, manager

4.5.6 Barriers to reducing workplace sedentary behaviour

The initial analysis of all transcripts identified barriers and facilitators which encompassed lower-order themes from which emerged four higher-order themes. These higher-order themes were identified as: intrapersonal (individual); interpersonal (social influences); organisational (work-related structures); and environmental. A total of 18 barriers emerged from the data. Many lower-order themes were essentially both sides of the same coin and could be viewed as potentially both barriers and facilitators. Themes were not intended to be mutually exclusive but cut across and between the different levels of influence.

4.5.6.1 Intrapersonal Factors

Primacy of work

The main overarching theme within the intrapersonal barriers to reducing workplace SB was the obvious issue of the primacy of work. Participants considered that the type of work that they engaged in could only be performed sitting down, and not in any other position. The men reflected that they must sit, or their work performance would be adversely affected.

"The majority of work is at your computer, it's at your desk so you have to be at that desk for the majority of the day." Focus group 3, employee

There was a sense of permanence and inflexibility in terms of fulfilling work requirements, and the need to remain seated. An opinion that these two aspects were inextricably linked was held by many.

"You know we can't change what we need to do for a living." Focus group 2, manager

"I think actually you know there's certain parts of our job there's actually no choice but you're sitting down realistically unless you have a stand up desk but we're sort of working on documents or things like that or writing emails or that kind of thing sitting down and that's the end of it. There's no way around that." Focus group 2, manager

Productivity

A worry surrounding the issue of interference in the achievement of the work, and the resulting reduction of productivity by engaging in SB reducing strategies, was highlighted equally by managers and employees.

“Because again in terms of productivity I would have thought if we all got into the mind-set of oh every sort of hour I better stop and go and walk around and come back... There’s the cost of productivity in that.” Focus group 2, manager

“I could imagine it would become something of a procrastination, like sit down and do something and maybe get up for a walk around the place, you keep putting off actually getting stuck into the thing which is what you do when you’re distracted kind of a thing, see that angle of it.” Focus group 3, employee

The inevitability of time pressures within the workplaces was highlighted by many participants. There was a concern that if time was taken away from the working day to leave the desk for walking breaks, that this would be detrimental to work tasks and output.

“Sometimes you’re kind of like more not forced but em you’re actually going to stay at your desk to get the work done, like there’s no incentive to me to get up and go and walk around the building because it’s detrimental to my work and my time actually spent doing my job, so if I end up going I don’t know around the building two or three times a day that could be five minutes each time, maybe 10 minutes, that’s 30 minutes out of my day that I really want to make sure that I don’t lose out on because you know it’s my work. It’s not that I like sitting or anything, it’s just part of my job.” Focus group 3, employee

It was expressed that reducing SB by means of being away from the desk would result in reduced work capacity, and the knock-on effect of this would be to remain at work later in the evening and delay leaving the office. This was expressed as a barrier to reducing occupational SB.

“The thing is as well a few of us have to record our time so we have to do like the minimum of 7 hours recorded every day allocated to certain tasks, so I suppose definitely from my perspective I wouldn’t want to be having any effect on that like if you could build it in because you don’t want to have to stay longer when you could be out earlier and then like for example if you went

for your walks on a Tuesday and you're stuck in a bit later because of that and so the next day you'd just skip it so that you can get out of here on time." Focus group 3, employee

Participants perceived the stress that work demands placed upon them as strong barriers to leaving their desks to reduce prolonged SB by standing up and walking.

"If you're trying to get something urgent done then you're putting off getting a cup of tea or coffee or going to the bathroom or something just to sit there and get it done as quickly as possible. Focus group 3, employee

"But so, you're under pressure to do something, it's very difficult to get up and walk away from it for any length of time." Focus group 2, manager

Preference to sit

Some participant's spoke of a preference for sitting to achieve their work, and this was a barrier to reducing SB by standing while working.

"For some tasks though I think sitting would definitely be the preference like for example like researching when you're reading books em like I'm not sure that you could do that standing." Focus group 3, employee

The preference to remain seated while working was linked with the concentration and focus required to conduct certain work tasks. It was acknowledged that some types of work could not be completed while standing up.

"When I am doing individual work like I'm at a laptop I think being seated like the idea of a stand up desk and the likes yeah maybe if you're just doing some fairly low level stuff like if you're answering the odd emails or you're doing whatever, fairly mundane tasks or sort of simpler tasks you know maybe you could do that standing up but I think if you're getting into the guts of something I think sitting would be probably be important to me just from a focus perspective." Interview, manager

This was further discussed in terms of the mental processing required to carry out a new skill or behaviour, such as exercise movements, which would potentially distract from the work.

“We’ve only spoken about standing or walking, is there you know obviously other people do other Pilates type moves or whatever but a lot of that takes a lot more for your mind to focus on and that would distract you entirely from other work so you couldn’t, it’s very hard to introduce anything that you didn’t learn as a baby how to do, and to do your job at the same time, I’d imagine.” Focus group 2, manager

Workplace habits

The habits that are engrained within the workplaces were highlighted by managers as a barrier to reducing workplace SB. The habitual behaviour of SB in the workplace was perceived by some participants as difficult to overcome.

“You know the way you say we have campaigns and we have impact and then it dies off and old habits kick back in.” Focus group 2, manager

“Yeah I think it’s just very easy to fall into the default habit by the nature of the work and the time and em the fact that the immediate mind-set around meetings is seat bound.” Focus group 2, manager

This acknowledgement that their predominantly sitting habits were entrenched, and even though attempts have been made in the past to change behaviours, the ‘old’ sitting habits returned over time.

Distraction

Participants were concerned that reducing SB may distract their colleagues, and they themselves had been distracted and irritated by other work colleagues taking phone-calls while walking around the office space.

“If they’re walking around and taking calls or something like that then that would probably end up being a bit annoying for people.” Focus group 3, employee

“There’s nothing worse than someone taking a phone call outside your office.” Focus group 3, employee

In these cases, it may have been the noise associated with speaking on the phone that was the main cause for distraction as opposed to the movement around the office space.

It was acknowledged that movement by walking around the workplace may been used as a distraction technique in terms of employees' own work tasks.

"I could imagine it would become something of a procrastination, like sit down and do something and maybe get up for a walk around the place, you keep putting off actually getting stuck into the thing which is what you do when you're distracted kind of a thing, see that angle of it".

These quotes suggest that movement around the office workspace may be somewhat undesirable in terms of others' and one's own distraction away from work tasks.

Physical discomfort

A barrier to reducing SB in the workplace was the physical discomfort associated with standing. Issues surrounding the weather when going outside to engage in PA in the working day was also highlighted. It was acknowledged that strategies used previously, such as walking meetings, promoted discomfort, due to the weather being uncomfortably warm for the participants to enjoy them.

"I tried that with some of my team to do a walk around the block meeting. It was a disaster because it was so warm, we were all sweating by the time we came back right." Focus group 2, manager

"Our boss tried it last year when it was really, really hot out and he took us for a walk to [nearby shop] and we ended up getting burnt! It was like why the hell are we doing this?!" Focus group 3, employee

It was also highlighted that cold weather would be a deterrent to engaging in outdoor PA for participants in the wintertime.

"But again, it depends on the weather as well because you're probably not going to do that in winter if it's really cold, it depends." Focus group 2, manager

Lack of solutions and ideas to reduce sedentary behaviour

A lack of ideas or solutions to breaking long periods of workplace SB was reflected by many participants as an intrapersonal barrier to changing behaviour. Without having access to information on ways and strategies to reduce prolonged SB in their workplace setting, participants cannot have the psychological capability to enable them to change their behaviour in this context.

"I don't think we're conscious of what is out there, certainly I'm not really aware of ideas to reducing sedentary behaviour in the workplace. You know go down stairs, get the post, walk back up the stairs, that kind of stuff little bits here and there so that's how I try and break up my day a little bit from an activity perspective but actually as I'm in the office itself I am devoid of ideas in all reality". Interview, manager

"That's kind of, you kind of need a plan you know like a training plan, the same thing right if you don't one you just kind of drift." Interview, manager

Compartmentalisation of exercise outside of work context

Finally, a barrier reducing SB by engaging in PA was that PA was not associated with the context of the office. Exercise and PA are somewhat compartmentalised to times outside of the workplace setting.

"You know the mind-set around exercises is highly compartmentalised and it tends to be gym associated and then nothing you know." Focus group 2, manager

"You know so I do leave exercise outside the building in the gym." Focus group 2, manager

Engaging in physical activity in order to reduce sedentary behaviour in the workplace was not currently considered by some participants. Physical activity was somewhat defined as 'exercise' and therefore was not seen as appropriate within the workplace setting. Occupational habits did not currently include PA, which was associated with the gym and after worktimes.

"It's not a conscientious decision to try and do that. I think people would more, the time that they would put into exercise would be more after work where they try and do gyms or whatever but not actually a 5-minute walk around the building." Focus group 3, employee

These quotes highlight the current sedentary workplace habits of both employees and managers. Physical activity was constructed as a leisure-time pursuit and not currently considered as being possible within the working day.

In summary, many intrapersonal barriers were acknowledged by the participants. These included the primacy of work, concerns regarding productivity that may occur from endeavours to reduce SB, a preference to remain seated while working, entrenched workplace sitting habits and fears of distracting others while moving around the office space. Participants expressed a fear that alternatives to sitting such as standing may cause physical discomfort, however, declared a lack of solutions or ideas to reduce SB in the office, as physical activity was currently compartmentalised to primarily outside of the workplace setting and predominantly engaged in in leisure time hours. The following section outlines the results in terms of intrapersonal barriers to reducing SB in each worksite.

4.5.6.2 Interpersonal Factors

Social and work culture norms

Social norms existed in the workplaces, and descriptions of the normative aspects of the workplace as being oriented towards sedentariness, were suggested as interpersonal barriers to reducing SB.

“The norm in our office is as you describe, pretty sedentary. You sit at your desk, you do your work, you go to a meeting. Most of the meetings you would sit down in through it” Interview, manager

“You know we inevitably default to sit down meetings because that’s just what most people do.” Focus group 2, manager

Participants described a lack of a conscious effort or normative behaviour of other co-employees to reduce SB, and movement was described only in terms of general daily habits and routines.

“Not in our office anyway, myself and [colleague] both work in IT and pretty much no one would do that [reduce SB] I don’t think. Anyone who gets up just probably gets up to go to the canteen or to get some coffee or go to the toilet. They’re not actually focusing on actually their

sedentary lifestyle and doing something about it I don't think. It doesn't seem like it anyway."

Focus group 3, employee

The general habits and characteristics of conducting business and the workplace social norms of co-employees was felt to be increasing SB unnecessarily, and could be changed to both increase efficiency and reduce prolonged workplace SB.

"An hour meeting is the default; you should actually cut it to 45 minutes and try and push the time thing so that you are actually sitting less and get up in between. I think it's amazing how people think you need an hour to discuss everything." Focus group 2, manager

There was general consensus that the stairs were distinctly underused despite being seen as a useful asset to enabling workplace PA,

"The stairs is fantastic and it's not used enough." Focus group 2, manager

"The amount of people using the stairs I'd say is less than 5%, much less than 5%." Focus group 2, manager

The normative behaviour by both the participants and their colleagues was to use the lift when moving between floors in the workplace, which was a barrier.

"I'm amazed you know when you talk about that, I would be amazed at the number of people taking the lift a floor, even a floor down." Focus group 2, manager

Dissenting voices of co-employees

Reactions from some fellow colleagues were suggested to be an interpersonal barrier, by non-participant's somewhat deriding those who were making efforts to reduce SB in the workplace.

"I think we don't have any nay-sayers as well because there would be a fair few people around here would consider this bullshit realistically, where it's a desk job get on with it, do the job so if you had that sort of dissenting voice it might just simulate a bit more thought, because we

seem to have a bit too much buy-in to make this a really challenging environment.” Focus group 2, manager

Self-consciousness or embarrassment

Most participants wanted to fit in with their peers and engage in acceptable workplace norms. A fear of self-consciousness or embarrassment was a powerful theme that emerged from the data, where the men were somewhat anxious not to appear ‘weird’ to their peers.

“The only thing I would be wary of is that as well as doing some stupid exercises you’re also doing some weird movement, and somebody walks in and you’re doing this you know whatever.” Focus group 2, manager

“I think meetings is one that we would try and do more of like if you were in meeting like this and across this big table and try and stand that that just looks a bit weird as opposed to maybe a smaller room being more suitable.” Focus group 3, employee

Some participants also stated that performing exercises that may induce sweating in the public and professional setting of work was a barrier to higher intensity physical activities during work hours.

“I tried that with some of my team to do a walk around the block meeting. It was a disaster because it was so warm, we were all sweating by the time we came back” Focus group 2, manager

“But I found that and as well I tried to get into the habit of going to the gym at lunchtime but then I’d come back sweating and it’s kind of awkward if you have a 2 o’clock meeting and you’re still pumping sweat and the same for the morning time so it’s kind of you’re trying to figure out the best time to do the gym.” Focus group 2, manager

This last quote highlights the consensus for any physical activity engaged in within the workplace setting to not induce sweating in the men.

Judgemental perception of avoiding work

Participants feared that by using strategies to reduce workplace SB they would be judged negatively to be avoiding work, and they anticipated the negative social judgement of others.

“I don’t know it’s kind of like you see people now and again going out doing it but like it’s kind of like a stigma if someone saw you going out for a cup of coffee, they’re dossing, and they’re not actually doing their job.” Focus group 3, employee

“You could definitely imagine some people like it could become a thing where like such and such is taking liberties.” Focus group 3, employee

The results highlight some of the interpersonal barriers to reducing workplace SB in the worksites. These included work and social cultural norms where stationary sitting was the cultural norm and acting outside of these normative behaviours was seen as a barrier. Colleagues’ negative reactions and judgements to individuals who attempted to reduce SB was another significant barrier expressed by the men. Self-consciousness or embarrassment invoked by others’ perception of the men potentially being observed as ‘weird’ or unhygienic were further powerful barriers to PA in the workplace. The following section presents the organisational level barriers that emerged in the data.

4.5.6.3 Organisational Factors

Management expectations

Managers expressed concerns that work was achieved, and that productivity was maintained while reducing SB. One manager highlighted that if there was an increase of walking throughout the day, employees would be expected to stay later in the evening to accomplish their expected work tasks.

“People are becoming more and more aware of it, so I don’t think there’s a barrier to it em you still have to get through your day’s work right so that’s the reality at the end of the day. So if you were to say to me would they be willing to get up and do a bit extra you know walking around and then stay half an hour extra in the evening I don’t know the answer to that.”

Interview, manager

“Because again in terms of productivity I would have thought if we all got into the mind-set of oh every sort of hour I better stop and go and walk around and come back.” Focus group 2, manager

A barrier was expressed by many managers that if employee members left the office to go for walks, they would not be available to them, which could invoke the appearance or impression of a reduction of productivity.

“Unless everybody decided I’m going to just walk out and do a lap of the dock or whatever it is and you suddenly find that at any given time there’s all your people walking around out there that would look like a sort of productivity issue you know.” Focus group 2, manager

“Joking aside if you were to say from now on if you want to chat to somebody walk out the door, do a quick walk around the block, come back in so you can move around, all of a sudden everyone is out the door and the place is like a ghost town, it would look like a productivity problem.” Focus group 2, manager

Employees also acknowledged this scenario as a barrier to leaving the office, and they envisaged a sense of frustration from management employees if employees were not available to them forthwith.

“I can easily imagine a situation where somebody above me in the hierarchy is looking for me, or I’m looking for somebody below me, and it’s like where’s such and such in a panic and it’s busy, you know it’s in a rush, it’s panicky or whatever and they’re gone for a walk! It would be a bit frustrating. So that would be a definite thing. But em yeah I think they would be conducive to doing stuff like that but it’s just the day to day reality.” Focus group 3, employee

Traditional culture – restrictive formal workwear

The requirement of formal workwear was mentioned as a barrier. This type of clothing was felt to be physically restrictive and not comfortable for exercise or PA while at work.

“I mean people if they’re wearing sort of non-formal suits where I think it would be more likely to be able to move around and stretch that kind of thing than if they feel they are constrained in a suit.” Focus group 2, manager

Additionally, there was a resistance to a change in the requirements for formal workwear from some managers who were apprehensive that this may be akin to a 'slippery slope' towards a reduction in professionalism in their view.

"So that would be a definite thing I think that could have other effects, a downward spiral, you'd have people coming in in tracksuits." Focus group 2, manager

"But there's no rips in jeans!" Focus group 2, manager

The results show that expectations from managers that employees are available to them if needed were significant barriers to reducing SB if that required moving away from the workstations. A key concern from management emerged as a barrier to strategies that may entail a reduction of work performance. Finally, the maintenance of an appearance of professionalism within the office setting needed to be balanced with strategies to reduce SB was important to management in one of the worksites; whereas formal workwear was perceived as restrictive to movement and seen as somewhat of a barrier to reducing SB by engaging in PA. The following section presents the results in terms of barriers to reducing SB that operate at an environmental level.

4.5.6.4 Environmental Factors – office environment

Design of the workplace

The overall consensus in one of the workplaces was that the office space was very physically restrictive, with no opportunity for incidental movement, for example, walking to a remotely located printer. This office was open plan but small and contained many employees working within this space with no physical space to stand in.

"So yeah the kitchen is 20 yards away, there's no movement in the office because it's so small" and *"well there is only one printer, but the office is tiny, like it is tiny right."* Interview, manager

Employees in this worksite described the context as being so small you could call around the room and everyone would hear – thereby negating the opportunity to increase incidental movement by walking to speak face-to-face with colleagues.

A barrier to reducing daily workplace SB in the second workplace was the design of the office, it was felt that an open plan would provide more opportunity for incidental movement throughout the day. It was acknowledged that individual offices inhibited movement by requiring conscious and cognitive effort to stand up and break SB.

“A contributory factor today is that it’s predominantly not open plan and it’s more office bound so...open plan will tend to get a bit more criss-crossing and shouting over and walking over to people whereas if you’re in a room you know it’s making a conscious decision to get up to exit.”

Focus group 2, manager

Reliance on Information Technology and desk-based equipment

It was universally agreed that the design and set-up of traditional workstations and the need for access to IT throughout the day in order to achieve participants’ work tasks, was a barrier to leaving their desks and incorporating more movement to reduce SB.

“You’re generally taking notes as well on a lot of calls so that would be, not workable.” Focus group 3, employee

“Probably much the same I’d be normally sitting down unless I have to go out and do a one-to-one. I do frequently use the phone call as well just because you need to be at your PC when you’re talking to somebody, so it is hard to break it up.” Focus group 3, employee

Managers who were motivated to enable and encourage their employees to have walking meetings also acknowledged the reliance on computers as a barrier to moving during the working day.

“I think about taking some of my team out for just a stroll around as we do our team meetings but then quite often we need screens so that would be the most important thing.” Focus group 2, manager

Although the alternative to a traditional workstation, such as stand-up desks was mentioned, there was a sense of inevitability of sitting down to achieve most working tasks. This was a barrier to reducing SB.

“I think actually you know there’s certain parts of our job there’s actually no choice but you’re sitting down realistically unless you have a stand up desk but we’re sort of working on documents or things like that or writing emails or that kind of thing sitting down and that’s the end of it.” Focus group 3, employee

4.5.6.5 Environmental factors – building environment

High-rise building

Having a workplace situated in in a high-rise building with the requirement of having to use the stairs or lift to get outside of the building, was perceived as a barrier to reducing SB to some participants.

“you know in reality being on the 7th floor you know you go for a little bit of a stroll even for 5 minutes even getting the lift if you don’t want to use the stairs up and down in itself is a barrier. You know that’s just calling a spade a spade.” Interview, manager

Cost of stand-up desks

A barrier to stand-up desks was the concern raised by participants about the cost implication of height-adjustable desks. The question was raised whether this outlay would be cost-prohibitive.

“We don’t have stand up desks so like if we were to go down that route now and get 20 of them it would be €500 a piece, it would be 10,000 right. That’s what it is, if you’re starting from scratch you probably buy stand up desks because you have desks you know you’re going backwards to go forwards.” Interview, manager

The results show that the design of the office and the larger building space presents barriers to reducing SB in both of the worksites. Participants expressed that the traditional work-desks restrict movement and promote SB, which is difficult to overcome. The reliance on IT equipment that is desk bound further restricts reduction of SB throughout the working day. Finally, the location of the office being situated on the 7th floor was expressed as a barrier to walking breaks to reduce SB. The following section presents the results of the facilitators to reducing SB in the worksites.

4.5.7 Facilitators to reducing workplace sedentary behaviour

A total of 16 facilitators to reducing workplace SB emerged from the data collected from the focus groups and semi-structured interview.

Work-related - increased productivity

A facilitating factor was the increase in productivity and efficiency anticipated by reducing SB in the workplace. Taking a walk or break may increase afternoon productivity and was seen as a potential benefit.

“You know you might get it done in the same time period but more productive because you’ve gone for a walk, the afternoon might be better than it would otherwise be.” Interview, manager

Standing while speaking with colleagues was associated with increased efficiency and productivity, and thereby seen as a facilitator to reducing SB.

“The other good thing about it is that people spend less time talking to you that you don’t want, you know if somebody comes in and sits down they will spend longer there whereas if they come in and they’re standing up they don’t spend as long in your office so it’s actually increased the productivity.” Focus group 2, manager

Having stand up meetings was acknowledged as a facilitator to reducing workplace SB. This was perceived as increasing efficiency and resulting in a reduction of time taken to conduct meetings with colleagues.

“Well they move a lot quicker. The fact that you sit down for a meeting always kind of indicates that it’s going to be longer than it needs to be and you know we inevitably default to sit down meetings because that’s just what most people do but you know if we bring in stand up meetings on a regular basis you actually get through an agenda much much quicker, there’s a better flow and actually there’s a bit of movement going on type of thing.” Focus group 2, manager

“One person got a high table and stuff in our office and we had a standing meeting there last week and it was actually great. It was just 10 minutes running through some documents just through various aspects and eh really good, really useful and apparently standing meetings are

a lot quicker than sitting meetings because you're a lot more inclined to finish them quicker."

Focus group 3, employee

4.5.7.1 Intrapersonal Factors

Motivation to reduce sedentary behaviour/increase physical activity via education/knowledge

A facilitator to reducing workplace SB at an individual level, was a motivation driven by the education and knowledge acquirement of the dangers of prolonged SB. Some of the participants felt motivated because of the education piece that was conducted at the outset of the study, and in taking part in the focus groups themselves.

"Certainly for meetings where everybody is in a room without any kind of outside influence, a lot of them could be held standing up, there's no reason why they couldn't be right, that's just an awareness thing, or a let's try and do it kind of thing. Being conscious of it and pushing it yourself." Interview, manager

"If there was a way it was facilitated like if when we were organising meetings instead of just going to a sitting room you could try to organise like a standing meeting, I'd definitely try and do that more often" Focus group 3, employee

Receptivity to new ideas

A facilitator to reducing workplace SB was an openness to change or try new ways of operating within the business, for example moving more in meetings. Both managers and employees expressed receptivity to trying new strategies and being open to changing work practices.

"In the main part people will be, I would expect people to be relatively open to trying something different." Interview, manager

"I think there are ways we could change our ways of working to make it better like that, I think it's quite a good idea." Focus group 2, manager

Reduction of physical discomfort

A facilitator to increasing movement, changing position, and reducing SB was the reduction of physical discomfort associated with prolonged SB.

“Even getting up and sitting down at your desk and doing this three or four times you know every two or three hours will really loosen up your back.” Focus group 2, manager

“if you’re in a meeting like this that’s going on for ages, I actually find it quite claustrophobic and my back gets stiff so I actually do get up and walk around, just up and down the room and look out the window or get water and it certainly loosens you up em and I think even on a con-call you can do that a little bit em so I do think you can work it in because those long sitting for hours taking notes on a conference call can be pretty tough.” Focus group 2, manager

Some participants in focus group one were very mindful of this, and even had alarms set to prompt movement at regular intervals due to chronic neck pain.

Experiencing mental benefits of taking a break

A facilitator to moving and reducing SB in the workplace was the experience of taking a mental break from the work and the environment. Breaking up SB by moving away from the desk was associated with a sense of wellbeing among the men.

“This maybe ties in more with the mental aspects of it, it’s like this is a very samey environment to come in and out of, in and out of and spend the entire day in there every day and sitting is just like the extreme end of that where you’re actually sitting in one very specific room in the very same environment from one end of the day to the other whereas I imagine people who are have a more varied environment in the day to day are probably a bit more happier or a bit less restricted feeling or something like that.” Focus group 3, employee

Participants in focus group one felt that the primary reason that they left the office setting was for mental break reasons rather than physical reasons.

Ideas/plan/schedule/reminders

Having a plan or reminders in place would act as a facilitator to prompt regular movement. This was the general consensus among all of the participants.

“You probably just need to be told, come up with a plan, it’s measure it or like having a plan around it or something I think I probably would. That’s kind of, you kind of need a plan you know like a training plan, the same thing right if you don’t one you just kind of drift.” Interview, manager

“I think you need to be reminded as well or you won’t even just remember to go and do something you know. Make that conscious decision whereas if you were on some kind of a schedule, ok now you need a 90 second break to walk around, if you were told to do that it would kind of force you to do it a little bit.” Focus group 3, employee

The use of technological prompts was suggested as a facilitator for providing reminders to individuals to break up prolonged SB.

“you know we can’t change what we need to do for a living so therefore the question is whether we change certain aspects of it so that they can be done while in a sitting or standing, stationary or sedentary position and being able to kind of appraise ourselves of that is maybe we need to get that into our mind-set. Maybe coupled of things that are technological prompts and whatever.” Focus group 2, manager

Movement while working

The ability to continue working while also moving, was acknowledged by the participants to be a facilitator to increasing movement and decreasing SB.

“Like if you say to me that thing you know wouldn’t you go for a walk in the afternoon for an hour or something like that I’d go well where is the work going to happen right but if you say to me there’s things you can do while you’re at your desk, while you’re in a meeting, while whatever, at lunchtime or whatever while still getting through your work, 100% be behind it.” Interview, manager

A participant in focus group one also expressed that he would favour the ability to increase exercise in his working day that he was not engaging in since changing job.

Various intrapersonal facilitators to reducing SB emerged in the data. The men articulated a motivation to reduce this health risk behaviour and were highly receptive to new strategies

and ideas to assist them in this endeavour. Facilitators included a reduction of physical discomfort experienced as a result of prolonged sitting, and the mental break experienced from breaking occupational SB. The men expressed that having a plan or schedule, together with prompts to remind them to break their SB would be facilitators. Finally, movement while continuing with work tasks was expressed as a strategy to enable the reduction of SB without impacting work performance. The following section presents the results in terms of interpersonal facilitating factors to reduce SB.

4.5.7.2 Interpersonal Factors

Social influence of co-employees who reduce sedentary behaviour

The social influence of co-employees adopting strategies to reduce workplace sedentary behaviour was a powerful facilitator. By changing social norms and normative behaviour, thus changing the rules of conformity, may be a strong facilitating factor to reducing SB.

“I think well there’s a little bit of a trend, I think. I mean I’ve started, I’m at a standing desk now and one of my colleagues [colleague] down the corridor is after because he saw me doing it, he’s after getting one as well and [colleague] who’s across the way has got one as well so there’s been a few standing desks around.” Focus group 2, manager

One manager, already motivated to use the stairs while in work, was encouraging of his co-employees to also use the stairs. This participant used what he described as “banter” to dissuade or shame them into not taking the lift to move up the floors of the building.

“The stairs is fantastic and it’s not used enough. I have one particular habit and God help anybody who meets me in the basement when we park because I will make them walk the stairs. I bumped into [colleague] coming in the other day and [colleague] is reasonably fit and made him come up the stairs and I let him off not going to the 6th floor and back down because he was panting by the time he got to the 3rd.” Focus group 2, manager

“I do think if it is a small change that you’re asking people to make it’s much easier to get it engrained in their habits so if you did actually I mean people get embarrassed when I’m in the lift with them and they’re taking it one floor, possibly two, sometimes there’s always a bit of banter. It’s a small thing, now and again you might take the lift because you’re exhausted but you might actually just push yourself just that little bit.” Focus group 2, manager

The social influence of work colleagues and management employees emerged as a powerful facilitator to reducing SB at an interpersonal level. In a workplace setting, therefore, behaviours may be affected or changed, both positively and negatively by work colleagues and those in authority. Organisational level facilitators are presented in the following section.

4.5.7.3 Organisational Factors

Culture - Management flexibility and encouragement of employees' wellbeing

A flexible and encouraging culture as set by management within the workplaces was a facilitator to reducing workplace SB. This was acknowledged by both managers and employees across both workplaces.

"We're very flexible. As an organisation we're very flexible." Interview, manager

"Yeah no I think management kind of encourage different lifestyle things as long as the work is done at the levels that we're expected to do it at. They don't really mind. They're trying to encourage us to do various things to achieve that and make us happier, if you're happier and you're healthier then you should be happier as well so I don't think they'd have a major issue with it." Focus group 3, employee

Motivation for increased social interactions

From a manager perspective, an incentive and desire for increased social interactions was seen as a facilitator to movement by moving around to speak with colleagues.

"Maybe I have more time for it, maybe it's more important in my case but I like eye to eye contact em but I actually think there's something particular in what you say in that if you're going to talk through an issue taking a walk around the block while you're solving the problem with a case you have or whatever and I don't think, I think there are ways we could change our ways of working to make it better like that, I think it's quite a good idea." Focus group 2, manager

Comfortable clothes in the workplace

An acknowledgement of the recent adoption of workplace policies to allow more comfortable (less restrictive) clothes to be worn in the office, thereby reducing the restrictiveness of formal wear, was expressed as a facilitator to movement and to reducing SB,

“Well actually one of the things and em just the idea of kind of moving around doing stuff at your desk I think one of the em the ways you could hook it in is the recent move to smart casual I mean if they’re wearing sort of non-formal suits where I think it would be more likely to be able to move around and stretch that kind of thing than if they feel they are constrained in a suit and em you know that’s the type of thing if you were promoting certain practices I think you might be able to say by the way this is way easier now than it was because you’re dressed marginally more appropriately for movement than you used to be.” Focus group 2, manager

Top-down modelling of behaviour

A facilitator at organisational level was top-down modelling of behaviour reducing workplace SB. Some managers did get up and move in meetings of long duration,

“I actually do get up and walk around, just up and down the room and look out the window or get water and it certainly loosens you up em and I think even on a con-call you can do that a little bit em so I do think you can work it in because those long sitting for hours taking notes on a conference call can be pretty tough.” Focus group 2, manager

A manager used earphones to walk while speaking on a phone-call as a strategy to reduce workplace SB.

“Like if I’m on a call I will put my earphones on and walk up and down the office for 5 minutes. If it’s a simple call and it’s not confidential or whatever right.” Interview, manager

In terms of facilitators operating at an organisational level, management flexibility was seen as a strong enabler for employees to reduce their occupational SB. Managers themselves anticipated increased social interactions as a result of reducing SB. This positive reaction and behaviour coming from a ‘top-down’ direction was observed to be a facilitator for employees

to reduce their own SB. The following section presents the environmental facilitating factors to reduce SB from the participants' perspectives.

4.5.7.4 Environmental Factors – office environment

Alternatives to traditional desks

A facilitator to reduce workplace SB was having an alternative to a traditional sitting desk workstation.

“Obviously the people with the high tables maybe, we sit because that’s the way our desks are, we don’t have the option of the high tables, whereas maybe that’s something that would actually give us an alternative as opposed to sitting.” Focus group 3, employees

Centralised printers

Having printers positioned in a centralised location, as opposed to individual printers was a facilitating factor to increase incidental movement and reduce SB.

“One thing we did do when we moved into this building which was positive was we used to have, certain people used to have printers in their room or their office so they never or very rarely would leave their office from the beginning of the day until lunch time or mid-afternoon but by having to go to the printer.” Focus group 2, manager

“Having to go to the centralised printer they now have to walk” Focus group 2, manager

Office design

A varied or open-plan office design was a facilitator to increased movement throughout the working day.

“Open plan will tend to get a bit more criss-crossing and shouting over and walking over to people.” Focus group 2, manager

4.5.7.5 Environmental Factors – building environment

High-rise building

Working in an office located in a high-rise building with stairwells that are bright, open, and safe was a facilitator for movement and reducing SB.

“The stairwells are fine from that point, there’s carpet.” Focus group 2, manager

“They are very respectable and incredibly under used.” Focus group 2, manager

Participants in focus group one also acknowledged that the bright and safe stairs in conjunction with having their office located on the 7th floor in particular were facilitators to reducing SB. One participant felt that the views were an inspiration for him to go outside more regularly that he otherwise would not get if he was looking out at buildings from his office location.

This section presented the facilitators in both worksites that were perceived to enable the reduction of SB, namely centralised printers, and the high-rise location with bright safe stairwells. Suggestions included alternatives to traditional work-desks and an open plan office design would enable greater facilitation of reduction of occupational SB. The following section presents the results of the participants’ views and perceptions of the suggested intervention components and study overall.

4.5.8 Participants’ views and perceptions of intervention components

In the second part of the focus group and interview sessions, participants were presented with the components of the proposed intervention, and asked to give their opinions and views on each component in turn, their perspectives on the intervention overall, and how appropriate it would be in each specific workplace context.

4.5.8.1 Environmental level component - pedal device

Positive feedback

The pedal device was presented to all participants in each focus group/interview. Participants were asked in turn to sit in a chair and try out the pedal machine to elicit their initial reactions to using the device. There was a sense of excitement from participants that they ‘would all be

getting one' in terms of each receiving their own individual device for the duration of the intervention period.

Participants were asked to test out the pedal machine to observe how it felt to them to use it. Different resistance settings were tried, and it was ascertained that a lower resistance may be more comfortable to begin the intervention period with.

"Yeah it's good yeah. I have it on 3 so that's quite low but it's easy." Focus group 3, employee

"Aw yeah that's a bit easier alright. It would probably depend on the level a little bit." Focus group 2, manager

Participants expressed that the device could be used on a low resistance setting until the activity became more learned and habituated. There was an immediate recognition of which work tasks could be accomplished while also cycling on the pedal machine.

"Yeah I would say that one might be a starting point. If I was on a call or something like that, if I was on a conference call, I do an awful lot of calls right and they would be the perfect time for it if you had it." Interview, manager

It was acknowledged that the cognitive processing involved in this new activity would reduce over time through use of the pedal machine.

"I'd say if you got used to it though." Focus group 3, employee

The design and operation of the pedal machine were deemed to be appropriate and desirable to participants in both workplaces. Participants commended the lack of sound emitted from the device when in use.

"It's not noisy anyway which is good, it's very quiet." Focus group 3, employee

"It's a very good idea. It's very subtle." Focus group 3, employee

In terms of the fitting of the pedal machine within the confines of participants' desks, there was agreement that participants' desks could be modified to ensure comfort while using the pedal machine.

"I can put my desk up alright." Focus group 2, manager

Potential issues

Four main potential issues were identified by the participants with regard to pedalling the machine in a workplace setting, during working hours. The initial concern was the ability to fully concentrate on work tasks.

"Do you think you could sit at your desk and work away and do that at the same time, and concentrate?" Focus group 3, Employee

"Yeah, yeah. I'd be a little sceptical. It could only very, you know em maybe get used to it but I would now if I was doing something now you'd be a bit distracted." Interview, Manager

However, it was acknowledged that there would be specific and suitable tasks throughout the working day that could be completed whilst also using the pedal machine.

"I'm not sure about if you're actually writing or doing something like that but I would think maybe more around call times and meeting times." Focus group 2, Manager

The second issue raised by participants in one of the workplaces was the concern of potential discomfort in terms of the restriction of clothing and sweating.

"I might need to change my trousers". Focus group 2, Manager

"That's the thing you'd be really sweaty." Focus group 3, Employee

The question was asked with regard to whether the device would fit underneath existing traditional style desks.

"What about knees banging though?" Focus group 3, Employee

"Did you check with the guys whether it goes under the desk and all that sort of thing?" Focus group 3, Manager

Finally, the question was raised by one participant on the benefits of this light PA from cycling the pedal machine. He held the belief that the behaviour of sitting is detrimental to health as opposed to being 'sedentary' and was dubious that moving while still sitting would be of benefit.

"I see no harm for sure. I assume, it's still sitting though right. I know you're moving your legs or whatever but I wonder how much you get, how much benefit you'd get out of that. I'd love to know like." Interview, manager

This participant was cognisant that although he would feel that he had conducted PA in his leg muscles, he himself would also gain relief from physical discomfort associated with prolonged sitting, from changing position and walking.

"But the physical effort of standing up or walking or stretching or whatever, you feel better for it on some level right. That obviously my legs would feel like they've done something but I'd still have the knots and the stiffness and that sort of thing from sitting down." Interview, manager

4.5.8.2 Individual level component - Garmin watch

The participants were asked for their views on the Garmin watch. This was a component that each participant would receive to record and upload their cycling data to the Garmin Connect platform. The watch and associated platform would enable self-monitoring, social comparison, and goal setting in the intervention.

Positive feedback

Participants were familiar with these physical activity tracker watches and in fact many were already using them for their own activities. Participants were open and accepting to using them in the intervention period.

"Sure, we all have them anyway." Focus group 2, Manager

"Oh 100% yeah yeah. I think everyone now has some form of one of these things... so I'd have no issue with that." Interview, Manager

Participants in focus group one were also interested in the various data that the watch could monitor and store and mentioned the feature of the heart rate monitor as interesting and desirable to them.

Potential issues

Participants who didn't normally wear these type of sports activity watches or did and wanted to continue wearing their own physical activity tracker watches raised the questions of wearing the Garmin watch.

"I was going to say, do you have to wear that all the time?" Focus group 2, Manager

"So, you can't wear the other watch?" Focus group 2, Manager

The second question was raised in relation to how the Garmin watch would record and collect the cycling data. This process was not automatic due to the technological capability of these types of physical activity tracker watches and the pairing with an under-desk pedal machine of this type. This meant that participants would have to start the watch upon commencement of their cycling activity to record the data, and then stop the watch upon completion of that bout of activity.

"I think for myself my day does have a lot of stop-start and different doing different things, you might start doing one thing and then an email comes in that requires you to really focus and you kind of stop and then you get that finished and you could start cycling again. So, would you be starting it?" Focus group 3, Employee

"It would really suit you know you could do 30 seconds or a minute or two and then being tied into something and coming back and going at it again." Focus group 2, Employee

4.5.8.3 Challenge component via Garmin app

Positive feedback

The men were interested in the competition element of the intervention. Participants would be able to see activity behaviours others in their team had achieved in terms of cycling via the Garmin Connect platform.

“Be a bit of competition!” Focus group 2, Manager

Participants in focus group one made the point that because they were men, they were innately competitive and that they were looking forward to this element of the intervention.

From a management perspective, participants acknowledged that the general principles of workplace challenges and competition in the workplace were ‘100%’ acceptable to them.

Potential issues

Participants were asked if they perceived any potential issues to initiating competition between the men in the study. This was felt to be the flip side of the same coin in that the men would find competition to be stimulating to them to cycle while at work – however, there was a concern that it might get in the way of the primacy of work.

“Yeah it goes back to the same thing right, at the end of the day if it becomes too successful and everyone is going oh I’m going to go for a really long walk because I want my team to win the step challenge this week so I’m going to take the afternoon off and go up the Wicklow Mountains right that’s an issue but em like in the main like I don’t have any issue with it, as long as it just comes back to the same things right which is we have to get through our day’s work so as long as we can fit in that and everyone is still as productive as they are today, or more in some ways hopefully but em I don’t have an issue but it’s one of those things you know yourself. If everyone gets too competitive or too focused on it and then they kind of lose the reason why we’re actually here! (Laughs)” Interview, manager

4.5.8.4 Ecological momentary assessment

Positive feedback

Participants were asked about their perspectives and views on receiving random notifications throughout the day on their smartphones using the PIEL Survey app. Participants noted that they were all using smartphones throughout the day anyway and the EMA data would not present any significant extra burden to them in the study.

“I can’t see any issue with that, we’re all connected and for that length of time no issue I would have thought. That should be straight forward enough.” Interview, manager

4.5.8.5 ActivPAL3

Participants were presented with and demonstrated how the ActivPAL3 accelerometer would be used and affixed to participants’ thighs during baseline, intervention, and control periods.

Positive feedback

Participants were accepting to use the device during the study periods, acknowledging the comparable small size of the device and the location of attachment to the body.

“I don’t think so like its fairly inoffensive now isn’t it? It’s quite small.” Interview, manager

Potential issue

Questions was raised by some participants with regard to conducting certain activities such as washing while having the device attached to the thigh, and the issue of airport security while travelling abroad.

“I won’t be even able to wash.” Focus group 2, manager

And no issues with that going through an airport or anything?” Focus group 2, manager

4.5.8.6 Overall intervention and study processes

With regard to the study overall, its processes and expectations of the participants, the feedback was resoundingly positive. The understandable and pertinent issue of data privacy and protection was highlighted.

“Certainly from our team like em you know things to watch out for like people are a bit sensitive about the privacy stuff that goes on right so that’s an important piece to make sure everyone is comfortable with but I think once you get past that all the stuff that you have described today they’re sort of...you know they’re not invasive in your life or in your working day and stuff like that so I can’t see any barriers, I can only see benefits to be honest.”

Interview, manager

Overall, there was general enthusiasm and a drive for change of this health risk behaviour in the manner of the suggested intervention processes, and using the components described in the intervention.

“I think they’d be fine; I think they’ve signed up to reduce sedentary behaviour and that’s part of it. If you don’t measure it you can’t manage it you know the old phrase right, so I don’t see, there’s nothing in that that’s sensitive in any way shape or form. We all know we’re sitting during the day so yeah.” Interview, manager

“Thank you, it will be very interesting.” Focus group 2, manager

Table 15 (below) shows the barriers and facilitators of the participants in both worksites.

Table 15 Barriers and facilitators to reducing workplace sedentary behaviour mapped onto the domains of the socio-ecological model

	Barriers	Facilitators
Work-related	Primacy of work /productivity	Potential for increased productivity
<i>Intrapersonal</i>	Preference/motivations	Motivation to reduce SB
	Current workplace habits	Receptivity to new ideas
	Physical discomfort of reducing SB	Reduction of physical discomfort
	Lack of solutions/ideas of how to reduce SB	New ideas/strategies
	Compartmentalisation of PA outside workplace	Movement while working
	Distraction to others	Experience mental benefits
<i>Interpersonal</i>	Social/work culture norms	Social influence of others
	Dissenting voices	
	Self-consciousness/embarrassment	
	Judgemental perception from others	
<i>Organisational</i>	Management expectations	Management flexibility
	Traditional culture – formal workwear	Comfortable clothes
		Increased social interaction
		Top-down modelling
<i>Environmental</i>	Office design	Open plan design
<i>Office environment</i>	Reliance on IT/ desk-based equipment	Alternatives to traditional workstation
		Centralised printers
<i>Building environment</i>	High rise location of office	High rise location of office
Costs	Cost of stand-up desks	

4.6 Discussion

Qualitative analysis of data collected using focus groups and a semi-structured interview with male participants in various work positions (employees, managers and managing partners), revealed the barriers, facilitators and participants' views of a proposed gender-sensitised intervention to reduce sedentary behaviour (SB) within the specific context of these workplace settings (Table 15). Heretofore, limited evidence is available of the barriers and facilitators to reducing SB in professional men. Senior managers' and managing partners' perspectives have been incorporated in the minority of studies to date and are necessary to understand the appropriateness and acceptability of potential intervention strategies. To bridge this identified gap in the literature, Study 2 explored the views of male professional employees, managers, and managing partners with regard to workplace SB reduction. The barriers, facilitators and acceptability of intervention components were incorporated into the final design of the intervention tested in Study 3 (Table 16, Chapter 5). This study, guided by the MRC framework and the adoption of best practice for developing complex interventions, resulted in a deeper understanding of barriers and facilitators to reducing SB in professional workplaces. A novel finding that emerged in the data was the importance of the maintenance of professionalism in undertaking strategies to reduce occupational SB. This may be a useful insight when designing interventions that target these types of worksites.

The four main influencing factors identified were consistent with the socio-ecological model SB (Figure 17) (56,57); individual; social; organisational; and environmental. Hadgraft et al. (560) recently conducted a qualitative systematic review exploring barriers and facilitators to reducing SB at work, and categorised emerging themes in line with this model of SB. The themes identified by Study 2 were broadly consistent with barriers and enablers identified in the review (560). The socio-ecological model was a useful framework in this study as the themes that emerged in the findings mapped directly to the important levels of influence of behaviour.

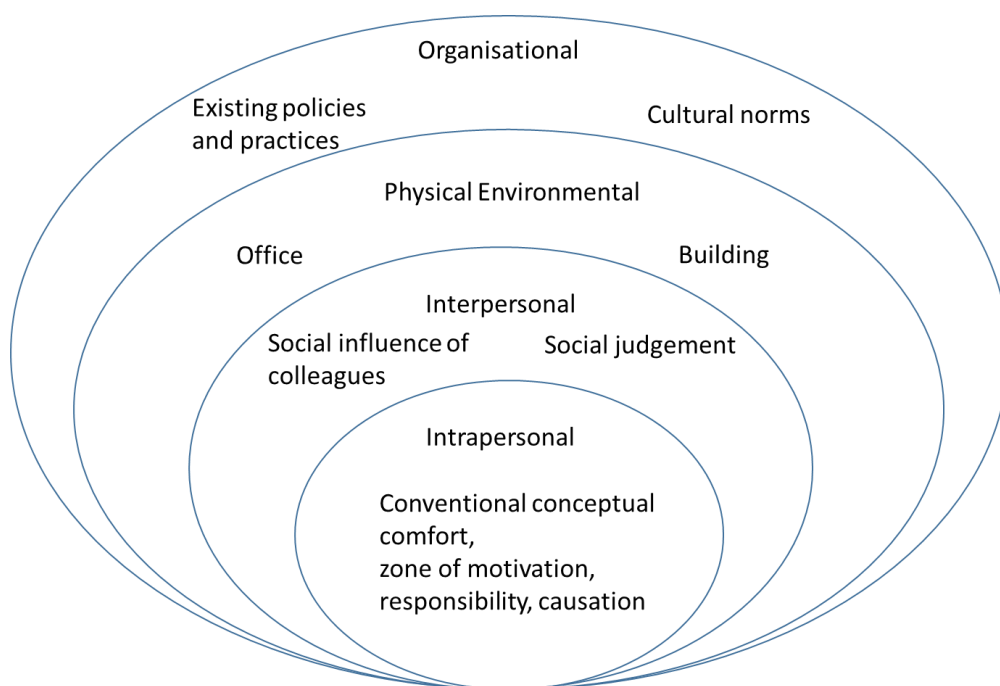


Figure 17 Barriers and facilitators of Study 2 mapped to socio-ecological model of sedentary behaviour (58)

The primary observation and overarching theme was the primacy of work in the workplace settings. Therefore, in designing interventions to reduce workplace SB, initiatives must come secondary to work tasks, or at least allow the continuation of work tasks to be conducted simultaneously. Barriers to reduce SB included: the design and set up of the office based around sitting down and being sedentary for long periods of time, the reliance on desk-based equipment and information technology, concerns about impacts on productivity, lack of ideas or strategies to reduce SB, a preference to remain seated while working, social judgement and workplace normative behaviours, management expectations, and being situated in a high-rise building. The main facilitating factor on an individual level was participants' inherent motivation to reduce workplace SB and increase PA. Being receptive to and provided with new ideas and strategies, experiencing the mental and physical benefits of reducing SB, and being able to move whilst simultaneously working were further individual level facilitators that emerged from the data. Interpersonal level facilitating factors included the social influence of co-employees, while organisational level facilitators involved encouragement, flexibility, and top-down modelling from those in management roles. Enabling factors operating at an environmental level comprised: an open office design with alternatives to traditional sitting desks, bright and safe stairwells to use, and outside views that motivate movement. The majority of potential and suggested strategies to reduce SB centred on technological and

behavioural prompts, while educating people to the dangers of prolonged SB and the removal of choice to use the lifts in the workplace were also suggested. Participants were overall accepting and interested in the intervention and the various components.

The 'primacy of work' must be the main consideration when developing and implementing workplace interventions, and has been reported in many studies exploring the barriers to reducing workplace SB (451,474,571,601–603). In the present study, this theme emerged from the perspectives of both managers and employees. Inherent time pressures felt by employees to fulfil their daily work responsibilities was an important barrier to reduce SB. This is a common and understandable theme in workplace SB reduction studies (451,474,571,602,603). A study of Spanish employees (604), reported that walking meetings or lunch-time walking sessions were seen as undesirable due to excessive workloads. This differed between employment roles, with administrative employees reporting a more structured and supervised schedule in the working day compared with academics. In this present study, although some managers arranged to have walking meetings with their employees, contrastingly, it was also somewhat of a worry to managers that if employees were out for a walk to break SB, the office would feel like a 'ghost town'. This led to a concern regarding a perceived reduction of productivity.

Habitual workplace behaviours were perceived as a barrier for individuals to reducing SB and difficult to overcome. Participants articulated that although there may be some awareness to reduce workplace SB, entrenched individual-level normative behaviour associated with 'work mode' had somewhat prevented changing habits in the working day, and has been reflected in studies investigating common barriers to reducing SB (566–568). To address the habitual nature of prolonged SB, technological (via mHealth) and behavioural prompts were suggested. These could be used to remind people to take breaks in their workplace SB. This is similar to the computer prompt suggestion in Hadgraft et al. (560).

A personal preference or motivation to remain seated at work was an individual level barrier to reduce workplace SB if it was to be replaced with standing. This is similar to previous studies where participants articulated a preference for a seated working style (475,571,605).

While it is acknowledged that comfort may be a factor with regard to sitting and SB, a previous lack of knowledge of the dangers associated with prolonged SB reduces the ability to enact a target behaviour due to the requisite cognitive processing such as attention, memory, knowledge and skills needed to engage in a behaviour (606). A strong facilitating factor that emerged from the data in Study 2, however, was an inherent motivation – motivation being

the belief system surrounding the guidance of the behaviour - and a commitment from participants to reduce their prolonged SB. Motivation further encompasses habitual processes, and emotional responses, which has, in general, been seen as a barrier due to a poor understanding of the negative health consequences of prolonged sitting (601,607). Education has been viewed as an important strategy to motivate employees to reduce their daily SB (607), however, this type of intervention strategy has elicited varying results (339,355,559). The findings of Study 2 strengthen positive results regarding the strategy education. Participants reflected that as a result of the education piece received in the introduction to the study session of the dangers associated with prolonged SB, they now had a desire to embrace and try new strategies to break up their SB with some movement.

The provision of ideas and strategies to participants on how to reduce workplace SB was acknowledged to be a strong facilitating factor to change behaviours in this and previous studies (60,567,571). The capability to enact the target behaviour by providing knowledge and skills allows the psychological ability in individuals to reduce SB (567), and is essential in behaviour change interventions. Having a discussion of strategies to provide more choice and ensure approval from both employees and employers has been identified as a key intervention characteristic to reduce workplace SB (64,571). This can be developed using participatory approaches tailored to specific organisational contexts (608).

A concern that participants themselves might be distracting to others, as well as a reflection that colleagues had in the past been distracting to them when moving about in the office space, was seen as a barrier to reducing SB. Using the strategy of taking phone-calls using earphones, or performing exercises at or beside the desk, were acknowledged overall to be too distracting to colleagues. There was a conflicting view with some participants believing that using these strategies to take breaks from SB had a positive impact. Inconsistent views have been noted elsewhere that workplace health interventions may distract employees from their duties, thereby negatively impacting productivity (475,566), while Stephenson et al. (601) reported varying views on how interrupting sitting with other activities may affect productivity, with some believing breaks were detrimental and others noting a positive impact. The limited evidence directly investigating the effect of workplace SB on productivity may explain the conflicting views (339,427,609). This highlights the need for future studies to use productivity as an outcome measure when examining intervention efficacy to explore associations between breaks in sedentary behaviour and productivity.

Physical discomfort was experienced by participants when previously adopting strategies such as walking meetings, for example, the weather being uncomfortably warm and inducing sweating and sunburn were noted as barriers to trying this type of strategy in the future. The weather has been reported as a barrier in previous qualitative studies, however, the barrier has been primarily as a result of inclement weather as opposed to being too warm (604); and with a facilitator to reducing SB being 'nice weather' (610,611). Weather conditions can strongly promote or deter PA behaviours (612). Although the experience of the discomfort of uncomfortably hot/cold weather is experienced at an individual level, it is acknowledged that this barrier can also be categorised across environmental level influencing factors (611). In Owen et al. (57), the socio-ecological of SB places weather in the second most outer ring of the model. This natural environmental factor is referenced as a behaviour setting with access and characteristics that must be considered and accounted for when developing interventions. It has been argued that it is necessary for interventions to be developed in a way that supports activity all year and every day, by providing choices for PA that can present alternatives when weather conditions prohibit outdoor PA (612,613).

A reduction of physical discomfort was expressed as a facilitator to reducing SB by providing musculoskeletal relief of symptoms experienced by participants as a result of prolonged workplace SB. This factor was described as a motivator to some participants who were prompted to move regularly to ease soreness or stiffness. This finding is in alignment with previous studies (566,601,610). In terms of knowledge of the negative physical consequences of prolonged SB, neck and back pain formed the majority of participants' knowledge base. This was derived from personal experience of musculoskeletal consequences, or participants had heard the experience of others who suffered these impacts. There was an acknowledgement of some vague and minimal knowledge of the other negative physical health consequences of prolonged SB, such as weight gain and poor circulation, but participants lacked good insight. It has been identified in previous studies, that there appeared to be limited knowledge amongst employees and employers about the broader cardio-metabolic health implications of SB; participants typically linked excessive sitting with musculoskeletal concerns (60,61,601).

Interestingly, no knowledge or awareness of the detrimental mental health effects of prolonged SB was acknowledged by participants, although experience of the positive impact of breaking SB was noted. Previous studies have reported some level of knowledge of the detrimental psychological effects of prolonged SB (38,567,610). There was a complete lack of knowledge reflected by the participants in the present study, although participants in one workplace did mention the positive impact on mental health experienced by breaking

prolonged SB. Of note, one worksite was significantly larger, and the environment was one of notably competitive and traditional style organisations. Evidence exists on aspects of adhering to traditional masculinity norms which may be linked with higher levels of mental health stigma among men (614). The stigma of mental health issues is well documented (615), and may be especially maintained in a competitive environment. This may have inhibited an acknowledgement of the detrimental mental health effects associated with prolonged SB. This may be as a result of cultural norms and expectations. For example, in the present study, long hours of sitting were associated with 'working very hard', and an acknowledgement of mental health impacts of prolonged SB may potentially be subconsciously seen as a result of working hard, as opposed to being as a result of sitting for long periods, and therefore not mentioned. However, aspects of traditional masculinity practices, for example, norms of 'dominance' and 'primacy of work', have been found to related to greater preventative self-care behaviours (614), and this was reflected in the high level of interest and motivation participants in the present study displayed.

The final barrier at an intrapersonal level was the compartmentalisation of exercise and PA to strictly outside of the workplace context. This displays a certain rigidity of thinking in terms of behaviours and settings being mentally matched in a particular way. The idea that exercise and PA are set as being appropriate only for outside of the workplace needs to be addressed. However, it was acknowledged that a major barrier to moderate or strenuous exercise within the working day was a fear of sweating and the physical and social discomfort this induced. Previous studies (610,616) have also reported the potential for sweating as a barrier to certain types of PA in the workplace. In one of the studies, participants also made decisions to remain sedentary during working hours at times when they were not working as they enjoyed relaxation activities which were linked with sedentary behaviour rather than PA (616).

At an interpersonal level, socially influenced barriers were driven by the social and cultural normative behaviours of work colleagues. Perceptions of what was considered 'normal' behaviour, and the usual behaviours of others, did not, at present, include attempts to reduce SB in the workplace setting. One participant reflected that 'dissenting voices' of some colleagues who dismissed the importance of reducing SB, could be perceived as a social influencing barrier to engaging in strategies in the workplace. A fear of being judged or perceived as avoiding work acted as another barrier to reducing SB, especially if the strategies involved being away from the desk. However, this was perceived by employees only; the sentiment was not expressed by managers. This can be attributed to the inherent flexibility and autonomy garnered to those in supervisory roles, which represents greater freedom in

daily routines compared with those in lower grade roles, who are restricted to more structured routines within organisations. Bort-Roig et al. (604) reported differences in social influencing barriers depending on the occupational role of the individual, with academic employees enjoying greater flexibility in the schedule of their working days, compared with administrative employees.

Although the feeling of embarrassment or self-consciousness about exercise participation may be an internal barrier – the anticipation of a judgement of being ‘weird’ by colleagues was noted as an interpersonal barrier in this study. This type of social judgement and the importance of colleagues’ perception of oneself as being ‘normal’ has been reported in previous studies (617). Interestingly, the word ‘weird’ has been cited verbatim by participants in a number of previous studies to describe others’ judgement of colleagues behaving outside of accepted workplace norms (60,427). Sweating in the workplace induced an ‘awkward’ feeling in participants, by potentially inducing a fear of being observed as unhygienic to peers and colleagues and was indicated as a barrier to any type of strenuous exercise in the office setting.

The normative behaviour of co-employees using the lifts to travel even one floor within the building, and an observation of others taking the stairs ‘less than 5% of the time’, was seen as a barrier to increasing workplace PA by using the stairs. It was noted that ‘nobody does that [take the stairs]’, despite a general feeling from participants that the use of stairs should be increased as they were bright and safe in both worksites. The social influence of other work colleagues’ attempts to reduce SB, i.e. installation of stand-up desks, inspired others to install their own stand-up desk. Some participants described their enjoyment of using these stand-up desks while taking a meeting and was noted as a facilitating factor within one workplace setting. One participant encouraged and supported colleagues to take the stairs with him by using ‘banter’ to dissuade or shame them into not taking the lift to move up the floors of the building. This type of behaviour has been described and associated with unhealthy competition (e.g. aggression, criticism) from female perspectives, and created obstacles and demotivated employees from participating (618). However, this method of communication described as ‘friendly banter’ has been reported in previous studies of interventions with men as being a successful facilitator (619–621). Moreover, banter has been found to be useful in male-only interventions to enable a sense of teamwork and camaraderie (553). The participant in Study 2 is an example of an ‘early adopter’, which influences at an individual level but also as a manager with top-down modelling impact which can tip interventions into wide scale

popularity, and can be seen as important to improve intervention adoption and adherence in participants (348).

The apparent strength of the influence of the social environment as reflected in the findings of this study is supported by the literature (427,566,567,622). This is relevant in particular in terms of the gender-sensitisation of interventions, and Sharp et al. (553) found that gendered social spaces for doing health was a valuable technique to engage and retain men in a study to increase PA in the community. Social relations are of the upmost importance in influencing behaviour, and can increase compliance to workplace interventions centred on PA (and potentially SB) in men (616). Furthermore, although poor social relationships may be a psychological barrier for participating in workplace interventions, by contrast, reducing SB and increasing PA together with good colleagues in a positive atmosphere may be motivating for participation (623). This is in accordance with Bandura's Social Cognitive Theory (440) that stresses the importance of social support for successfully improving individual health behaviour. As psychosocial work factors are modifiable through appropriate workplace interventions, the potential is available to harness these factors to researchers' advantage and can improve adherence to interventions by ensuring social support and a sense of 'togetherness' when implementing interventions.

The understandable issue of the fear of a reduction of productivity from managers was found to be an important organisational level barrier to reducing SB in the workplace. Previous studies have reported this as a risk to compliance in interventions to increase workplace PA. Despite managers and employees initially supporting and approving of the intervention, the internal working culture signalled the low priority of increasing PA, and the intervention itself (616). Management expectations, and the perceived negative demands on employees can be a powerful barrier to intervention participation (616,623). A number of qualitative studies have reported that crucial enabling factors were manager support and team leader engagement (427,564,565). It is therefore important to ensure management buy-in, flexibility, and support to employees who participate in interventions. Failing to overcome this barrier may detrimentally affect compliance and adherence to PA and SB interventions. In the present study, participants described the management employees as 'flexible' and supportive of participation in the intervention specifically, and in improving the health and wellbeing of employees generally. Some top-down modelling of the behaviours of breaking up SB by managers standing up in meetings and moving around the office while talking on the phone had already occurred. However, consideration must be made that managers experience a level of authority and autonomy to stand in long meetings which might not filter down to

employees, who may not perceive to have the freedom to engage in this behaviour. This may be viewed as a gradual and progressive change in workplace culture to adopt more movement to decrease prolonged SB. In a recent review of organisational culture and its implications on interventions to reduce office-based SB (624), the conclusions were centred on the effectiveness of integrating and combining individual approaches with cultural components to reduce SB. One of the recommendations outlined that organisations should focus both on top-down and bottom-up approaches to create the needed paradigm shift to move behaviours from one norm to another.

Managers suggested the removal of choice and personal responsibility from employees in terms of either disabling the lifts so that individuals were forced to take the stairs, or by setting off the fire alarm to force employees to take the stairs every hour. This is in contrast to restrictions on individuals who would like to be more active in the workplace, and where management may act as a barrier to reducing workplace SB (560,625). Managers also recommended the use of motivational and/or directional signs to increase stair-climbing. In workplace interventions this has been found to be effective in increasing the use of stairs in workplaces (626,627). Recently, the use of choice architecture has gained momentum in the public health field by targeting and changing habits in the micro-environment by, for example, prompting individuals to use stairs by placing footprints on the floor that lead to the stairwell (628). It would not be recommended to force individuals however, to take the stairs by disabling the lifts, due to obvious ethical as well as health and safety issues.

Environmental barriers found in this study acted at the immediate office level: the design of the workplace centred on sitting and prolonged SB; the reliance on IT and desk-based equipment. At the building environment level, the location of the office situated on a high-level floor was perceived as a barrier. The set-up of the office around the traditional workstation of being seated and sedentary for long periods throughout the day was acknowledged as a significant barrier to reducing SB. The entire manner that office spaces are set-up with desks, standard meeting tables with chairs, and lack of break-out spaces all promotes sitting and discourages movement. The overall consensus in one of the workplaces was that the office space was physically restrictive with no opportunity for incidental movement, for example by walking to a remotely located printer. This office was open-plan and relatively small with many employees working within the space. Confirming that a centralised printer was indeed a facilitating factor, participants in the second worksite acknowledged that walking to collect printed documents did allow for an increase in incidental movement at various time-points in the working day. Within this larger worksite, the findings

showed that a barrier to reducing SB was the individual offices used by employees, and an open plan design would allow significantly more incidental movement throughout the day through the behaviour of 'criss-crossing' by employees around the office space. Having a clear understanding of the various issues that may arise in different organisation types is illustrated here highlighting that a 'one-size-fits-all' solution to workplace intervention design may not be appropriate (566). The predominance of furniture designed for sitting has been reported in previous studies as a barrier to the reduction of SB (60,566). Although some alternative to the traditional desk was observed as a potential facilitating factor by participants in the present study, in Hadgraft et al. (560) recent review, when reducing SB via the implementation of stand-up or treadmill workstations, design issues were raised as a barrier. These included, unstable surface areas on workstations, insufficient space to work, and difficulties adjusting the workstation set-up to meet ergonomic requirements (451,475,571,611,629,630). The cost implications associated with stand-up desks was a concern for some in the present study, and has been reported as a barrier in many previous studies where the concern at management and organisational level is to keep costs low in terms of the requisite investment for equipment by employers (46,64,445,449,631).

These findings may be indicative that novel solutions and incorporating the views and input of potential participants into the design of interventions so that equipment can be tested at the design stage to ensure participants are satisfied with the solutions that are suggested by intervention developer. The location of participants' offices situated on the top floor of a building was reflected by some as a barrier, and others noted this as a facilitator to reducing SB. The conflicting views were rooted in some individuals reflecting that the requirement to take the lift or stairs to go outside for a walk was an inhibiting factor, whereas others acknowledged that the views afforded by being on the 7th floor inspired them to go outside more often than they would if their office was situated at a lower level. However, participants from both worksites acknowledged that the stairwells were bright and safe to use, and could thereby be seen as facilitators to a reduction of SB. The level of usability and safety of stairwells can vary depending on the worksite, as Mackenzie et al. (566) reported in one workplace (a charity), the location and state of the stairs were barriers to using them, whereas local authority participants explained that, in their workplace, the stairs were central and were reached before the lift, thus promoting their use.

In summary, the most important barriers outlined by participants were the primacy of work and a concern regarding a reduction of productivity, the judgement of others in terms of slacking off or acting outside group norms, and restrictive and traditional desks that do not

allow movement. Facilitators to reducing SB were an inherent motivation to change behaviour, enablement of movement while simultaneously working and being seen to be at the workstation, management support, and social support of colleagues. A potential strategy that could meet the needs, preferences and motivations across the themes is the idea of active sitting. This would allow participants to remain in their preferred position of sitting while meeting their motivation to reduce SB. Active sitting is desirable on multiple levels: first, it allows movement while continuing to work thus addressing the main and overarching theme of 'primacy of work' given as the strongest barrier by employees and managers due to the concern of a reduction of productivity if employees leave their desks to reduce SB. Secondly, it allows for steady hand-eye coordination necessary during computer work compared with other types of activity permissive workstations (treadmill desks). Third, it enables light intensity activity necessary to short circuit the physiological mechanisms by which SB exerts its negative impact. The use of mHealth has been found to be acceptable and effective in workplace interventions to reduce SB, and enables the important and gender-sensitive behavioural strategies such as self-monitoring, social comparison and goal setting, as well as technological move prompts that emerged as popular strategies in the present population. All of these factors were considered and collated to design a multicomponent intervention to reduce SB and were subsequently presented to participants to elicit their perceptions and views.

4.6.1 Perceptions of the proposed intervention

The main components of the multicomponent intervention comprised: a Garmin watch with associated web-based platform/smartphone application; an under-desk pedal machine; and management participation and support. The intervention development and design are described in further detail in Chapter 5.

The variety of suggested strategies proposed in the intervention were described and presented to participants and results showed an overall view of acceptability. Participants were accepting of and interested to try the Garmin watch in the future intervention. Stephenson et al. (490) found in their systematic review, that mobile technology is acceptable and effective in reducing workplace SB. According to participants in Study 2, there is potential value in using the Garmin watch and its associated technology as a platform to self-monitor SB as a strategy to reduce occupational SB. This is an encouraging finding as self-regulatory techniques, such as self-monitoring, have been demonstrated as frequently used strategies in promising

interventions to reduce workplace SB (432,632). Further strategies reported in the 'most promising interventions' in work by Gardner et al. (432) were goal setting and social comparison, will be targeted using the Garmin watch, and through participant engagement with the Connect website/app in the intervention. By focusing primarily on increasing individuals' psychological capability to reduce SB through the BCTs - goal setting and self-monitoring, and maximising opportunities to limit or restrict SB (e.g. through modifying the physical environment by enabling LPA through the provision of the pedal machine), the potential for reducing SB is increased. Previous gender-sensitised interventions to increase PA in males have reported that technology (i.e. pedometers) that enable goal-setting and self-monitoring is an effective tool to engage men in increasing their PA (552,633) The social comparison behaviour change strategy, using a degree of friendly competition, is in line with a gender-sensitive approach to intervention design (554), has been used in previous promising interventions (432), and was acceptable to the men in both workplaces in this study. While non-competitive strategies may be preferred by 'older' men (555), recent intervention studies have drawn upon masculine values and interests in sport to identify as highly effective tools for engaging men in health-behaviour change (552,553). A potentially useful strategy to reduce SB that emerged in the findings of this study, were prompts to break prolonged sedentary bouts. The 'move' bar on the Garmin watch performs a wearable technology cue to interrupt SB at work by alerting the user to move (i.e. begin pedalling) after 60 continuous minutes of non-movement. This may be particularly helpful as reminders or prompts for desk-based employees are often in 'work mode' at a desk which is constructed to sit for the duration of the working day. The nature of sedentary behaviour is unconscious for the majority which likely limits awareness of accurate time spent sitting (634), and the prompt may act as a timely reminder to break employees' SB when their concentration is on work tasks.

Participants noted that if individuals were better informed about the negative health concerns they may face in the future due to prolonged SB, they may be more motivated to change. Previous SB interventions have not sufficiently attended to motivation (432). Education can work as a strategy by highlighting the potential future negative health consequence associated with a sedentary desk job, thereby motivating participants, and has been used as a strategy in previous intervention studies (445,470,605,635,636). Gardner et al. (432) suggest that the use of education was found in the 'most promising' interventions. Increased motivation could clearly be seen in the findings of this present study, with participants reflecting that the knowledge gained through participation in this study and via the education piece at the study introduction session, strongly affected their motivation to reduce workplace SB.

Participants raised some considerations about the pedal device with regard to the ergonomic fit and set-up of the machine under their desks. Cho et al. (637) investigated the ergonomic characteristics associated with using this type of desk bike (DeskCycle™) in a traditional style office workstation. The results determined the recommended adjustable ranges of workstation settings when using the DeskCycle™ for the general U.S. population; and although the findings raised issues of leg height clearance with the machine, the researchers operated from an assumption of a standard desk having a leg clearance of 718.8 mm. In the developmental stages of this intervention design, it was established that the participants' desks in both workplaces have an adjustable height clearance of up to 820 mm, which would allow for significantly increased leg clearance room. The pedal device was interesting to participants, and most individuals tested it out, and all were interested to use it in the intervention. These types of devices have been found to be acceptable, feasible, and effective in previous studies of predominantly female participants (483,484).

Participants in the present study did not express concern about the frequency and methods of the electronic measures to be used in the intervention (EMA, ActivPAL3). Considerations were made by participants in terms of being able to shower and go through airport security while having the device attached to the thigh. Data privacy was raised by one manager with regard to a potential concern in other participants. It was reassuring that all participants were satisfied with the procedures in place for the safety and protection of data collected and stored for the intervention.

Participants were presented with all proposed components of the intervention, as well as a description of what would be required of them throughout the study. Findings from Study 2 were used to inform the final design of the intervention tested in Study 3 (see Table 16, Chapter 5). Overall, the consensus was that the intervention was 'interesting' to participants, would be beneficial to them and effective to reduce SB, and they were happy to take part in the study. This multicomponent intervention guided by the socio-ecological model, targeting influencing factors of workplace SB, had not been tested in previous intervention studies, nor in this particular at-risk target group. The intervention was relevant and appropriate to professional males, and taking this participative approach, ensured that the views and perspectives of the target population were incorporated to the final design.

4.7 Strengths and Limitations

The strength of this study was the provision of insights into the perspectives of professional male employees, managers, and managing partners regarding occupational SB, and a multicomponent intervention to reduce SB. Their voices were deemed crucial to explore the context-specific barriers and facilitators as the first step in the development of successful interventions (64). This is important to provide an understanding of the previous experience of the intervention's target population, and has allowed the anticipation and discussion of the issues that arose; and is in line with guidance from the MRC (413). This consultation with, and involvement of all stakeholders, both employees and managers, in the planning of the intervention has provided an understanding of salient factors that are different within this group with regard to the different elements of the intervention (67).

A further strength is the incorporation of senior managers and managing partners' perspectives which are necessary to understand the acceptability and feasibility of potential intervention strategies in specific organisational cultures. Varying social and political contexts within the workplaces created different climates of workload pressures that create significant barriers to reducing SB. The target population, professional males, has not previously been investigated as a specific target group. Research suggests that males are under-represented in intervention studies despite the lower life expectancy and premature mortality of men (574,575). This study provides an understanding of the factors that motivate and encourage men's participation in intervention studies by incorporating their expressed preferences into a gender-sensitised intervention design and planning. This facilitates participation of this traditionally difficult to reach group (13).

However, a limitation of the study was that it was a convenience-based sample from two companies in Dublin, and it can be argued that, by taking part in the study, the participants were already motivated to reduce negative health consequences, and thus more interested to reduce their SB. The sample provided differing views on the topic and covered various important stakeholder perspectives. The barriers, facilitators, and strategies that the men expressed were sometimes based on hypothetical cases rather than lived experience. It is important, that when designing interventions, their understanding and ideas are considered. The education session given by the researcher at the introduction of the focus groups in terms of defining SB and negative effects to health that are associated with the SB potentially engaged in by the men, is likely to have affected the discussions. It has been documented that the general public lack insight and knowledge into the difference between SB and physical inactivity, and SB is a relatively new health risk factor, therefore this was necessary as part of

the education strategy of the intervention overall (638). Using the socio-ecological model to structure the topic guide ensured a robust theoretical basis to the interview schedule design that encompassed the important behavioural influences (57).

Thematic analysis allowed analysis to be guided by the data as well as by the broader socio-ecological domains. This analytical approach has been used successfully in a previous theory-based, qualitative study exploring workplace SB in differing organisation sizes and sectors (566). Analyses of the data were carried out independently by two researchers to ensure reliability of coding and initial data interpretation. Although there were not the requisite available numbers of managers in one worksite to conduct a focus group, a semi-structured interview was conducted instead. This was in contrast to the second worksite where a total of nine managers and managing partners volunteered to participate in the focus group, demonstrating the high rate of interest at this level within the organisation. A limitation was that there was not the requisite time available to return to the participants for feedback on the findings.

4.8 Conclusion

To the researcher's knowledge, this study was the first qualitative study to investigate perceptions of professional male employees, employers, and managing partners regarding the use of a gender-sensitised multicomponent intervention incorporating mHealth and activity permissive restructuring of the environment as a potential strategy to reduce workplace SB, in order to inform development of such an intervention. The study was guided by best practice in intervention design as recommended by the MRC (412,413). Furthermore, the socio-ecological framework provided a useful, practical, and valuable theoretical underpinning by which to investigate and frame the barriers and facilitators, as well as the intervention design, of this important health risk; sedentary behaviour in those most at risk. The findings provide qualitative insights into the barriers, facilitators, views of potential interventions strategies and considerations that must be given attention to when designing interventions to reduce occupational SB. It was identified that above all, in the workplace, the primacy of work takes precedence and intervention designers must be cognisant that interventions to reduce SB should not impact on work. The results highlighted that the preferences of individuals, as well as the physical environmental factors, the judgemental culture, concerns regarding productivity, and the knowledge levels of employees and employers should be considered when developing interventions. The various barriers and facilitators elicited from these results

would suggest that intervention developers need to identify and address context-relevant factors and incorporate a range of behaviour change techniques to target the multi-level influences on behaviour.

Chapter 5 Study 3 Pilot feasibility study: Acceptability and feasibility of a gender-sensitised multicomponent intervention to reduce workplace sedentary behaviour

5.1 Introduction

As described in Chapter 2, there is a strong body of evidence demonstrating that in general, high levels of sedentary behaviour are unfavourably associated with all-cause mortality (24), cardiovascular disease incidence and mortality (32), and cancer (137). In particular, occupational SB appears to be associated with increased incidences of pancreatic, lung and breast cancers (138,139). In recent years, time spent in SB in middle- to high-income countries has dramatically increased, and set to continue to do so without intervention (639). A serious public health concern is presented in today's society given the range of detrimental health impacts, as well as increased mortality risk of prolonged and uninterrupted daily SB (640). The World Health Organisation, in 2020 (294), for the first time published new guidelines targeting a reduction in SB in the general population. It is now imperative to develop and test an intervention in the key setting of the workplace, and in the target population most at risk.

Results of Study 1 identified that adults spend more than 7.5 hours of their day being sedentary, most of which occurs while working. After controlling for individual, social and environmental factors, adult males who have attained a third level education, are in professional roles, and who live in an urban location have the longest sitting times (525). These findings are in line with previous studies investigating multi-level correlates of SB (407,535,641). As outlined previously in this thesis, males are over-represented in the prevalence of many conditions such as CVD, diabetes, as well as increased cancer mortality. Furthermore, men are under-represented in health promoting activities and in intervention participation. Evidence suggests that when gender issues are used to inform programme design, men will engage with appropriately gender-sensitised interventions, and using gender-sensitised strategies greatly improves recruitment, engagement, and retention (551–553).

Reducing workplace SB is important to curtail the physical and mental health risks associated with prolonged SB (129,642–644). Mullane et al. (645) found that those in public office spaces sit less compared to those in privately-owned offices, which indicates that private office employees may be at increased risk of the associated deleterious health outcomes such as all-cause mortality (24), cardiovascular incidence and mortality (32), and cancers (138).

Multicomponent workplace interventions targeting physical inactivity are cited in the WHO's

'Best Buy' recommendations for the prevention and control of non-communicable diseases (327).

5.2 Multicomponent Interventions

Multicomponent interventions - as opposed to targeting only the individual - have reported the most success in reducing workplace SB (355). The largest reductions in daily SB reported in interventions involved environmental restructuring (e.g. activity-permissive workstations) (340). A major strength of the SEM approach to health promotion is its integration of strategies of behavioural change and environmental enhancement within a broad systems theoretical framework (440). The socio-ecological model integrates and acknowledges the dynamic interplay of three core assumptions and distinguishing features that constrain or promote SB: 1) behavioural change and lifestyle modification, 2) the influence of social and cultural surroundings, and 3) enhancement and restructuring of the environment (347). It is the interactive effect of all three components in an intervention that delivers the most gains rather than targeting a single level (646). The following section describes the individual level behavioural change target of the intervention and the rationale for incorporating them to the Cycle at Work intervention.

5.2.1 Intrapersonal behavioural change techniques

At an individual level in health promotion interventions, ensuring relevance and individualisation are fundamental and effective methods, which is traced especially to Social Cognitive Theory (SCT) (440). To ensure relevance, pretesting the participants' knowledge, beliefs and circumstances and using this information as a basis for intervention development is required (647). One of the aims of Study 2 was to explore the perspectives and opinions of the participants on the practicalities of the proposed intervention to reduce SB in each local worksite, which would in turn inform the development of the intervention. The value of Study 2 was to gather evidence of population and context specific barriers and facilitators to reduce SB, and the incorporation of the views and beliefs of the target population to inform and shape the intervention to be tested. Core determinants of health behaviour advocated in SCT include setting health goals, perceived self-efficacy knowledge of health risks, outcome expectations, perceived facilitators and barriers, and social and structural impediments to change. The most frequently used intervention functions in studies to reduce SB are: enablement (i.e. facilitation of SB reduction), education of the dangers of prolonged sedentariness and strategies to reduce

SB, and restructuring of the environment (432). Setting behavioural goals, providing unspecified forms of social support, and the addition of objects to the environment, have been cited as the most promising strategies in interventions centring on SB reduction (432). These BCTs have been used successfully in gender-specific interventions to increase PA in men (552,633)

Advances in digital tools such as mobile phones, the internet and wearable technology have been found to be useful in providing a platform to target the individual to change behaviours. Interventions using computer, mobile or wearable technology (such as PA trackers) to reduce SB have reported an average reduction of 41 minutes per day (490). In these interventions, the behaviour change techniques (BCTs) most commonly used were prompts/cues, self-monitoring of behaviour, unspecified social support and goal-setting. Mobile health (mHealth) technology includes wearable PA monitors and trackers that connect to smartphone applications (apps). In a recent review of interventions utilising mHealth in physical activity and sedentary behaviour interventions, evidence for effectiveness and feasibility in reducing SB and increasing PA, suggests that mHealth may be a promising method by which to target individual-level behaviour change techniques (492).

To increase compliance with wearing activity monitors, team-based competition as opposed to individual monitoring may be more effective (492). In Study 2, self-regulatory techniques such as self-monitoring, goal-setting, and prompts and cues to reduce SB and increase movement were found to be of value to participants. These behaviour change strategies can be targeted by using a PA tracker watch (Garmin Forerunner 35) and its associated platform (Garmin Connect). The social comparison behaviour change strategy using a degree of friendly competition, is in line with a gender-sensitive approach to intervention design (554). The strategy has been used in previous promising interventions (432), and was acceptable to the men in Study 2. Targeting motivation by highlighting the potential future negative effects associated with sedentary roles, and providing education and awareness is also an effective BCT (470,635,648). The following section describes and provides the rationale for each behaviour change technique used in this intervention.

Behaviour change techniques used in 'Cycle at Work':

The eight key behaviour change techniques used in the intervention in Study 3 were:

- Goal-setting

- Self-monitoring
- Feedback
- Education and knowledge provision
- Social support
- Social comparison
- Digital prompts
- Environmental restructuring

The behaviour change techniques targeted in Study 3 operated at intrapersonal, interpersonal, social, and environmental levels as outlined in the socio-ecological model and are described below.

5.2.1.1 Goal setting

Goal-setting was chosen to be included as an intervention component based on best practice guidelines outlined by the WHO for workplace interventions to prevent non-communicable diseases (52), and the National Institute for Health and Care Excellence (649) recommend its use in behaviour change interventions. Having a goal can positively affect persistence and action, and it serves as a directive and energising function (650). A recent systematic review identified goal-setting as one of the most commonly used BCTs in SB interventions (432). Powell and colleagues (164) reported that five to 30 minutes/day of LPA was associated with estimated decreases in BMI (0.15–0.79 kg/m²), body fat (0.28–1.49%) and fat mass (0.35–1.89 kg). Therefore, the goal of cycling 30+ minutes/day (i.e. ≥ 5 minutes/hour for 8 hours) was chosen in Study 3 as the minimum amount of exercise break to fractionate SB.

5.2.1.2 Self-monitoring

Self-monitoring of behaviour is a method for changing behaviour described by Michie et al. (651) where the participant is asked to record a specified behaviour(s). Given that a large part of sedentary behaviour is for the most part habitual (i.e. minimum reasoning is involved and it is performed without conscious decision making (371)), strategies are needed to assist in breaking and reducing it. A powerful technique to disrupt habits is to bring the habitual behaviour and its context into conscious awareness. This might be achieved by means of self-monitoring (652), and using mobile technology has been found to be an effective method to incorporate self-monitoring in behaviour change interventions (653). Self-monitoring of

sedentary behaviour was used as a component in this intervention as meta-analysis suggests that monitoring a goal is an effective strategy to reduce sedentary behaviour (632), and it has been used in the most promising interventions to reduce SB (432). Self-monitoring was targeted in the present intervention by requiring participants to manually record their pedalling bouts and upload this data to the Garmin Connect website/app.

5.2.1.3 Feedback

Michie et al. (651) define feedback as a behaviour change technique as the reinforcement of performance of the specific targeted behaviour. This may involve the provision of feedback by the researcher on the participant's performance in the intervention. Using this technique has been found to be an effective way to change habits, irrespective of the target behaviour or technology used (652). Furthermore, feedback on performance has been found in promising worksite interventions to reduce SB (432). Therefore, this behaviour change technique was deemed important to include in this intervention. Weekly feedback in graphical form was provided via email to each participant on their own patterns and levels of SB, as well as how they compared with their team-mates in terms of SB and cycling time. Reminders of goals and encouragement were also provided.

5.2.1.4 Education and knowledge provision

Education as an intervention technique is defined by Michie et al. (606) as 'increasing knowledge or understanding' (pg.7). Although we know that SB is a distinct health risk behaviour with separate physiological mechanisms, it remains an emerging field of research. It cannot, therefore, be assumed that the general public are aware of the dangers of prolonged SB. Providing information and educating participants of the associated risks has been found to be an effective behaviour change strategy to reduce occupational SB (432). In males, positively framed messages to reduce SB by increasing PA have been found to be particularly effective (590–592). In the present study, the behaviour change technique education was targeted at the presentation session at the outset of the study provided by the researcher. This underlined the dangers of prolonged SB and the provided positively framed messaging in terms of ideas and ways to reduce SB throughout the workday. Furthermore, the title of the intervention 'Cycle at Work' was positive in its message.

5.2.2 Interpersonal behaviour change techniques

5.2.2.1 Social support

Social support can be created through shared experiences and group membership (618). Psychosocial support from supportive colleagues and managers in a workplace may influence the motivation, participation and adherence of the workforce through a positive social supportive culture (654). Providing social support was reported as one of the most frequently observed behaviour change techniques used in behaviour change interventions (432). The importance of this strategy has been highlighted in previous SB intervention studies (655), thus was incorporated in the present intervention. This technique was targeted by the recruitment of management staff to participate in the intervention which was intended to provide employees with social support in terms of highlighting the organisational commitment and shared experience of reducing SB.

5.2.2.2 Social comparison

Social comparison 'involves explicitly drawing attention to others' performance to elicit comparisons' (pg.1493) (656). The facilitation of social comparison through information about the performance of others has been found to be effective in interventions targeting men (554). Using a degree of friendly competition, is in line with the gender-sensitive approach to intervention design and was an acceptable strategy to the participants in both workplaces in the Study 2. Furthermore, social comparison has been observed in previous promising interventions (432). Thus, the BCT was included as an intervention component in Study 3. The strategy was targeted by using the Garmin Connect platform. Participants were asked to upload their cycling bouts to the platform which would enable all participants in each worksite to view (and compare) cycling times. Social comparison was encouraged in the weekly emails from the researcher which provided information on how each participant was performing compared to others within their worksite.

5.2.3 Environmental behaviour change techniques

5.2.3.1 Digital prompts

A digital prompt or reminder was suggested by participants in Study 2 as a mechanism to draw attention to long periods of sedentariness and encourage breaks. Methods of incorporating this strategy include mobile apps and tracker watches. Michie et al. (651) define the prompt/cue behaviour change technique as an 'environmental or social stimulus with the

purpose of prompting or cueing the behaviour', and this may be useful to break the 'habit' of sitting (657). In a recent review of mHealth interventions, the majority of studies employed the BCT 'prompts/cues' (658). In terms of SB interventions, the use of prompts to encourage breaks in sitting has produced promising results (167,452,464,659). Digital prompts have been found to be more effective than education alone at reducing occupational SB (465). Gardner et al. (660) suggest that 'someone who is habitually prompted to act is more likely to frequently perform those actions and to do so without relying on intention' (pg.4). The current evidence base, coupled with the prompt strategy that emerged as a facilitating factor in Study 2, resulted in the inclusion of this behaviour change technique in the intervention. A 'move bar' on the Garmin watch was used as a digital prompt to alert the participants to periods of inactivity to break SB.

5.2.3.2 Physical environment restructuring

Restructuring the physical environment to enable the targeted behaviour is particularly important in workplace interventions to reduce SB due to the restrictions to movement that exist with traditional style workstations. Adding objects to the environment such as height adjustable desks or activity permissive desks can overcome the barriers to movement in workplaces and allows participants to remain at their desks. This emerged as desirable to participants in Study 2. A systematic review by Gardner et al. (432) examining behaviour change techniques for all types of SB, suggested that interventions to reduce SB at work that restructure the environment may be among the most promising interventions. This echoes conclusions made by Healy et al. (661) that the built environment plays a significant role in reducing occupational SB, and is a key consideration in developing workplace interventions to reduce SB. In Study 3, the participants' desks were restructured by adding an under-desk pedal machine to the traditional workstations that were currently in use. The rationale for the specific environmental level intervention target – the pedal device - is outlined in the following section.

As found in Study 2, the strong reinforcing, and restrictive properties of the physical environment of the office workplace act to promote SB and limit physical activity (PA). The findings revealed a strong barrier to reducing workplace SB was the design of the office workstation. Sit-stand desks have been by far the most commonly used strategy in studies aiming to reduce workplace SB (340). These interventions have enabled the break-up of prolonged SB by replacing some SB with standing, however, the metabolic benefits of light physical activity (LPA) are significantly greater than those observed by standing (166). Standing

(and SB) is also associated with increased body mass index (BMI), body fat and fat mass (164); and with an increase of ischemic heart disease and varicose veins, and other deleterious cardiovascular outcomes (476). Occupations involving predominantly standing been found to be associated with an approximately two-fold risk of heart disease compared with occupations involving predominantly sitting (662). Therefore, advising sedentary employees to increase workplace standing time is misguided if the basis for a reduction in SB is to improve cardiovascular health (477). The findings of Study 2 highlighted a preference to remain seated while at work by the participants. Furthermore, an expectation of physical discomfort because of long-standing periods was expressed by some participants. Together, these results highlight the potential unsuitability of sit-stand workstations as a solution to reducing occupational SB in terms of optimum health benefits and acceptability.

Using activity-permissive workstations (418), or treadmill desks (466) to combine low intensity PA with sedentary practices may increase daily energy expenditure (EE), and thereby reduce cardio-metabolic risk factors (484,663). In workplace settings where the choice of employees and/or employers is to remain seated, the concept of 'active sitting' as opposed to 'reduced sitting' may be the preferred solution (566). Movement while continuing with work tasks emerged as a theme in Study 2, with participants expressing a desire for strategies to reduce their SB to coincide with their capacity to continue working.

The benefits of cycling workstations appear to provide greater short-term physiological changes than standing workstations, which could potentially lead to better health (664). Pedalling an under-desk device operating at a low resistance setting can result in the expenditure of energy similar to that of slow walking, i.e. twice that expended by standing (663,665). Furthermore, combining PA with sedentary activities such as office work could reduce time-related costs of PA, a common barrier to regular PA in adults (666). Given the need to focus primarily on the delivery of work-based tasks, increasing light to moderate PA while being able to continue a work task does not require the dual-hinge process, and may be easier to target in a workplace situation (473). In Study 2, the under-desk pedal machine was observed as an appropriate solution to reducing SB where work tasks take precedence in busy workplaces. In laboratory settings (637,667), and in studies predominantly including women (484,663), the feasibility of using under-desk pedal machines to reduce SB has been established. A review of the literature exposed important gaps in the current evidence base which warrant further attention. The acceptability and feasibility have not been established in real-life workplaces with males. Different populations or sub-populations might have sufficient characteristics in common to carry an intervention forward, however, it is strongly

recommended to gain an understanding of any variability in intervention acceptability and feasibility across different groups (188). Study 3 sought to address this gap by establishing the acceptability and feasibility of this type of intervention, which aims to reduce workplace SB and increase PA in professional men.

Providing sedentary employees working in professional environments with under-desk pedal machines, where pedalling can be performed for long periods throughout the day without causing perspiration was a rationale for the choice of intervention component. A reluctance to engage in a physical activity intensity that may invoke sweating emerged in the findings of Study 2. These types of devices are less intrusive and expensive than other activity-permissive workstations (e.g. treadmill desks). Breaking up prolonged SB with many short bouts of light intensity PA may be most acceptable and effective in terms of workplace interventions to address SB (473).

Low intensity cycling in the workplace has the established benefits of:

1. allowing employees to complete computer-based work tasks (473);
2. energy expenditure using self-selected resistance may be increased by a median of 87.9 kilocalories (range = 19.7–178.6) more than expended per hour of sedentary sitting, an EE equivalent to a median MET value of 2.2 (range = 1.3–3.9) (667);
3. increasing EE by twice the amount of METs compared with standing workstation using a resistance setting of 20-30 watts (668);
4. significantly reduces systolic blood pressure compared with walking or standing (669);
5. increasing arousal and reducing boredom significantly better than standing workstations (670);
6. no reductions in motor task performance (637,671).

Although it is not feasible to conduct an economic evaluation in this small pilot study, and direct comparison is not possible; the cost outlay of the equipment in this intervention is similar to multicomponent interventions targeting standing using sit-stand desks. These interventions have been deemed cost-effective when compared to the healthcare costs accrued if sitting was not reduced (672). The LPA target in the present study may result in significantly more daily EE than standing does, thereby increasing the health benefits observed (673). In terms of economic evaluations, Lutz and colleagues (674) identified a significant difference favouring the intervention in six of eighteen studies, with intervention costs ranging from €71.69 to €511.02. Most effective interventions offset costs either to healthcare or to the

wider society (e.g. in productivity gains, reduced absenteeism/presenteeism), thus providing returns on investments to both the healthcare budget and to the employers (674).

As well as the physical environment intervention target to reduce occupational SB, an important influence of workplace SB reduction is the social and cultural environment. This target is described in the following section.

5.2.4 Organisational culture target of intervention

Changing the social environment or workplace culture, by exposure to interpersonal modelling or changing cultural practices have been found to foster health promotive behaviour and can lead to collective well-being (47,570). Social norms reinforce sitting as being the expected or most appropriate workplace behaviour (617). Being observed as acting outside the normative workplace behaviour may be undesirable to professional employees who do not want to be viewed as 'weird' or to feel embarrassed (Study 2) (427,603,675). These psychosocial work factors are modifiable through appropriate workplace interventions by ensuring social support and a sense of 'togetherness' when implementing interventions (676). Team-based components, where interaction takes place between employees in a team or group format to reach a competitive or non-competitive shared common goal or outcome, has been found to modify social norms (677,678).

Healy et al. (45) confirm that organisational support for reducing SB is essential in effective multicomponent interventions. Culture at an organisational level includes values, norms, structures, operations, strategy and policy that operate in a dynamic and non-static way to impact employees' opportunities and tendencies towards moving more at work (679).

Embedded in the facets of organisational culture are explicit and implicit orientations towards physical inactivity and SB. Although an organisation may explicitly declare goals to improve employees' wellbeing, when the opportunities to reduce SB centre on moving away from the workstation, an implicit pressure may be felt by employees surrounding a perceived reduction of productivity (Study 2) (616). Recruiting managers to participate in an intervention is an effective strategy to promote a supportive culture at an organisational level, and endorses wellbeing values through modelling behaviours of senior management (469,470).

5.3 Gender-Sensitive Approach

In the Regional Committee for Europe Strategy on the health and well-being of men in the WHO European Region, gender responsiveness in terms of the prevention of NCDs is described as,

‘[The] gender approach to health refers to the socially constructed roles, behaviours, attributes and opportunities for males and females. The influence of early socialisation patterns and social structures and institutions determines what is considered masculine and feminine’ (pg.4) (583).

Gender-sensitised interventions recognising men’s interests and tailor health promotion efforts for this specific group have been found to be more effective in increasing PA (554,680). For example, men may be more likely to favour competitive and exercise oriented activities (681), and interventions that require low time commitment (554), whereas women may prefer a more holistic approach that includes healthy diet and relaxation or wellness (681). The literature provides compelling evidence that well-designed interventions for men can lead to positive changes in behaviours (682). The literature also highlights what to avoid, for example, mixed gender programmes, by refining what fails to invigorate men in the context of PA-focussed health promotion programmes (554). The barriers to engaging men, together with principles underpinning participation should be incorporated through shared observations which are key to advancing the application of health promotion theories to the design of men-centred interventions. Social comparison was used in Study 3 as a strategy to focus on the masculine ideal. By engaging men in PA, this concept draws upon, as well as provides opportunities to garner masculine capital by affirming competitiveness and/or striving for physical prowess (554,588). Regarding these gender-sensitive elements of the intervention, the findings of Study 2 suggested that the male participants were interested in and activated by the elements that were suggested to them.

5.4 Intervention Relevance and Context-Appropriateness

Adopting a participatory approach to intervention development and evaluation of an intervention’s acceptability and feasibility, benefits the development of effective interventions (64,683). Practical barriers and facilitators to reducing workplace SB were used to frame the intervention and confirm the proposed approaches and content. Specifically, the development process focused on the provision of environmental restructuring to enable a reduction of SB by replacing it with LPA, while minimising impact on work tasks. Concerns of being seen as ‘weird’

were addressed through the team aspect in order to change the group normative behaviour sufficiently to reduce perceived self-consciousness of the pedalling behaviour. Management support and behaviour modelling were considered in the development process by recruitment of managers and managing partners to participate in the study. As highlighted in the conclusion of Chapter 4, the intervention was deemed relevant and context-appropriate by participants in both worksites. The process of the integration of the findings of Study 2 within Study 3 is further described in Section 5.2.16.

5.5 Design of Study 3

The protocol for this study has been published in *Journal of Pilot and Feasibility Studies* (684) (Appendix B).

Nicolson, G.H., Hayes, C. & Darker, C. A theory-based multicomponent intervention to reduce occupational sedentary behaviour in professional male employees: protocol for a cluster randomised crossover pilot feasibility study. Pilot Feasibility Stud 6, 175 (2020). The study protocol was registered International Standard Randomised Controlled Trial Number (ISRCTN11584275).

As described in detail in Chapter 2 Section 2.19, the guidelines set out by the MRC framework (412) (Figure 19) recommend that exploratory work should be conducted in the second phase of complex intervention design. The aim of this is to optimise and assess the feasibility of an intervention and/or the design of a full-scale effectiveness evaluation prior to the full scale definitive evaluation (421).

Pilot work is used to inform the design of future trials by providing evidence of potential for intervention effectiveness, and quantifying feasibility by providing data on recruitment and retention rates (685). In this PhD research, a cluster-randomised controlled wait-list crossover design was employed in the pilot feasibility study.

The potential efficacy of combining pedal machines and motivational behaviour change strategies has been previously tested (484). However, to my knowledge combining BCTs such as goal-setting, providing feedback and education, social comparison using friendly competition (i.e. affable and non-serious competition among work colleagues), self-monitoring and prompts in a multicomponent intervention using mHealth technology, together with an under-desk pedal machine, and recruiting management employees to participate in the intervention, in a male only sample, has not been investigated. This pilot feasibility study was

designed to inform refinement of the intervention content, in terms of acceptability and feasibility of the intervention components and measures, so that the format may be suitable for real-world implementation and evaluation in a future definitive trial. Its primary aim was to address key design uncertainties, including the feasibility of recruiting eligible participants in terms of recruitment and retention, as well as the appropriateness, acceptability, and feasibility of the intervention. The qualitative component of the study allowed for in-depth exploration of the study procedures and assessment methods. Issues surrounding the acceptability of the under-desk pedal machines, as well as the mHealth component from the perspectives of the users, i.e. employees and management, were explored.

5.5.1 Aims and objectives

The aims of this study were to assess the acceptability and feasibility of an intervention, developed and designed using the socio-ecological model, to promote active sitting in professional men in a cluster randomised crossover pilot study, and test a set of feasibility objectives to ascertain if a future randomised controlled trial is viable in terms of recruitment and retention. Differences in SB and PA between the intervention and control periods were examined.

The primary objectives of this Study 3 were:

- To ascertain the acceptability of trial-related assessments and study procedures burden, as well as evaluate the experience of the intervention overall and its components by using focus groups and semi-structured interview.
- To describe recruitment and retention rates by reporting the number of those approached and those who consented to participate; and those who were retained in the intervention at follow up (8 weeks), respectively.
- To analyse the level of completeness of the data and the suitability of measurement tools by reporting missing data.

The secondary objective was:

- To assess the potential intervention effectiveness by collecting accelerometry data, which provided information on minutes spent sedentary, standing, and moving.

5.5.2 Intervention development process

Preclinical phase of intervention development

This intervention was developed using guidance from the Medical Research Council (MRC) (412,413) and encompassed three distinct phases. The phases targeted in this PhD research are highlighted in blue in Figure 18.

Phase 1 Intervention development

Phase 1 involved the identification of intervention components and the underlying mechanisms by which the outcomes are influenced. This involved defining the problem in behavioural terms, being specific about the population who are at risk of the behaviour, clarifying what the behaviour itself is, and finally, identifying and understanding the needs of the target population in the local setting to enable successful behaviour change (413).

Qualitative testing and the adoption of a participatory approach through focus groups and semi-structured interviews with both employees and managers (which included managing partners and directors) was also conducted in Phase 1.

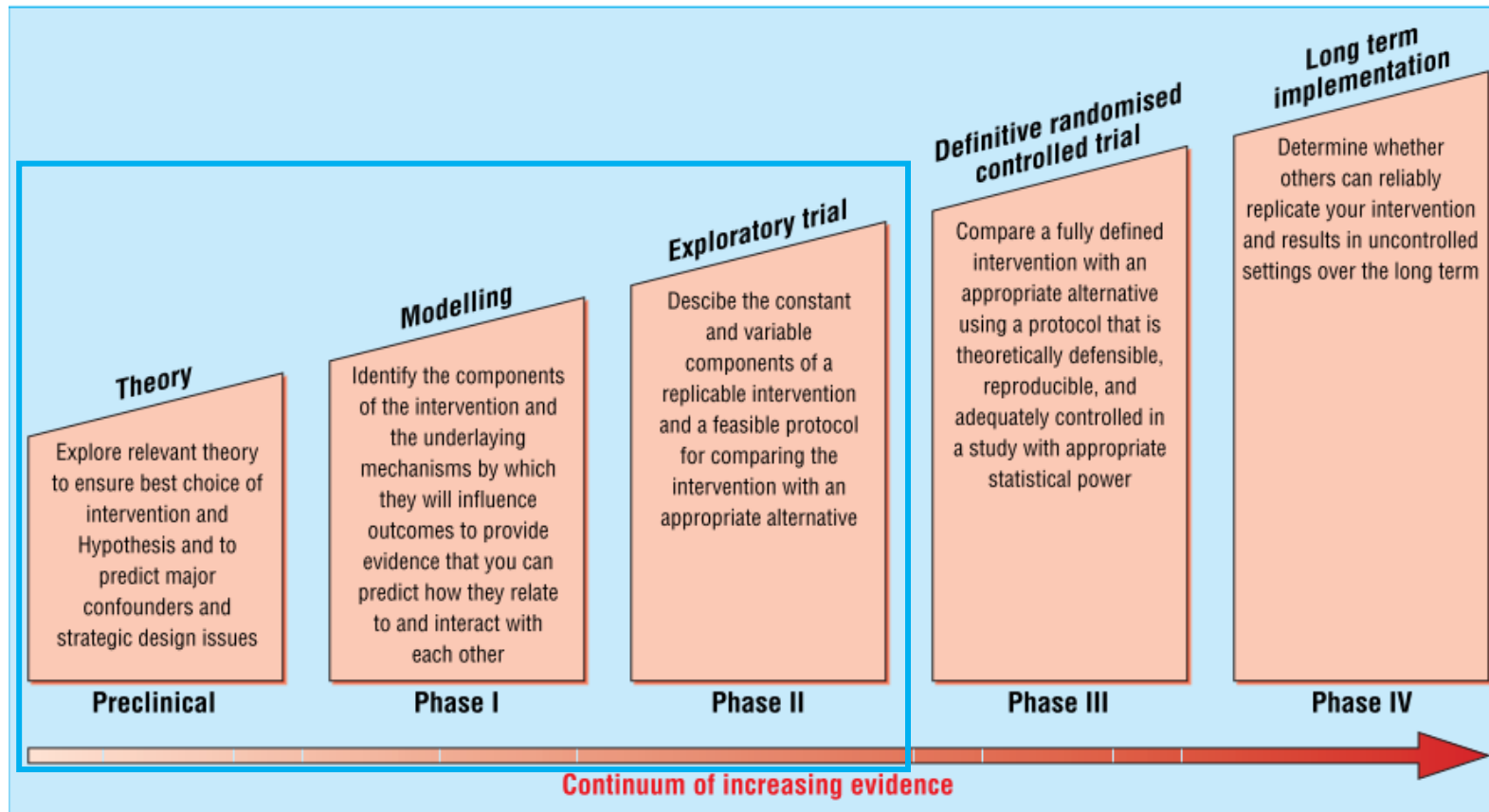


Figure 18 Sequential phases of developing randomised controlled trials of complex interventions (412)

Table 16 illustrates how the conceptual elements and preferences of the participants in Study 2 were explicitly linked with specific behaviour change intervention strategies in Study 3. The intrapersonal, interpersonal, environmental, and organisational level elements appear emboldened in each section of the table. In Study 2, participants were presented with the proposed components of the intervention, as well as a description of what would be required of them throughout the study. Results of Study 2 confirmed that all participants were supportive of Study 3 intervention and interested to take part.

Table 16 Preferences of participants mapped to intervention components

PREFERENCES OF TARGET POPULATION (STUDY 2)	INTERVENTION COMPONENT STRATEGIES (STUDY 3)
PRIMACY OF WORK	Pedal device allows PA while working
PREFERENCE TO REMAIN SEATED	Pedal device allows PA while sitting
AWARENESS OF DANGERS	Education received in introduction to study
HABITUAL BEHAVIOURS	Move alert on Garmin to prompt movement
SWEATING	Light intensity PA promoted in the study
SOCIAL JUDGEMENT	Participants engage in shared activity
SOCIAL SUPPORT	Psychosocial support from managers/colleagues through shared experience and group membership
SOCIAL COMPARISON	Team-based competition comparing others' attempts to reduce SB and increase of PA
DISTRACTION TO OTHERS	Pedal machine is discrete and unobtrusive
OFFICE DESIGN RESTRICTS MOVEMENT	Environmental restructuring via pedal machine enables PA
WEATHER	Intervention enables PA at participants' desk
MODELLING OF DESIRED BEHAVIOURS	Management participation provides top-down modelling

Study 3 (Figure 19) tested the acceptability and feasibility of the intervention to reduce workplace SB to develop an optimum intervention, as well as feasibility objectives to test the viability of a future trial.

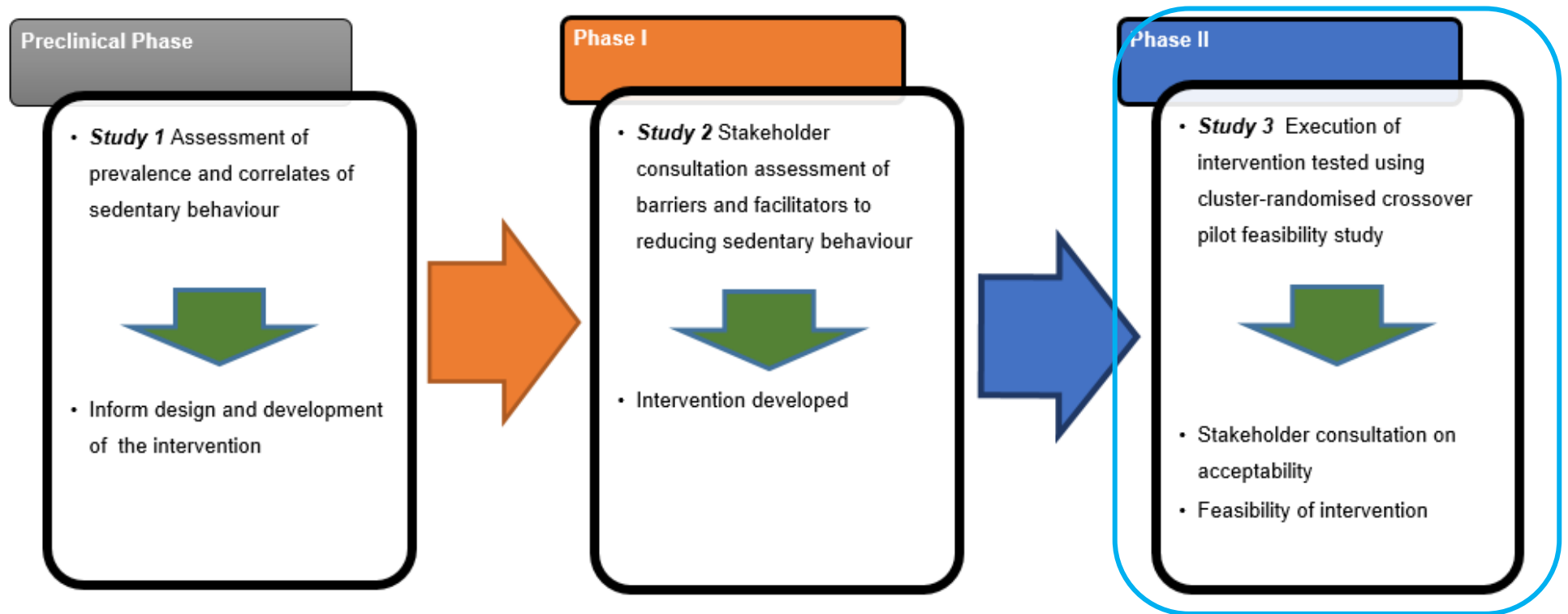


Figure 19 Studies involved in overall PhD research project

The intervention, therefore, comprised intervention components for inclusion which were determined by:

1. Results of extensive review of the literature (Chapter 2).
2. Results of prevalence and correlates of those most at risk of SB in Study 1 (Chapter 3).
3. Confirmation of relevance and appropriateness of the intervention behaviour change strategies in Study 2 (Chapter 4).

5.5.3 Cycle at work intervention

As extensively described in the thesis, the proposed intervention components target the main influences of workplace SB as outlined in the socio-ecological model of SB (57). Figure 22 illustrates how each component of the intervention mapped onto each level of the SEM.

- Garmin Forerunner 35 (Appendix L) and its associated website/smartphone application (Appendix M) (Garmin Connect; Garmin.com) target the individual level and interpersonal levels influences.
- Deskcycle2™ (3D Innovations LLC., Greeley, CO, USA) was provided to each participant to restructure the environment to allow LPA (Appendix N).
- Recruitment management employees to the study, thereby garnering support for employees to participate in the pilot study targeted the organisational-level influences.

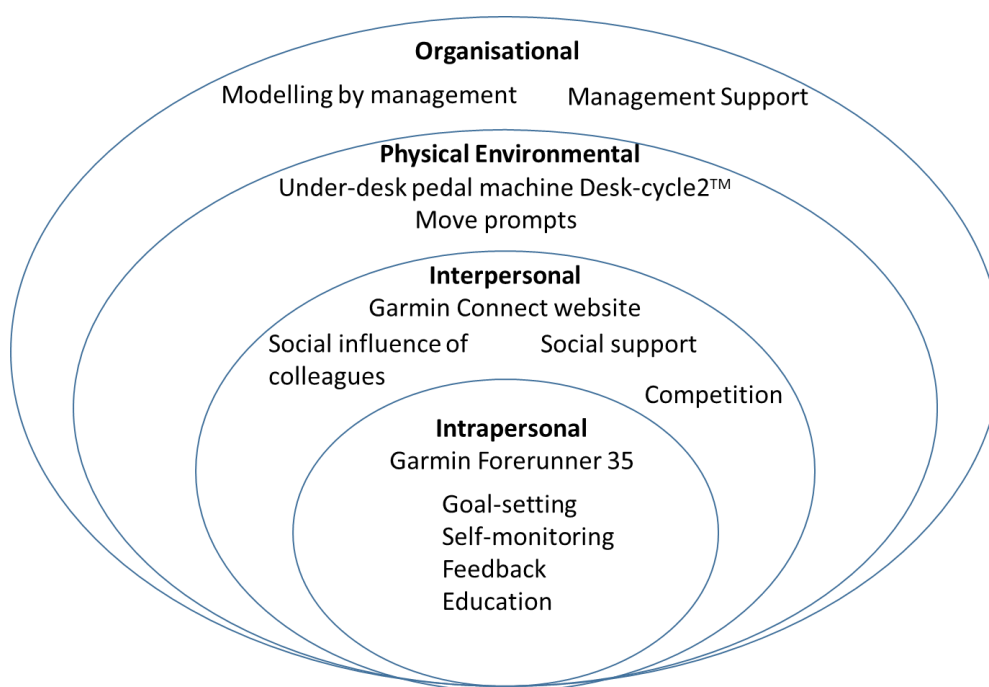


Figure 20 Intervention components of Study 3 mapped to socio-ecological model of SB

The intervention communicated the key message: '*Cycle at work*'. Managers and employees were recruited to the study to provide social support within each worksite for the intervention duration. Each participant was provided with an under-desk pedal machine. The goal of ≥ 30 minutes pedalling time per working day was set for each participant. Participants self-monitored their pedalling behaviours by manually recording their bouts using the Garmin watch. Feedback on participants' progress was provided within a weekly email with reminders of goals and encouragement. Social comparison was also targeted within this weekly email with updates of everyone's own progress, as well as how they compared to their co-participants, within each organisation. Social comparison was provided through the team-based competition element, where members of each worksite were assigned to groups and involved explicitly drawing attention to others' performance to elicit comparisons. The 'move' prompt on the Garmin Forerunner 35 wrist-worn device prompted the men to move every 60 minutes of accumulated SB. The full intervention and participants' information and instructions are detailed in the Participant Information Leaflet (PIL) (see Appendix O). This study is guided by the TIDieR checklist (Appendix P) for intervention description (686) and structured using the updated CONSORT guidelines for reporting feasibility trials (Appendix Q) (426); an adapted CONSORT flow diagram is presented (Figure 23).

5.6 Methods

5.6.1 Trial design

This feasibility study was a cluster randomised crossover trial, in which participants were allocated to one of the two clusters on a 1:1 basis. The crossover design included a 2-week '*Cycle at Work*' intervention period and a 2-week control period, separated by a 1-week washout/usual habits period. The study took place from October to December 2019. The active intervention involved the use of an under-desk pedal machine to interrupt SB every hour and accumulate ≥ 30 minutes of LPA during the working day, while recording and uploading bouts of cycling, and engaging with, the Garmin Connect website/app. The washout period was used due to a possibility that the effect of a treatment/intervention in one period may carry over into the next period (687). These are known as carryover effects. To ensure negligible carryover effects, there is a need to have sufficient washout periods between intervention periods. To minimise carryover effects, all components of the intervention, such as the Garmin watch and under-desk pedal machine were removed. The washout period was essentially identical to the control period except no measurements taken, and no contact from the researcher was made.

In circumstances where a participant suffered any adverse outcome such as pain while taking part in the study, they were advised to immediately discontinue participation in the study and to contact their doctor.

5.6.2 Ethical approval

Ethical approval was obtained from the Research Ethics Committee of the School of Medicine, Trinity College Dublin (ref. 20190702) on the 18th of September 2019 (Appendix R).

5.6.3 Sampling

Male participants were office-based professional employees and managers from two companies in Dublin, Ireland.

5.6.4 Inclusion criterion

- Adult men who spend most of their working week performing desk-related activities

5.6.5 Exclusion criteria

- Male participants who have limitations with or contraindications to, physical activity as indicated by the Physical Activity Readiness Questionnaire
- Do not have a personal desk
- Are aged under 18 years
- Plan to be absent from the workplace for more than two days in one week during the study period
- Are involved in another programme or intervention to reduce sedentary behaviour.

5.6.6 Setting and context

The proposed randomised pilot feasibility study was conducted in two private-sector professional organisations in Dublin, Ireland (online medical education provider (Worksite A) and a legal firm (Worksite B)). The sites were chosen to target professional males as outlined Chapter 3 (Study 1) as those with the highest risk of prolonged SB. Management approval was obtained for employee recruitment, permission to make environmental changes in the office setting, and for study contacts to occur during work-time at the introduction and presentation session. All participants provided written informed consent before inclusion in the study.

5.6.7 Selection and recruitment

A two-step sampling process was used in this study. Convenience sampling was used to recruit two organisations, who had been involved in the development of the pilot study (Study 2). The organisations were initially approached through the researcher's personal networks. The researcher approached managers (including themselves) to participate in the study, and to obtain permission to contact employees to inform them about the study. Purposive sampling was then used to recruit eligible participants via an email sent by a contact within each company (Appendix S). Participants recruited in this study included members of management, and managing partners, as well as employees. Participants did not receive any remuneration.

5.6.8 Procedure

An open call was given to all employees who met inclusion criteria, regardless of area/department, to take part in the research in worksite A. In worksite B the research contact person sent an email to a network of colleagues outlining the study and inviting participation. Figure 21 shows an overview of the intervention components and the study timeline. When preliminary agreement to the study was obtained, the researcher met potential participants at their workplace, where they were provided with a consent form (Appendix T) and PIL. At this stage, a presentation of the study comprising what is known about sedentary behaviour, and the risks associated with prolonged SB was given to all participants by the researcher. Participants who were interested in taking part in the study were asked to consider the consent form and PIL for a 24-hour period. Arrangements to meet all participants who were willing to participate were made and consent was obtained. The Physical Activity Readiness Questionnaire (rPARQ) health screening tool (688) has been validated against medical examinations that included resting blood pressure and recordings of resting and exercise electrocardiograms and is a reliable PA screening tool (Appendix U). The rPARQ was administered to participants at the information/briefing stage to ensure participants' physical capability to safely participate in the study. Those who self-identified medical conditions, had a family history of a heart condition, or answered positively to any other rPARQ question, were permitted to participate only if they provided written approval from a doctor stating that it was safe for them to participate in the study (Appendix V). Following the baseline period, all participants were provided with a report via email on their weekly SB and PA derived from their baseline accelerometer data. Participants randomised to the intervention group were then given the intervention equipment and instructions on how to use them, in a face-to-face session at their workplace.

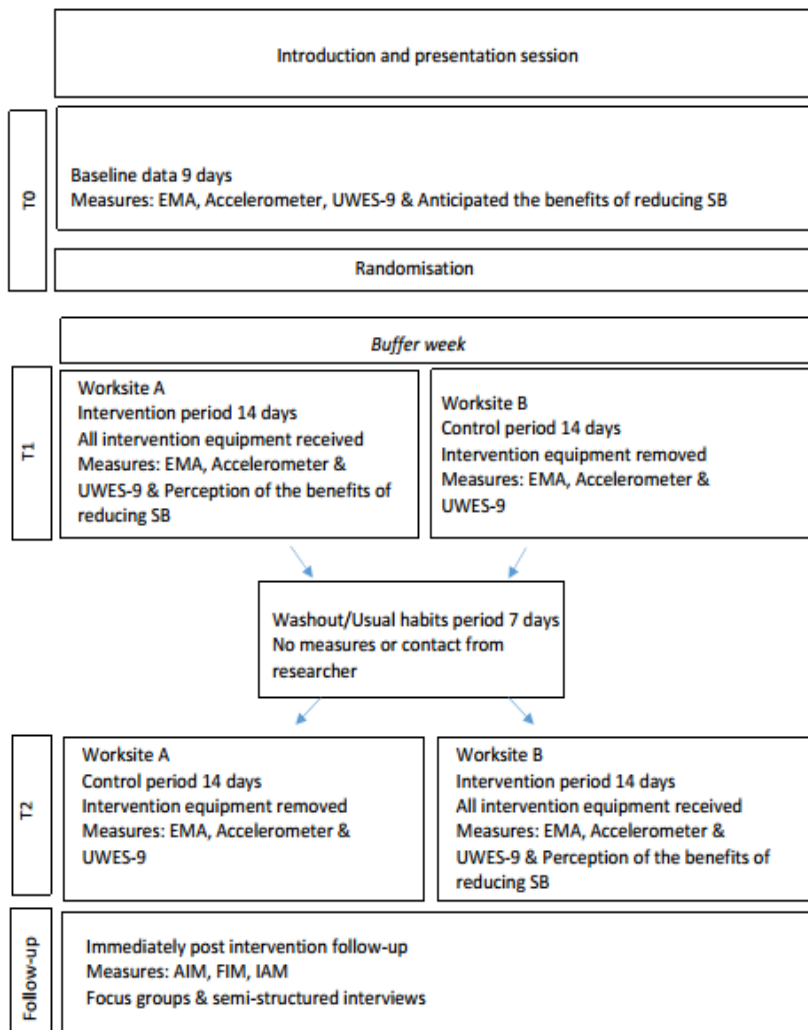


Figure 21 Cycle at Work Study Participant Flow

5.6.9 Intervention period

The intervention was delivered by the researcher (MSc, PhD Candidate). Recruitment of managers and managing partners to the study, thereby garnering support for employees to participate in the pilot study targeted the organisational-level influences. To target the individual-level influences, a Garmin Connect account was set up for each participant, and teams were set up within the platform. Permission was granted to access participants' account throughout the study, and participants were advised to change their passwords at the end of the study period. Each Garmin watch was paired with a Bluetooth cadence sensor on the participant's pedal machine. There is a lack of commercially available devices that accurately detect under-desk cycling and provide the user with immediate feedback. Therefore, it was decided that the Bluetooth cadence sensor in conjunction with manual recording and uploading via the Garmin watch was necessary for this intervention. Measuring cycling times in this way facilitated self-monitoring to increase conscious awareness of breaking SB with LPA. This was used to record minutes of cycling upon participants pressing the start and stop buttons, to begin and end each cycling bout. In the intervention period, the completed activity was transferred wirelessly via Bluetooth to a smartphone application (Garmin Connect), or to the website on participants' workplace computer using a wire.

Segments appeared every 15 minutes of inactivity on the Garmin watch 'move bar' and provided a sound and vibration alert after one hour of inactivity. The move bar was reset by engaging in a small amount of physical activity (i.e. walking a short distance, recording stationary cycling). The Garmin platform does not allow the setting of SB goals but allows cycling time goals. Prior to the intervention commencement, all participants were assigned teams formed within sites (e.g. managers versus employees), which targeted the social comparison behaviour change strategy. The Garmin platform allowed self-monitoring of participants' own time spent in SB, PA, and cycling, and participants were encouraged to visit the site regularly. A weekly email from the researcher provided encouragement and feedback on participants' activity progress. To target environmental-level influences of workplace SB, all participants were provided with a compact stationary under-desk cycling device (DeskCycle2 model; 3DInnovations LLC, Greeley, CO) for the full intervention duration (2 weeks) and were given instructions on how to use it. For logistical and practical reasons there was a buffer week after randomisation. This was to allow the researcher to attend the workplaces to deliver the pedal machines and Garmin watches.

5.6.10 Control period

Participants in the control period were informed that they had been randomised to a delayed intervention that would begin after three weeks and were asked to continue their normal workplace habits. All measures collected in the intervention group were collected in the control period.

5.6.11 Primary outcomes

The evaluation of this intervention was guided by a programme logic model (Appendix W). This outlines the “roadmap” that was used to plan the assessments of the intervention (689). It outlines the projection of the relationship between how each component of the study would work, what the anticipated outcomes would be, and how the progression of elements would lead to the expected outcomes.

The primary outcomes of the study were to assess the acceptability and feasibility of the intervention in terms of:

- Trial-related assessments and study procedures burden
- Acceptability and feasibility of the study processes overall
- The experiences of participants regarding using the intervention
- Eligibility, recruitment, and retention rates
- Level of completeness of the data and the suitability of measurement tools in terms of missing data.

5.6.11.1 Trial-related outcomes

These outcomes were explored at follow-up within the focus groups and/or semi-structured interviews which included:

- Acceptability of the trial-related assessments by the users – from a management and employee perspective
- Acceptability of the study procedures burden by the users – from a management and employee perspective.

5.6.11.2 Qualitative evaluation

Evaluation of the user experience of the intervention from participants' perspectives was assessed at follow-up via focus groups and/or semi-structured interviews using the following themes:

- Experience of using the under-desk pedal machines, including factors perceived as affecting the pedal machine, issues (e.g. contextual, practical, individual or others), and adverse consequences (e.g. work, health or otherwise related)
- Experiences of the mHealth intervention components (e.g. Garmin watch and Connect platform)
- Organisational-level and management perspectives on employees' participation
- Acceptability of the overall intervention by the users – from a management and employee perspective.

Focus groups and semi-structured interviews were carried out within 2-weeks post intervention follow up. An interview schedule was designed based on existing literature as well as themes that arose from Study 2. The areas of focus was guided by Orsmond and Cohn (690) (interview schedule Appendix X). The schedule was pre-piloted with two employees within the researcher's place of work, i.e. the Discipline of Public Health and Primary Care. No changes were made as a result of piloting the interview schedule. Two focus groups (one comprising managers and one comprising employees) at each worksite were conducted to establish and explore the acceptability of the intervention, its individual components, and of the trial processes overall. Data collection was conducted from October to December 2019 in participants' workplaces by the researcher (GN). Only the researcher and participants were present for the duration of each focus group/interview. Prior relationships were established prior to the study commencement, as the participants had participated in Study 2. The PhD candidate (MSc) has previous experience of conducting focus groups and conducted the data collection. Prompts were used to keep the flow of conversation going if needed, or if it did not happen spontaneously. The questioning route was similar for employees and managers except for when the questioning specifically asked about the other group. The order of the questions was changed as required and depending on how the discussion proceeded. Field notes were taken during and after each focus group/interview. The focus groups/interviews lasted approximately 30-40 minutes.

A discussion of the main findings occurred with the research team (primary supervisor CD) and included global impressions and differences between the focus groups. The focus groups took place at the participants' convenience. They were recorded using a digital audio-recorder, and they were transcribed verbatim by a professional transcriber. Transcripts were not returned to participants.

5.6.11.3 Recruitment and retention

The effectiveness of participation recruitment to the study was calculated from logs detailing recruitment and retention rates collected by the researcher.

5.6.11.4 Completion rates and usable data

- Completion rates of data collection at baseline and each follow-up point were recorded by the researcher; incidences of adverse events and technical issues were logged, including wear-time and compliance information of the activity data
- Missing data from questionnaires were recorded by the researcher.

5.6.11.5 Implementation Outcomes

The study focused on acceptability, appropriateness, and feasibility, as they are the forerunners of indicators of implementation success. Additionally the indicators are simultaneously conceptually discrete, yet likely to be highly correlated which suggests that individual indicators may be seen as proxies for the other indicators (691). Weiner et al. (691) have developed three scales with four items that measure acceptability, appropriateness and feasibility. These included: acceptability of the intervention (AIM), the appropriateness of the intervention (IAM), and the feasibility of the intervention (FIM). These three measures have been developed to be conducted as a group to assess implementation outcomes of an intervention. These three scales have similar psychometric properties and layout. The AIM, IAM, and FIM measures were assessed at follow-up.

The AIM, the IAM and FIM items require responses on a Likert scale ranging from completely disagree to completely agree and have values ranging from 1-5 (691). Higher scores indicate a greater perception of acceptability, appropriateness, and feasibility towards the intervention, respectively. All three scales have a Flesch reading ease score of 95.15 which is a grade five reading level, and there are no specialised skills or training needed to administer, score or

analyse the scales (691). The scales have good psychometric properties being both valid and reliable and have a Cronbach's alpha score of 0.85 (691).

Acceptability

The AIM is a four item scale developed in order to measure stakeholders' perceived sense of acceptability towards an implementation (691). Acceptability is defined as the extent to which a service, practice or treatment is seen as satisfactory or agreeable (692). Acceptability is believed to be based on personal values. According to Proctor et al. (692), therefore, two individual's opinions of the same intervention may differ depending on their own preferences, needs or expectations.

Appropriateness

The IAM measures stakeholders' perception of the appropriateness of an intervention (691). Appropriateness is defined as the extent to which stakeholders see an intervention as being compatible or relevant in the environment in which they would utilise the intervention and how it would assist a specific issue (692). Although a similar construct to acceptability, appropriateness is distinct in that it is able to determine if there is any resistance to implementing an intervention by stakeholders involved. In this way, an intervention may be suitable for a particular issue, but its features may make the intervention unacceptable to a stakeholder.

Feasibility

The FIM determines the extent to which an intervention or innovation can be successfully carried out within a given setting. Again, feasibility is connected to the construct of appropriateness although on a conceptual level, they differ. For example, an intervention may be appropriate in that it is relevant in a given setting, but at the same time it may not be feasible because of access to resources such as funds or time (692). Therefore, an intervention can be appropriate but not feasible and vice versa. Feasibility centres on the practical component of the intervention implementation, seeking to understand how easily the intervention can be implemented given the resources available and the context in which it will be delivered.

5.6.11.6 Anticipated and perceived intervention benefits of the intervention

The anticipated and perceived benefits of reducing SB in the workplace were assessed at baseline and post intervention time points using a questionnaire devised by the researcher. Based on the review of the literature (Chapter 2), the three main issues of mental health, work productivity, and musculoskeletal discomfort emerged as key concepts important with regards to workplace SB. Following Study 2's exploration of how SB may affect mental and physical health, and work outcomes, the questions in Study 3 asked about how an intervention to reduce SB would be *anticipated* to impact, followed by how participants *were* affected, following the intervention. Responses were recorded using a five-point Likert scale, where '1'= 'Strongly disagree', '2'= 'Disagree', '3'= 'Neutral', '4'= 'Agree', '5'= 'Strongly agree'.

The questions specifically asked, 'Please say how much you agree or disagree with the following statements:

- Reducing workplace sedentary behaviour will/did improve my mental health
- Reducing workplace sedentary behaviour will/did increase my work productivity
- Reducing workplace sedentary behaviour will/did reduce my neck/back pain.'

5.6.12 Secondary outcomes

Secondary outcome (trial-related outcomes) were measured at three time points – baseline, T1 (1-week post baseline) and T2 (5-weeks post baseline):

- Total sedentary behaviour: waking hours
- Total sedentary behaviour: work hours
- Total physical activity: waking hours
- Total physical activity: work hours
- Cycling time: work hours

5.6.12.1 Accelerometer measurement

Sedentary behaviour and physical activity were assessed at baseline (before randomisation) and throughout the control and intervention periods. Based on key recommendations when using the activPAL3 monitor in field-based research by Edwardson et al.(693), the following were adhered to:

- The employment of a 24 h wearing protocol
- Deployment of activPAL3 for at least 7 days

- Provided verbal, visual (all participants received a link to a demonstrative YouTube video), and written instructions to participants on how to wear the device correctly and change dressings; as well as the researcher demonstrating how to attach the monitor (693) (see Appendix Y)
- Provided a diary (paper) to collect information on wake and sleep time, time in and out of bed, any removal times, and other contexts of interest (e.g. work times) (see Appendix Z)
- Used events files for data processing, especially if reporting measures relating to bout durations
- As no waking wear identification method is universally accurate and accepted, quality controls (e.g. visual examination heat maps) were used to check classifications, and as suggested, against the external source of diary data

A continuous wear protocol was achieved with the activPAL3 monitor by waterproofing the device with a small flexible nitrile sleeve to cover the monitor. This was then adhered to the leg using a waterproof medical grade adhesive dressing (Tegaderm™). At baseline, participants wore the thigh-based accelerometer (activPAL3) device for 24 h/day, for nine consecutive days (and 14 days each for control and intervention periods). The monitoring period was chosen in order to attempt to incorporate a full working week and non-working days for comparison, and to meet the threshold of three to five days of monitoring deemed to be a reliable estimate of the habitual activity outcome variables being measured (694). Participants were asked to keep a written wear diary during the control and intervention periods. This was to record wake times, sleep times, any reasons for removal and any other comments to be made. The purpose of this was to allow the outcome data to be visually checked and periods of interest to be removed for further analysis and the end of the study period. Prior to being attached to the participant, the device was set to record at 20 Hz. The ActivPAL3 was set to start recording at 0001h on the day after the participant received the device. Each device was attached to the anterior aspect of the midline of the right thigh using a nitrile sleeve and waterproof Tegaderm dressing. Sleep, sedentary time, standing time, physical activity (i.e. stepping time (minutes) (Cadence \geq 100, duration $>$ 1 minute) were derived from the ActivPAL3 data. Time spent sitting, standing, and engaging in physical activity was calculated using the postural function of the monitor, through the associated software (ActivPAL3 v8.10.8.75).

5.6.12.2 Ecological momentary assessment

Contextual information on SB was measured using self-report via Ecological Momentary Assessment (EMA). The use of EMA has been recommended to collect ecologically valid and context-specific outcome data alongside objective measures in studies (695,696). EMA involves repeated sampling of participants' current behaviours and experiences in real time and in their natural environments. This is useful to specify the type of activity or contextual factors (e.g. physical, social, temporal, affective) surrounding these behaviours which are important factors to consider when developing interventions, and that cannot be provided by objective measures (239). These EMA questions have been reported as a valid and reliable measure of SB and PA in adults (245), and for use in a workplace setting (241). Each day six notifications appeared on participants' own mobile smartphones at random times between 8am and 10pm, using the application PIEL Survey (pielsurvey.org, v1.2.4.2). Participants received training on how to download and use the PIEL Survey app at the instruction session, as well as printed instructions on the correct use of the app (Appendix AA). The notifications were interval-based and scheduled at random times to obtain a representative sample of participants' activities over the course of their study participation. The questions have been found to be valid and feasible (Appendix BB) (245). An adapted STROBE checklist for reporting EMA studies (CREMAS) (697) developed with the goal of enhancing reliability, efficacy, and overall interpretation of the findings for studies that use EMAs, was used to report the EMA results (Appendix CC).

5.6.12.3 Work Engagement

The concept of work engagement is characterised by a high level of energy and strong identification with one's work (698). The Utrecht Work Engagement Scale (UWES) (short form UWES-9) assesses levels of work engagement via nine questions on a 7-point Likert-type scale (0–6) targeting these three constructs: vigour, dedication, and absorption (698), with high correlations and internal consistencies (698,699) reported between all 9-items (see Appendix DD). Schaufeli et al. (698) employed the constructs of vigour, dedication and absorption to describe the psychological state of work engagement which 'is a positive, fulfilling, work-related state of mind', with vigour and dedication considered the direct opposites of exhaustion and cynicism, respectively. Absorption is characterised as happily immersed and engrossed in one's work. Thus, as an accepted measure of work engagement when using the shortened version (UWES-9) (698), the mean score was calculated for each participant. A

higher UWES-9 score represented a higher level of work engagement. Work Engagement was measured at baseline, post control and post intervention periods.

5.6.13 Sample size

As this was an exploratory feasibility trial, no formal sample size calculation was conducted (67). The target sample size ($n = 30$) was determined by other feasibility studies with similar aims (675,700), and was decided on pragmatic terms and based on resources available within a PhD study. A sample size of thirty participants has been deemed adequate in pilot studies as it allows sufficient useful data while minimising research costs (422). Focus groups comprising separate management and employee participants in each worksite were recruited for intervention evaluation purposes. Where the requisite number of individuals in a role was not available (in Worksite A), a semi-structured interview was conducted instead. In qualitative research of this kind, this is considered appropriate, with diversity of sampling (i.e. all stakeholder groups) more important than numbers of focus groups (701).

5.6.14 Randomisation

Following baseline assessments, worksites were randomised to the intervention or control period of the trial. Cluster randomisation was employed as it mitigates contamination between groups. Simple cluster randomisation was determined by a statistician not associated with the project, who used randomisation software to allocate each worksite to begin with the intervention or control period.

5.6.15 Allocation concealment

Participants were not advised of their group allocation by the researcher until after baseline assessments were made. The allocation concealment mechanism is important to reduce selection bias as it prevents foreknowledge of the period (control/intervention) in which participants are enrolling, which negatively affects recruitment (702).

5.6.16 Blinding

Due to the nature of the study, i.e. environmental restructuring, neither the participants nor researcher were blinded to group assignments.

5.6.17 Data analysis

Acceptability and feasibility outcomes were measured quantitatively and qualitatively. Qualitative data from participants' experience of acceptability and satisfaction with the intervention, as well as trial related processes were assessed using data from the focus groups and a semi-structured interview. Analysis of the qualitative data using a semi-structured interview schedule was used to explore and evaluate participants' perspectives of the intervention. Transcriptions of audio recorded interviews were analysed using thematic analysis (593). At each stage of analysis, findings were verified and discussed in order to assess the accuracy of the interpretation, promote reliability and ensure rigour (703). The main analysis of this study included thematic analysis and no software package was used to analyse the data. Thematic analysis was used to systematically identify, organise, and offer insights into patterns of meaning i.e. themes (593). The thematic analysis procedure used here was the same as the process used in Chapter 4 where it was discussed in detail. Briefly, the responses were read thoroughly by GN and CD multiple times to familiarise the researcher with the content. Codes were applied to the data and were then used to devise an initial set of themes which were revised iteratively before producing a final thematic framework summarising participants' experiences of the intervention. Quotes that were deemed to best represent the essence of each theme were then extracted. The Consolidated Criteria for Reporting Qualitative Research (COREQ) was used to improve the reporting of the qualitative findings (Appendix EE) (600).

As this was a feasibility trial inferential statistical tests were not deemed to be appropriate (704). Demographic and quantitative outcome data were entered into a Microsoft Excel 2013 spreadsheet. All data were visually inspected to identify irregularities or errors. The data were analysed using the Statistical Package for the Social Sciences V.25 (IBM Corp., Armonk, New York, USA), and Microsoft Excel 2013 and reported as descriptive statistics (mean, standard deviation, percentages). If missing data occurred at control or intervention periods for participants with baseline data, the missing data was not imputed.

For SB, standing, physical activity, EMA data, and intervention perception outcomes, the magnitude of change between measurement periods was calculated by subtracting intervention scores from control period scores. Categorical variables from the implementation questionnaires were reported as frequencies and percentage prevalence and data were presented graphically. The median and interquartile range (IQR) were used to measure central tendency and levels of dispersion of ordinal data. Descriptive analysis accounted for the recruitment and retention.

Sedentary behaviour and physical activity

ActivPAL3 data were downloaded from the devices using ActivPAL3 software (ActivPAL3 version 7.2.32; PAL Technologies, Glasgow, Scotland) to create events files. Sedentary time and standing time were calculated using the postural function of the monitor through the associated software. The resulting ActivPAL3 event files contained a chronological list of all bouts of sitting/lying, standing, and stepping.

The output data was visually checked against the diary data for unusual patterns or events. Further processing of data was required in order to isolate the periods of interest (i.e. time spent at work). This isolation process is required for high quality data (693). Each participant was asked to provide via email the detail of what time they started and ended work each day. The person-oriented day approach (693), that includes processing data from a participant's wake time to next day wake time offers a behaviourally relevant approach that avoids excluding valid data across arbitrary lines of sleep and wake-times. Often, activity event data does not match the diary reported start and end of the workday. In instances where participants did provide the start and end of work time, the normal work hours they reported in their demographic baseline questionnaire were used. Although each participants' day duration may vary, because this was a crossover design, the same participants were involved in the intervention and control periods; potential between-participant differences were controlled for.

Cycling time

An acceleration threshold was developed using Microsoft Excel 2013 to identify under-desk cycling, i.e. cut-point threshold acceleration exceeding 375.0 (Sum of Vector Magnitude), while seated (recorded as SB by activPAL3), and in bouts lasting ≥ 5 continuous minutes. Only cycling that occurred within self-reported working hours was analysed, and then quality-checked by comparing to user-entered Garmin recorded cycling time on the Garmin Connect website.

5.6.17.1 Progression criteria

As pilot studies are usually too small to estimate parameters required for estimating a sample size for a main cluster randomised trial (e.g. the intra-cluster correlation coefficient) with sufficient precision, and too small to provide reliable estimates of rates for process measures such as recruitment or follow-up rates, these are not calculated in the present study (705). This

study is an exploratory study and progression criteria should not be judged as strict thresholds but as guidelines using, for example, a traffic lights system with varying levels of acceptability (705,706).

Progression criteria includes protocol non-adherence and outcome data.

Protocol adherence was measured by the researcher validating the cycling times uploaded by participants to the Garmin Connect website and comparing these to the intervention goals.

Protocol adherence criterion:

- Green – ≥80% of participants engage in >60% of their cycling goal
- Amber – 60-79% of participants engage in >60% of their cycling goal
- Red - <60% of participants engage in >60% of their cycling goal.

Retention progression criterion:

- Green - ≥80% participants provide main trial-related outcomes (SB/PA) at T2
- Amber – 60-79% of participants provide main trial-related outcomes at T2
- Red - <60% of participants provide main trial-related outcomes at T2.

5.6.18 Data security

Actions were taken to ensure confidentiality of the data throughout the project. All data were stored on GN's Trinity College OneDrive home directory for personal file storage. OneDrive is recommended by the host institution as cloud software that is compliant with GDPR processes (707). This was password protected and only the researcher had access to it. Questionnaire based data were only accessible to the researcher and hardcopies were stored in a secure data storage room at Public Health and Primary Care, Institute of Population Health.

5.7 Results

5.7.1 Demographic characteristics

Twenty-two males from two worksites in Dublin city and surrounding area consented to participate in the pilot study. Worksite A was a medical training organisation employing a total of 16 employees, and Worksite B was a larger international organisation with a total of 460 employees, with employees from head office participating in the pilot study. Worksite A (n=8) was randomised to begin with the intervention and Worksite B was randomised to the control period (n=14). The characteristics of these participants are presented in Table 17. All

participants were full time employees working 42.6 ± 7.3 standard deviation (SD) hours per week and worked in the daytime of Monday to Friday. All of the participants were educated to at least third level education and the mean age of all participants was 42.9 ± 11.0 (SD) years.

Table 17 Participant characteristics at baseline

Characteristic	Worksite A	Worksite B	Total
Type of company	Online training	Legal firm	
Location	Dublin suburb	Dublin city centre	
Total participants	8	14	22
Total no. managers	1	7	8
Total no. of employees	7	7	14
Mean age years (SD)	44.4 (11.0)	41.5 (11.0)	42.9 (11.0)
Hrs worked per week (SD)	41.1 (4.1)	44.0 (10.5)	42.6 (7.3)
Work SB min (SD) n=20	399.7 (36.8)	406.7(141.1)	403.6 (111.2)
Total weekday SB	630.7 (82.4)	611.3 (115.4)	619.9 (105.5)
Total weekend SB	560.3 (85.0)	467.1 (81.7)	508.6 (97.9)
Work Physical activity	37.6 (7.8)	50.1 (12.7)	45.1 (12.9)
Total weekday PA	79.9 (18.6)	102.9 (21.3)	93.7 (23.8)
Total weekend PA	122.2 (64.7)	136.0 (38.3)	130.5 (52.3)
Work standing	73.4 (16.4)	122.5 (89.7)	102.9 (76.2)
Weekday total standing	171.6 (31.0)	225.9 (115.02)	204.2 (97.5)
Weekend standing	220.8 (64.7)	241.8 (57.3)	233.4 (62.8)
Work engagement (total)	3.7 (0.8)	4.2 (0.8)	4.02 (0.8)
Vigour	3.0 (1.1)	3.8 (0.9)	3.54 (1.0)
Dedication	3.9 (0.8)	4.4 (0.9)	4.22 (0.9)
Absorption	4.2 (0.9)	4.3 (0.8)	4.30 (0.8)

5.7.2 Participation

5.7.2.1 Recruitment

The recruitment of the worksites and individuals is documented in Figure 22. A total of five companies across Dublin city and suburbs were contacted via email, inviting them to participate in the intervention. Following provision of further information, two companies remained interested. Two companies who declined to participate cited time pressures as reasons for not taking part in the pilot study, and one company gave no reason for not participating. The two companies who agreed to take part were recruited to the study (40% of those approached).

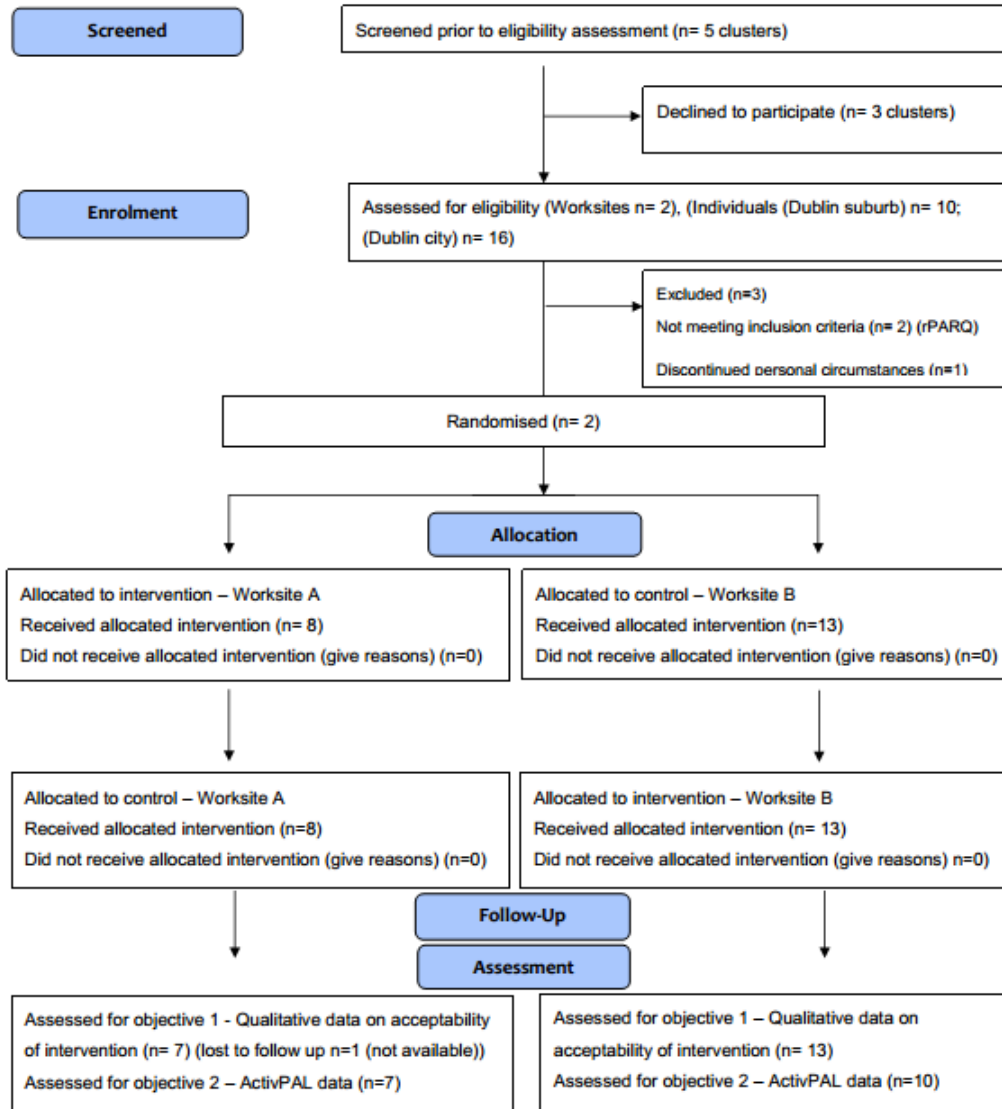
Of the 10 male participants employed in Worksite A, one individual did not reply to the invitation to participate and one individual met the inclusion criteria but cited a change in personal circumstances as a reason he was unable to participate. Eight men met inclusion criteria and consented to participate (80% of those approached).

In Worksite B, of the initial targeted recruitment email to 16 men who met inclusion criteria, 13 expressed interest in participating in the study. Using the rPARQ for screening purposes resulted in three individuals answering affirmatively to at least one of the questions. A letter from a general practitioner was necessary in these cases. One participant provided the letter giving approval to engage in the intervention goals. Two participants declined to provide the doctors letter and were therefore excluded from participating. Eleven men agreed to take part in the study (67% of those approached). A further three men agreed to participate following a second bulletin to the wider company via a general webpage. Fourteen participants thus provided informed consent. No reasons were given by those who did not respond to the invitation for not participating in the study. In total, 22 men provided informed consent.

5.7.2.2 Retention

One participant in Worksite B dropped out after baseline measurements were taken, giving a change in personal circumstances as a reason for dropping out. Twenty-one men participated in the intervention for the duration of the study and participated in the focus groups at follow up. Thus, retention rate was 95%. This suggests that the intervention is acceptable to male participants (managers and employees).

Figure 22 CONSORT extension for Pilot and Feasibility Trials Flow Diagram (78)



5.7.3 Qualitative data

The data were collected using focus groups of both managers and employees at follow-up. Themes and subthemes of evaluation of participants' perspectives of the intervention are outlined in Table 18 and mapped to the socio-ecological model. Intervention benefits and barriers are categorised in terms of individual, social, environmental, and organisational levels. Suggestions for improvement in future intervention studies are also presented.

Table 18 Themes and subthemes of evaluation of the intervention

Intervention benefits	Intervention barriers	Suggestions for improvement
Awareness Sense of enjoyment Motivation to improve cardiovascular health Domino effect for other health behaviours Self-regulation Benefit of having a goal Musculoskeletal relief	Time priorities Fatigue (overall study, specific components) Musculoskeletal issue Reduced interest in goal/social comparison BCT Sweating	Longer timeframe
Sense of togetherness Competitive aspect Opportunity for social interaction	Social judgement	Inclusion of women
Privacy of under-desk cycling Use of bike as alternative if other PA not possible Complementation of work tasks while cycling PIEL prompted moving Move bar prompted movement	Pedal machine set up/ergonomics Burden of watch set-up PIEL survey frustrating to self-report SB PIEL Technical issues	Improvement of/help with setup Automatic recording of cycling
No detrimental effect on productivity	Impact on productivity	

5.7.4 Intervention facilitators

5.7.4.1 Individual-level benefits

Awareness

Participants in both manager and employee roles in both worksites acknowledged that the intervention increased awareness of their levels of workplace SB.

“It’s hugely fascinating just to see how much I sit down during the course of the day you know you don’t realise.” Participant 6, WP (Workplace) 1, Employee

The feedback received by participants from the researcher in terms of SB and PA levels at baseline and throughout the study, was felt to be of value as it further increased awareness of participants own behaviours.

“What I did enjoy though is the em I don’t know what it’s called, was it the active wheel [graph of SB and PA levels] or something like that. That was kind of interesting, the thing you did from the original [data derived from ActivPAL3] you see your own patterns, and it’s always good to see these things in black and white isn’t it. Again, it goes back to the awareness.” Participant 1, WP1, Manager

The components of the intervention individually and as a whole served to induce conscious awareness to reduce SB and increase PA.

“I do agree with the commentary and the awareness feature or the factor of raising awareness because it’s on your wrist, it’s under your desk, you’re falling over it, it’s on your screens, it’s on your phone so it did make me very mindful of the need for activity.” Participant 4, WP2, Manager

These results highlight the lack of knowledge held by participants regarding the dangers of, as well as their own high levels of SB prior to the study commencement. The restructuring of the environment in the direct and proximal area of each participants’ workstation with the intervention equipment provided, served to act as a reminder visually and physically to them of their SB and to therefore increase PA.

Sense of enjoyment from pedal machine

A sense of enjoyment was perceived by many participants, both managers and employees, as a result of pedalling throughout the working day.

"Yeah I enjoyed doing it. You felt good afterwards." Participant 6, WP1, Employee

"I just thought it was a nice thing to have, my legs wanted to move under the desk at times if it was there and it was nicely set up." Participant 4, WP1, Employee

"I found the days I did it I found it quite a nice thing to have done." Participant 4, WP2, Manager

Overall, engagement in reducing SB by pedalling the under-desk device was rated positively by men in both employee and management roles. The sense of enjoyment was described as perhaps being invoked afterwards, possibly stemming from the sense of achievement participants felt as a result of pedalling, as well as in the moment through some automatic inclination for participants' legs to pedal and move.

It was acknowledged that this resulted in the intervention goal of pedalling for more than 30 minutes/day to be quite easily achievable for most participants.

"I was doing a particular type of task I was quite happy to do it for 20 minutes and I was actually quite fine, you know it was invigorating or whatever, so it was great. If you find the right work in the right facilities or the right setting it was very effective." Participant 1, WP1, Manager

Participants expressed surprise to have achieved a substantial bout of cycling, where the perception was of little effort while they also completed work tasks.

"I actually think it's quite clever in that sense because there are things that are difficult to do but there are things that are alongside it but there are things that actually if you're on the phone or something it's actually and you don't notice at the time going at all when you're having a discussion." Participant 4, WP2, Manager

“I had done it during a meeting earlier in the day in fact and the person who was in the room knew I was doing it because I had timed the whole thing and she said ok how long was that and I said 25 minutes you know which was actually...that surprised me” Participant 3, WP2, Manager

These results highlight that participants used the under-desk machine while completing a variety of work tasks. This illustrates the complementation of the device with particular work responsibilities throughout the working day. Furthermore, the goal set in the intervention was reported as very achievable for participants. The men sometimes engaged in pedalling for long bouts of up to 40 minutes at a time when engrossed or concentrating in protracted work tasks.

Motivation to improve cardiovascular health

One of the men was enthusiastic to continue with the pedal machine, in particular to enable some physical activity to elevate his heart rate while working, and thus demonstrating motivation to improve longer-term cardiovascular health.

“I liked the idea of raising my heart rate while I was working and if we can get the set up right, I’d be very interested in doing that long term.” Participant 1, WP1 Employee

Domino effect for other health behaviours

Many participants – both managers and employees –perceived that the intervention invoked a domino effect of increasing PA in other ways and times throughout the day.

“Actually on account of this [study], I’ve been sort of trying to do no lift days so I’ve been trying to not use the lift at all for a day or two but it’s entirely sort of because I’m thinking ok this is for 2 weeks but I need to develop habits that get me sort of moving more regularly.” Participant 5, WP2, Manager

Participating in the intervention and improving health habits acted as motivation to one of the men to increase his fitness, and to attempt to get back to his previous fitness levels that had been somewhat reduced in his current sedentary role.

“It’s kind of re-inspired me to get moving again. I have a big fitness background and going into an office job and sitting down, where did this weight come from all of a sudden so that I found beneficial and it was a good you know, energiser for me.” Participant 6, WP1, Employee

Some participants observed that participating in the intervention ‘triggered’ other work colleagues to engage in physical activity that they had not previously been viewed as undertaking.

“I pretty much go religiously at the same time of day for a walk, I started noticing fellas out that I never saw walking before. Because what it was doing was it was triggering other practices where they knew that they were on a timer, you know Liam being an example every day.” Participant 1, WP2, Manager

Participants gained knowledge of other health behaviours, in addition to SB and PA, with one participant expressing shock at his own perceived lack of time asleep.

“Yeah the sleeping thing was a freaking horror show! I couldn’t get over how bad that was. That was a wake-up call you know, I just need to actually start going to bed at a half reasonable time, not good, not good.” Participant 1, WP2, Manager

Overall, the results highlighted that as a result of participating in the intervention, the men sought to improve many health behaviours, i.e. SB, PA, and sleep. Knock-on effects were acknowledged in terms of participants’ own PA behaviours and fitness, but also observed in co-participants’ new PA habits that increased as a result of the intervention.

Self-regulation

As a collective group, the goal was set identically for all participants. The men in the study described themselves as motivated and determined to achieve that goal. Participants acknowledged their own self-regulation in terms of achieving the daily pedalling goal.

“Mentally I was just trying to ensure I was over it you know by doing longer stints so rather than trying to meet it bang on.” Participant 1, WP1, Employee

“Yeah, I focused on the day, I didn’t even think of the week. Just a day, have I done about 30 odd minutes?” Participant 2, WP1, Employee

One participant expressed a conscientiousness to achieve his set goal to ensure his overall accumulation of pedalling time was accomplished at the end of the week.

“Some days I was, I was kind of going for 40 [minutes] a day but I knew it had to be every day and I was a bit conscious of the fact that if you missed a day because you were too busy or you forgot or whatever that you had to play catch up then on say the Friday we were at it for an hour!” Participant 5, WP1, Employee

The results demonstrated that the men pursued to sometimes over-achieve the pedalling goal set in the intervention. The data highlights self-regulation techniques that the participants used, such as consciously monitoring their goals, and evaluating how much pedalling needed to be engaged in to maintain and reach the agreed overall cycling times.

Appropriateness of goal

In terms of the appropriateness of the goal, participants acknowledged that this was both helpful and easily achievable.

“Yeah the goal itself would be fine like you know 5 minutes an hour or 20 or whatever it was, 40 minutes a day would be easy.” Participant 1, WP1, Manager

“Giving yourself a goal does help.” Participant 1, WP2, Employee

This indicates that the goal set in the intervention of 30+ minutes per working day, as the minimum amount to fractionate SB, was realistic and appropriate to managers and employees in both workplaces.

Musculoskeletal relief

Some participants experienced musculoskeletal relief from using the pedal machine to reduce their SB and increase PA in the workplace.

“One of the questions on the survey is did you get any improvement in back and neck pain and I actually never thought of that until that question came up and then I thought yeah, it has improved a little bit.” Participant 2, WP2, Manager

Feelings of leg stiffness were described as being alleviated by pedalling the intervention device. Even low levels of movement on the device where full revolutions of the pedals were not completed, were perceived as improving the discomfort of stationary sitting.

“I like to put my feet loose and if I wasn’t pedalling I might just fiddle with my legs and moving it back and forth because sometimes on my chair you know my legs can go a little bit dead.”

Participant 4, WP1, Employee

Improvements in important issues such as neck and back pain, and lower limb blood flow emerged in the findings, indicating that pedalling at work may be beneficial some of the physical effects of prolonged workplace SB.

In summary, the benefits of the intervention operating at an individual level included awareness of the dangers of prolonged SB and a sense of enjoyment participating in the intervention. Some participants expressed a motivation to improve their cardiovascular health by the incorporation of LPA by pedalling during their working day, and others experienced motivation to continue the benefits of the intervention outside of worktimes and intervention targets. Self-regulation to achieve the goal which was deemed appropriate and beneficial emerged as an intervention benefit. Finally, some musculoskeletal improvements were acknowledged as a result of the pedal machine.

The benefits of the intervention operating at a social level are presented in the following section.

5.7.4.2 Social Influence

Sense of togetherness

Participants acknowledged a sense of togetherness with co-participants and perceived a 'buddy vibe' that was enjoyed by both managers and employees. Similarly, from a management perspective, the shared activity of managers and employee employees participating in the intervention was viewed as promoting team building.

"I think from a team building perspective it's a nice thing to do as well." Participant 6, WP2, Manager

Many participants acknowledged that the social influence of other participants was a powerful factor in promoting and motivating them to increase their PA and reduce SB throughout the intervention period.

"Is the catalyst for that the fact that your peers are all doing it or is it that you are self-conscious that you know I am sitting too much during the working day? Because I think it is more the former than the latter." Participant 5, WP2, Manager

"Having a look around the office you know people engaged with it and certainly I think most of them found the cycle thing actually more beneficial. [They were] quite positive about it and there was you know an effort in the office for people to become more... 'oh I better do my minutes', you know so there was a bit of that going on, I wouldn't say competition but just definitely there was people kind of supporting it and doing whatever but definitely there was more energy being expended because of it." Participant 1, WP1, Manager

The social influence was also important in terms of changing normative behaviours. It was felt by some participants that the shared activity of pedalling to reduce SB in the workplace, was beneficial to them, as it was perceived that other non-participating colleagues commented or laughed at the men's participation in the intervention.

"I think it was good that there was a bunch of people doing it because you can see others using it and you get your steps in and people would tend to walk past the office and just laugh."

Participant 1, WP2, Employee

Observational learning occurred through viewing others engaging in the intervention components was apparent in some participants' comments.

"Yeah but it was just remembering to do it I suppose was the main issue you know. Like if someone else in the office I heard kicking it off then I would go oh yeah they're doing that and that would trigger it." Participant 3, WP1, Employee

The results demonstrate that social influence is a powerful factor in professional men's reduction of SB. Both positive and negative feedback from others affected the participants in the study. Fortunately, the comments from non-participating colleagues were for the most part alleviated by the group normative pedalling behaviour and the sense of shared activity. Furthermore, it emerged that the individuals within the groups were stimulated to pedal through observing others engaging in LPA on the device.

Social comparison

Many participants expressed engagement in the social comparison and competition element of the intervention. In fact, one manager observed some of the employees potentially acting excessively competitive in the intervention period.

"It was good, certainly I noticed more competitiveness with different people, they were certainly way more competitive than I thought they should have been, to extremes, I think but not in a bad way but it was interesting watching it unfold." Participant 2, WP2, Manager

A combination of the watch as well as the pedal machine seemed to foster an increase in competitiveness in some participants. This was particularly evident among the employee team in one of the worksites, who continued the PA competition into the evening times.

"There was a competition thing going on among some of them, they were looking for the extra dimension, they were doing stuff at night-time that they would never like going out for a walk at night and stuff like that because they could put it on their watch and away they went. So, the watch was probably a driver of incremental activity and not just the bike." Participant 1, WP2, Manager

Social comparison from an organisational perspective meant that it was desirable for the worksites to be seen as forward-thinking and modern by others from outside the organisation.

“Yeah because people’s reactions would have been that’s a really progressive organisation to be doing that sort of thing.” P1, WP2, Manager

The results highlight that competition activities may be an important motivator to some participants. This emerged in the data through managers’ observations of employees engaging in evening time PA, which was not part of the explicit aims of the intervention. Judgement of peers between individuals and across organisations was highlighted as a motivator by some participants.

Opportunity for social interactions

Participants described a notable impact on the social environment and communicative aspects of work as a result of the intervention components. Those in management roles suggested that the intervention stimulated social interaction with others in both of the office workplaces. Some of this interaction was based around friendly rivalry.

“I mean from a management perspective I suppose to the extent that it does engender a sense of competitiveness whether they see it on the app or they start talking about it which was great and actually the fact that we’re a cross section in the office you know we had a whole different things to talk to and grill the lads about you know.” Participant 5, Manager

The pedal machine in particular stimulated some communication and interaction due to its novelty within the workplace setting.

“It’s a good talking point too you know with colleagues and clients over the whole course of the thing you know, it’s a novel thing to have some sort of a pedalling machine under your desk.” Participant 6, WP2, Manager

“There’s an awful lot of discussion around that [sedentary behaviour] just around the kettle and stuff like that.” Participant 1, Manager, WP1

The last quote reflects the consensus that the construct of sedentary behaviour itself was a topic of contemporary interest to the participants and non-participants in the study, in both worksites. This, together with the intervention components facilitated workplace interactions, specifically face-to-face communications, which managers in particular highlighted.

In summary, the powerful and positive social-level influences that operate in a workplace setting included a sense of togetherness, an enjoyment of the competition element, and the opportunity for increased social interactions as a result of the intervention.

The benefits experienced at the environmental level are presented in the following section.

5.7.4.3 Physical environment-level benefits

Correct ergonomic set-up

The enjoyment and capability of achieving the goal and cycling throughout the day was very much predicated on the correct and comfortable set up of the under-desk pedal machines. Although participants who were taller found this more difficult to resolve, there remained a sense of appeal to using the pedal machine.

“If there was a way to make it a little bit more user friendly to someone like me or the facilities that we have I’d have no issue doing it. I actually love the concept of it, I just think that there’s a few tweaks that need to be done to make it sort of more appealing.” Participant 1, WP1, Manager

“Once I got my desk raised it was actually very manageable to do it without banging your knees or anything like that.” Participant 5, WP2, Employee

Privacy of under-desk pedal machine

Participants perceived that the privacy of the under-desk cycle machine was a significant benefit. This sentiment was expressed particularly by managers in both worksites.

“Yeah because like that privacy and semi privacy thing can say well you know you’re more likely to use the machine.” Participant 1, WP2, Manager

“Lots of people there they do lots of solo or individual work or lots of calls, especially on a call, no one has a clue what’s going on underneath the desk like you’re pedalling away so it’s fine em so I think you know I think there’s a benefit.” Participant 1, WP1, Manager

The results highlight that from managers’ perspectives, privacy when engaging in PA was preferred. Similarly, the men indicated a worry about disturbing or distracting colleagues who may be working, and recognised that the privacy of the pedal device was a significant advantage to reducing SB.

Pedalling as an alternative

Participants perceived a significant benefit to having the pedal machine available to them on days of inclement weather or if other forms of exercise were not feasible.

“Yeah definitely. Definitely I would have been like while I was working, if I was staying in at lunchtime having that there helped to be able to chip away on or if the weather was miserable outside and it wasn’t great to go out for a walk that was definitely beneficial.” Participant 1, WP2, Employee

“It’s funny occasionally if I’m taking exercise I tend to do it first thing when I get up and I might go for a jog 15 minutes even and in the winter time I would tend to that less and less but knowing I was going into the office I might do the first 15 minutes of checking emails and this, that and the other while on the bike, that was fine that made me feel better about not going for my jog.” Participant 3, WP2, Manager

The results indicated that the barriers sometimes experienced by the participants to engaging in workplace PA, could be overcome by using the pedal machine. The men perceived the device as a useful alternative on busy days or if it was raining outside, and they could ‘chip’ away at some activity while continuing to work. Feelings of guilt or disappointment as a result of not exercising were somewhat assuaged by pedalling instead.

Complementation of work tasks while cycling

Overall, participants perceived the under-desk pedal machine as useful due to it allowing certain tasks that could be completed alongside cycling throughout the day.

“What I found easiest to do was if I had a document to read I would just sit back at my desk and read the document in a sort of a standard chair as opposed to a desk chair and that worked really well actually and sometimes I would be there for 40 minutes.” Participant 5, WP2, Manager

“Yeah but like 40 minutes, like everyone’s job is different but you know it’s not a huge amount of time over the course of a day and it actually doesn’t get in your way if you’re set up properly, you know you can do your typing, you can do a call, you know you can do your reading, it’s not that you’re going so fast that you can’t do your tasks.” Participant 1, WP1, Manager

Garmin Move bar prompt

Participants perceived that the ‘move’ bar that appeared on the Garmin watch after every hour of inactivity was effective in reminding participants to break SB both in the workplace and at other sedentary times throughout the day.

“One thing I did find very good at home but obviously also in work was if you’re not moving for a certain amount of time it sends you the little arrow to move which was good. Even at home just sitting watching TV I’d find that very useful just to get up and get a cup of tea or something but obviously in work as well just to get up and get a glass of water.” Participant 3, WP2, Employee

PIEL Survey prompted movement

Notifications received on participants’ smartphones from PIEL Survey app (EMA) were perceived to prompt movement and break SB. Participants acknowledged that answering ‘yes’ to being currently sedentary highlighted the prevalence of their SB throughout the day, which resulted in prompting them to move.

“It would make me just want to move just after getting the survey so if I’d say I was sitting down and getting the survey and picked ‘sedentary’, instantly I was getting up and going for a short walk or something or just standing up for a second. That happened quite regularly. Even at home when I was getting the surveys I’d go and walk around the block.” Participant 6, WP1, Employee

“I found the reminders kind of quite good in that way, jeez I really have been at my desk that much do you know I’m very conscious of it and an awareness was effective.” Participant 1, WP1, Manager

These reminders to participants of their sedentariness seemed to bring to consciousness the habits of prolonged sitting that the employees were engaging in. The impact of the electronic notifications (via the move bar or PIEL Survey) resulted in increased movement throughout the day, not just during working hours but also into the evening times.

The results showed that environmental level benefits of the intervention pedal component included the privacy of the device, its use as an alternative when other forms of PA were not possible, and the enablement of cycling while continuing with the performance of work tasks. Both the PIEL survey notifications and the move bar on the tracker watch acted as external prompts to increase movement and break SB.

The organisational level benefits of the intervention are presented in the following section.

5.7.4.4 Organisational level intervention benefits

No detrimental impact on productivity

In terms of productivity, the intervention was overall acceptable to management. It was felt that participating in this study did not adversely affect employees’ productivity, which was a worry from an organisational perspective. This can be elucidated from the fact that managers discretely checked up on how employees were performing their work tasks and while reducing their SB.

“But I was more concerned about what are the lads doing inside in the room, when are they doing it and is it disrupting their productivity so I have to say every time I kind of went in I wasn’t like, I was just going into the room, but they were doing it as they were working. Like Joe seemed to get it, he was doing it and he was working, he managed to figure it out. Eh and I

think the others did over time, I think the first two days were a bit awkward until you got your head around it.” Participant 2, WP2, Manager

An important intervention benefit of the intervention was that from a management perspective in particular, work productivity did not appear to be reduced as a result of reducing SB.

The barriers to the intervention that emerged in the findings are presented below.

5.7.5 Intervention barriers

5.7.5.1 Individual level barriers

Time priorities

Some participants expressed that that at certain occasions they simply did not have the requisite time to engage in pedalling, such as in the morning time when work tasks were prioritised.

“Like some mornings I found, I don’t know if you did it too, I actually just kicked it out of the way just because the first couple of hours I just didn’t want to be dealing with it. But otherwise it was grand.” Participant 3, WP1, Employee

Impact on productivity

Some participants acknowledged an impact on productivity in certain work tasks while pedalling.

“But I also think that productivity does suffer because I think you are just not able to do as much when you are doing it unless you do it in small batches here or there throughout the day but I certainly found that there were things that I just couldn’t do if I was doing this.”

Participant 1, WP2, Manager

For some participants, work tasks that required high levels of concentration were more difficult to achieve while pedalling.

“It was ok if you were on a phone call or if you were actually having a chat with someone beside you but if you were actually getting in and doing it it was a challenge.” Participant 1, WP2, employee

It was acknowledged that although productivity was affected when pedalling at a high intensity speeds, slow intensity pedalling reduced this productivity issue.

“If you’re trying to pedal fast as well you can’t really use, like as well you’d be missing things to click on or typing so you can’t like but if you’re doing it slowly you kind of can manage it a little bit better.” Participant 5, WP2, Employee

“I think it did distract me a little bit, maybe if I gave it a little bit more time, I would be able to find the optimum position for it, but I liked it.” Participant 4, WP1, Employee

The last quote reflected many participants’ views that although work performance was impacted upon, particularly at the initial ‘settling in’ period of the intervention, as time progressed the effects on productivity receded.

Intervention fatigue

Participants reported some fatigue in terms of participating in the study as the study duration proceeded.

“To be honest possibly a little bit less enthusiastic about it by the end than I was at the beginning.” Participant 2, WP1, Employee

A reduction of motivation to engage in the intervention as time progressed was reflected by one of the men. However, engagement was reinvigorated again at the end of the study duration.

“I’m a classic for starting something and then it fades away after time and as I knew this study was kind of ending certainly at the latter part of last week I had a meeting or two and then I

felt myself waning a bit more and then I got back again on the Monday.” Participant 2, WP2, Manager

Musculoskeletal issue

Participants experienced some musculoskeletal discomfort due to the sub-optimal set up of the desk and pedal machine.

“And I did find a little bit of pain in my lower back one of the days when I was cycling, probably just because of my posture so I could actually reach just wasn’t good but there was times where you could definitely maybe not put it to one side but just turn and do it that way.”

Participant 1, WP2, Employee

The above quote reflected some participants experience highlighting some discomfort using the pedal machine in the beginning or in particular positions. The issues were mostly resolved by changing position.

Reduced interest in the goal-setting/social comparison components

A minority of participants did not engage in the goal setting component of the intervention.

“It wasn’t even on my mind to be honest with you, I remember you saying it now that you mention it.” Participant 3, WP1, Employees

Similarly, some participants expressed a reduced interest in others’ activities on the Garmin app/website.

“I wasn’t interested in other people’s activities to be honest.” Participant 2, WP1, Employee

Some variation in preferences and motivation was found in the results. Some of the men differed in their engagement with the behaviour change strategies used in the intervention, highlighting some individual differences in methods to influence behaviour.

Issue of sweating

Participants who engaged in a higher intensity of pedalling than was outlined in the study targets, spoke of the issue of sweating.

"I think if you pushed yourself like I found on the first day I was getting very close to sweating so I couldn't go that far so you just do it at a pace that's ok." Participant 1, WP2, Employee

"I would prefer even shorter stints than longer stints...well you're not working up a sweat then." Participant 2, WP1, Employee

The issue of sweating emerged in the findings as being important to the men. At the beginning of the intervention period, an adjustment period was required, and in this the understanding of what intensity level invoked perspiration was acquired. Participants solved the problem of sweating by engaging in short, low intensity bouts of pedalling.

In summary, barriers to the intervention operating at an individual level included an initial productivity impact and time priority issues, and some intervention fatigue was expressed as the study duration continued. Participants also expressed some musculoskeletal discomfort, as well as the undesirability of sweating in the workplace.

The primary social-level barrier is presented in the following section.

5.7.5.2 Social-level barriers

Social judgement

Some participants perceived a sense of amusement from others who were not participants in the study in reaction to their pedalling of the bike in the workplace.

"You know people laughed at me doing it in a way." Participant 4, WP2, Manager

“Ah no like everyone I’d be pedalling away and then somebody comes into the room and they’d be like what are you doing and then like they’re chatting away and you’re kind of going, ok yeah I’m trying to....but they’d be laughing at us em but I think the novelty.” Participant 2, WP2, Manager

Social judgement, in the form of colleagues commenting or laughing at participants, was experienced by some. The novelty of the intervention components, in particular the pedal device, invoked interest and attention in both of the workplaces. The social and workplace cultural norms exerted some pressure on the men in the form of the amused reactions from non-participating colleagues.

In summary, it is important that behaviours are socially acceptable in workplace settings where group normative behaviours are oriented towards sedentariness. The results showed that behaving in ways that are perceived as different or outside the norms may be a barrier to reducing SB.

Environmental level barriers to the intervention are presented in the following section.

5.7.5.3 Environment level barriers

Issues with ergonomic set-up of the pedal machine

A significant issue expressed by many participants was the issue of comfortable set-up of the under-desk pedal machine. This was too difficult to overcome for some of the participants.

“I found the set up too hard to overcome, I was just banging my knees on the desk and I was too far away from the screen and losing productivity. The best use I got out of it was on phone calls.” Participant 6, WP2, Manager

“I’d probably need a little bit more on set up. And the seats that they move. That’s a challenge. Actually, I think it would have been a lot easier for me if they didn’t move because I was trying to hook my coasters, I suppose you’d maybe drop the coasters, the wheelie chair.” Participant 4, WP2, Manager

“The cycle part of it for me because we don’t have the facility to lift our desk high enough and I’m nearly 6ft2, I found it a little difficult em so if there was a way to make it a little bit more user friendly to someone like me or the facilities that we have I’d have no issue doing it.”

Participant 1, WP1, Manager

The results highlighted significant issues, particularly at the outset of the study, in terms of the comfortable set-up of the pedal machine underneath the traditional work-desks. The problems presented primarily due to the positioning required for some to pedal and use their computer, and the wheels on the office chairs increased movement. Participants who were tall, in particular reported difficulties to achieve a balance in terms of comfort in pedalling and working normally.

Burden of watch set-up

Participants acknowledged that there was significant burden involved due to the recording mechanism of the cycling times using the Garmin watch.

“Sometimes you’d be cycling and you’d be trying to do a certain aspect and I’d have to kind of stop em and kind of complete that and then start up again while your feet are still in the straps so it was a little bit stop/start.” Participant 1, WP2, Employee

“It would I think if it wasn’t timed, I would have done a little bit more because you have to remember to actually time it and there was a little bit of setting it up.” Participant 1, WP2, Employee

“I found having to fiddle with the watch every time you started to cycle to set up the recording of it was a little bit off putting. If it was just a simple matter of putting my feet into the thing and just cycling away, I probably would have done it more often. That’s probably why I did longer stints like Neil as well rather than the shorter stints because there was little bit of set up involved and you know getting used to it mentally and fiddling with the watch so you know a couple of 30 minutes a day you know in the same session I prefer that than say doing lots of 5 minute sessions.” Participant 5, WP1, Employee

The results highlighted that recording pedalling time using a Bluetooth cadence sensor on the pedal of the device that could connect to the Garmin watch, followed by the uploading process to the associated website/app was overly burdensome for the men. A more effortless system to perform this function in future trials was suggested by many of the participants.

Sense of frustration with EMA

The repetitiveness of answering affirmatively to being sedentary resulted in some participants becoming less engaged and reactive to the EMA notifications.

“I became a bit immune to it in the end actually. Just a bit because I knew I was going to be pressing sedentary again you know, but it was constantly saying yes, I’m sedentary you know what I mean” Participant 3, WP1, Employee

The majority of participants perceived significant frustration that the PIEL survey notifications did not appear at a time to capture PA that the participants were engaging in, and they were not afforded the opportunity to record the various PA throughout their day.

“It never really bothered me to be honest em except when you come back from a run and you’re sitting on the couch or you’re putting on, drying your toes and then beep and you’re actually sitting on your couch, you know that kind of way (laughs).. If you’re out for a run you don’t have your phone and therefore you miss that one and that’s the few times that you actually are active and you don’t get the opportunity to say that you were active.” Participant 1, WP1, Manager

“One thing is that when you’re sedentary you’re typically going to see the notification and respond to it. When you’re actively doing exercise you actually miss it and time out so most of the time when you’re sedentary, not because most of the time you are sedentary but that’s when you actually see them.” Participant 5, WP1, Employee

The above quote captures the overall consensus that the very nature of being sedentary meant that participants were regularly in a position to answer affirmatively to be sedentary. Unlike the men’s activity time, which typically involved them being largely occupied and resulted in the notifications being missed and PA not captured by the survey, and which invoked an understandable sense of frustration.

PIEL Survey time-out issues

Participants acknowledged that the time-out period due to the momentary element of the ecological momentary assessment, which aims to capture the activity in the moment, meant that a significant proportion of the surveys went unanswered.

Participant 6: *“I didn’t have any issues except that quite often I noticed every time something is flashing on my phone, it’s barred so I’d say you know at least 50% didn’t get answered because they were barred.”*

Participant 2: *“Yeah same here.”* WP2, Managers

“Yeah but like that, about 50% I probably missed.” Participant 2, WP2 Manager

“Yeah, I think doing the survey I don’t, I’ve no problem doing it but if you kept missing it you would get frustrated on a more permanent basis. That would be a challenge.” Participant 1, WP2, Employee

The findings highlight the high levels of missing data as a result of the time-out feature of the PIEL Survey. The survey remained available to participants for 20 minutes to complete, however, participants reported that a high proportion of the surveys were not responded to within the time allowed.

Disturbance of EMA notifications

Some participants expressed a sense of disturbance in terms of the EMA notifications being too numerous.

“I’d answer one and then like 10 minutes later I’d get another one.” Participant 4, WP2, Employee

There was an acknowledgement of some undesirability of receiving smartphone notifications to some participants.

“I got a bit fed up of them after a while because I don’t like notifications, I turned off the notifications after a while.” Participant 2, WP2, Employee

“I get enough bloody notifications from all angles. Yeah I don’t like increasing notifications.”

Participant 4, WP1, Employee

It was perceived by one participant that the notifications were somewhat disturbing to work tasks.

“Like they kind of interrupt my thinking and stuff.” Participant 2, WP2, Employee

Some participants expressed that the list of activities on the EMA survey was not exhaustive.

“There was a couple of times actually when I wanted to respond to what I was doing, and it wasn’t on the list. I can’t remember what they were now.” WP1, Employee

“The list could be expanded a good bit.” Participant 5, WP2, Employee

Overall, the findings showed various issues with the PIEL Survey EMA method. The notifications were felt to be too numerous, and to be somewhat disturbing in the workplace, and there was a desire not to increase an already sizable burden of smartphone notifications received by the men. Extending the list of activities was suggested by participants as it was expressed that sometimes the response category sought by the men, was not available in the list.

In summary, environmental level barriers to the intervention were present in terms of the equipment provided to the participants. Issues surrounding the ergonomic set-up of the pedal machine, and the overly burdensome watch set-up were deemed to be detrimental to engaging in the pedalling behaviours to the extent that the participants would have liked. The PIEL survey presented technological and content and methodological issues for the participants in the study. In terms of the acceptability of the intervention and study processes overall, the following section presents the results from a management and employee perspective.

5.7.6 Acceptability of Cycle at Work

Management acceptability

Overall, managers in each worksite agreed that the Cycle at work intervention was acceptable to them. Participants noted that participating in the intervention resulted in a positive experience.

“Yeah I think it’s good and people I think do see or feel the benefit of it.” Participant 4, WP2, Manager

It was acknowledged that going forward, at a company level, the intervention would be positive in terms of reducing SB, provided the barriers of the desk setup and the improvement of the cycling times with regards to technology development were resolved.

“Even us as a company in terms of the desk that we have or the technology evolves or whatever way it is, I think it could be a very effective way of reducing people’s sedentary behaviour at work.” Participant 1, WP1, Manager

“Just in terms of general awareness and creating consciousness about how sedentary we are I think it [the overall study] was definitely a good prompter to move or do something.”
Participant 3, WP2, Manager

The above quote reflected the overall consensus from the managers, that the intervention, and the knowledge that was acquired by participating in the study, created awareness of the dangers of SB, and was useful to the men to reduce this health risk.

Employee acceptability

Overall, employees in both worksites expressed acceptability of the intervention. Participants noted that they would consider participating in a future study of Cycle at work.

Interviewer: *“Just to finish that then, would you say that they are acceptable? The study, the components of it, the goal setting?”*

Participant 1: *“Yeah and like if we had to do another session on it yeah like it wouldn’t be prohibitive to.”* WP2, Employee

“I thought it was a very worthwhile study to do and just to be a part of.” Participant 1, WP2,
Employee

Participants expressed that participating in the pilot study had been an enjoyable experience, despite some of the set-up issues, and felt that the study was important and positive.

“It was interesting. I think it was worthwhile. A couple of things that could be improved just in terms of set up but yeah I thought it was very good, I enjoyed it.” Participant 1, WP1,
Employee

Participants reported that the study overall was not overly intrusive to them in terms of what was required of the men throughout the study. It was felt that the study was comprehensive in its aims.

“Yeah I didn’t find it in any way invasive or whatever, there was great detail in it.” Participant 1, WP1, Manager

One participant expressed a sense of altruism in contributing to scientific knowledge by participating in the study.

“I was glad to do it. I felt like I was making some sort of a contribution to some knowledge.”
Participant 2, WP1, Employee

The results of the study demonstrated a sense of overall positivity as a result of participating in the study. The benefits of the intervention were enjoyed by the participants, e.g. in terms of improvement of general awareness of this health risk, in the methods used in the pilot study to reduce workplace SB, and a sense of altruism of contributing to the SB scientific body of knowledge.

Acceptability of crossover design

Participants expressed acceptability of the crossover design.

“As you said we were told that there was going to be different phases so just whatever we were told to do during that phase we just did it. You just tried to go about your day as you normally would.” Participant 1, WP2, Employee

Participants reported minimal awareness of the crossover design feature and suggested that no impact was experienced as a result of this process.

“Aw yeah that side, the process didn’t really bother, I didn’t even, wasn’t really conscious of it or aware of it you know what I mean. It wouldn’t bother me at all.” Participant 1, WP1, Manager

Overall, the consensus was that the crossover design of the intervention was acceptable to both managers and employees in both worksites, thus highlighting that this experimental design is practicable and feasible in real-life workplaces.

Acceptability of ActivPAL3

Although participants anticipated a more negative experience of wearing the device, the results demonstrated that this was not realised, and the men were not at all conscious of wearing it in the study.

“It was much less intrusive than I expected. Having something attached to your leg for a couple of weeks sounded pretty awful but actually I completely forgot about it for the entire two weeks whenever I had it on.” Participant 3, WP2, Manager

“Yeah it was fine, it was totally non-intrusive.” Participant 3, WP2, Manager

Some participants expressed that they had experienced minor discomfort in wearing the ActivPAL3.

“The activPAL3 thing on your leg it was ok, but it was a bit of a pain. It was a little uncomfortable at times or just em just a little bit annoying.” Participant 1, WP1, Manager

Overall, participants acknowledged the acceptability of the ActivPAL3 measure for the study period. Although discomfort was experienced in the minority of participants, the majority expressed minimal awareness of the device attached to their leg.

In summary, the Cycle at Work intervention and study processes were overall acceptable from a manager and employee perspective. In terms of the measures, although one participant experienced minor discomfort with the ActivPAL device, the overall consensus was that the measures involved in the study were acceptable and not overly burdensome.

The following section outlines suggestions from participants for improvement of the intervention for future trials.

5.7.7 Improvements for the future

Automatic recording of cycling

In terms of improvements to the intervention for future trials, one of the overly burdensome elements of the study was the manual recording process of the cycling bouts, and the subsequent uploading to the Garmin website/ app. Participants suggested that an automatic mechanism to record and upload bouts of cycling would greatly improve the experience of the intervention.

“If I was to have one of those under my desk long term right I would do it just to do it and not to track it if you know what I am getting at with that because you are very conscious, it’s for the next 20 minutes I am going to do this whereas if you could just slap your feet in and do it whenever you’re free for the two minutes or one minute rather than having to parcel off an amount of time nearly to do it so I would probably do it more if I didn’t have to set it all up but for the study and everything it was fine, it was very simple like it was just take 10 seconds, it wasn’t a big deal at all but if I was to do it forever, if I had it at home at my desk, if I had it at home I wouldn’t track it.” Participant 1, WP1, Manager

The above quote reflects the consensus that the process of the pedalling bout recording was not user friendly and in its current form would be a barrier in the longer term.

Improvement of/help with ergonomics set up of pedal machine

Participants acknowledged that more help with the set-up of the pedal machine would be desirable and would enable greater comfort and participation in the pedalling throughout the intervention period.

“It’s probably not feasible but assistance with the physical set up would definitely help particularly when we are so dependent on the facilities guys coming along and helping us with everything that you know eh I think a lot of us were challenged by the idea of having to set it up and having to hook your chair leg to the end of the machine to stop it from [rolling away]...I don’t think those chords really worked but like I say it’s not feasible because you know you’re not going to have the resources to do that.” Participant 6, WP2, Manager

“If you were to do it again you could give a list of helpful hints to participants which would probably mean that they could get into the groove earlier and probably find that they would get more out of it.” Participant 2, WP2, Employee

These sentiments were reiterated throughout the majority of participants, i.e. future studies would need to assist participants in the correct and comfortable ergonomic set-up of the pedal devices to ensure maximal engagement with the device and to allow optimum reduction of SB.

Inclusion of women in future study

Several participants expressed a recommendation that future studies should include women, as opposed to the male-only sample recruited in the pilot study.

“A lot of women want one, they kept asking for them.” Participant 4, WP2, Employee

The results highlighted that the male employees had received comments from female colleagues who had expressed an interest in the intervention components, and the men suggested that future trials should include women.

Longer timeframe

Participants expressed a desire for the intervention to be conducted over a longer period. It was suggested that the intervention was conducted over a particularly busy time period (November/December) in one of the worksites, which possibly resulted in reduced engagement in the study.

“And I think certainly if I were on a 4-week study like I was particularly busy through part of this and there were days where I just didn’t do it at all but over a longer period you know I think I would probably average much better but with proper set up and a better reflection of what my average busyness might be.” Participant 2, WP2, Manager

“I do think over time we would get more used to it.” Participant 3, WP2, Manager

The above quote reflected many participants’ view that it would be preferable that the study be conducted across an extended period, which would allow for a settling in period in terms of work patterns and become accustomed to the intervention.

Individualised goals

Several participants acknowledged that individualised goals may be more effective and incentivising to engagement in the pedalling behaviours.

“Tom’s point there about a more personalised approach you know for me calories were a goal because I have high cholesterol, that’s me personally so the distance or the time wasn’t really the thing for me personally, it was how much I was dropping my calories on a daily basis you know. So that might be something you know, personalisation.” Participant 3, WP1, Employee

Although the collective goal set for the participants was acceptable and achievable, the findings highlight that office employees’ motivations likely differ. A preference for a reduction in calories was considered a more motivating goal for some of the participants, as opposed to pedalling time.

Intervention as part of wider programme to reduce workplace SB

It was expressed that implementing the intervention as part of a broader workplace programme to reduce SB and increase PA, to include women, and also to target healthy eating habits may be beneficial in the longer term.

“If you build it into a wider programme of getting people to change their behaviour and maybe you know it isn’t just for guys but you know it’s a part of a programme and it’s a way of getting people to be more conscious of the amount that they spend at their desks and you know build into sort of eating habits and so on, I think it’s part of an overall programme.” Participant 5, WP2, Manager

It was acknowledged that the culture in the worksite had changed and the knowledge gained from the study would impact wellbeing programmes in the future, and not simply at surface level.

“It would be interesting if we purposefully for example made a decision not to have the lifts operable at certain times of the day, would it actually change behaviours, it has to be around the mind-set beyond the bike and just general sedentary behaviour. And you know there are certain areas where we look at our wellbeing programme for 2020 and it would certainly be an influence in the ways that we approach it and we wouldn’t want to do anything in a cosmetic way anymore as a result of doing this whereas we would be more likely to jump on a cosmetic solution that would come our way on account of this exercise. I think we are a lot wiser to that now you know.” Participant 1, WP2, Manager

Overall, the consensus, in particular from managers, was to continue the good work of the intervention in terms of reducing workplace SB and increasing LPA, by incorporating the ideas and strategies to broader health and wellbeing programme. The participants reflected that the knowledge and education received through the study would be integrated to a deeper understanding of workplace health.

5.7.8 Implementation questionnaire

Figure 24 presents a graphical representation of the percentage prevalence agreement with questionnaire statements for all participants (n=21). In all but one statement across the three

questionnaires, the median was 4 (IQR 0-1) indicating a consistent level of agreement with minimal dispersion in scoring between the participants. Statement 4 relating to the intervention’s feasibility, ‘the intervention seems easy to use’ had a median of 3 (IQR 0-1). In all other statements, the level of equivalence (neither agree/disagree) was ≤33% and, in most cases (9/12 statements), the percentage prevalence was less than 25%. The level of disagreement was 24% in two statements, ‘the intervention seems implementable’, and ‘the intervention seems easy to use’. In all other statements (10/12 statements), the level of disagreement was ≤14%.

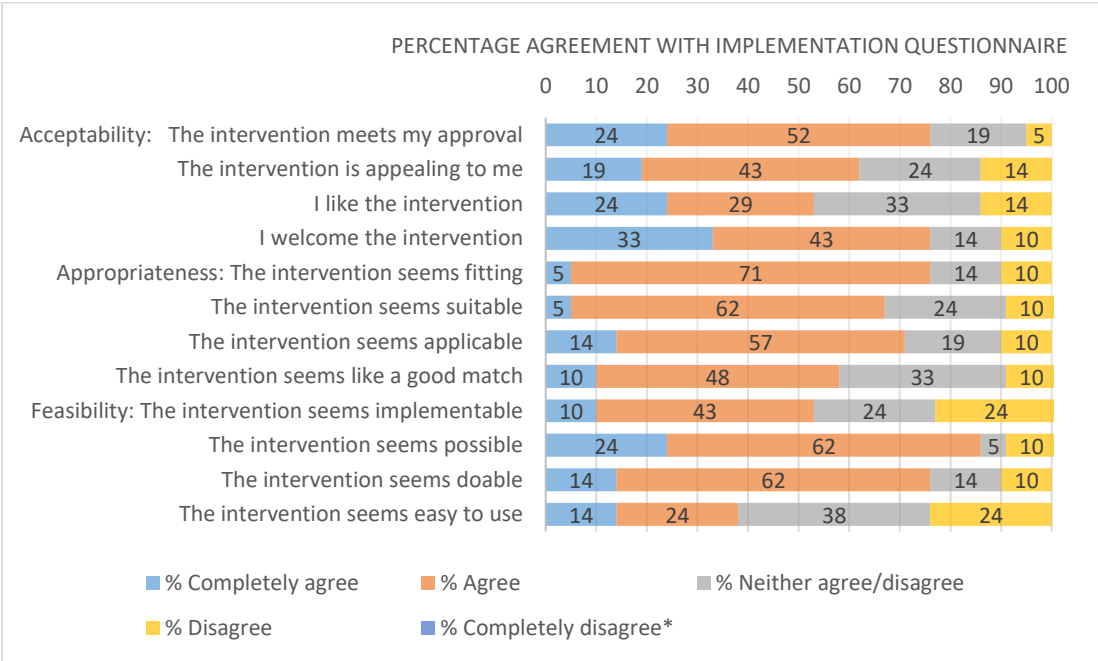


Figure 23 Percentage agreement with implementation questionnaire

*there were no responses in the completely disagree category

5.7.9 Anticipated and perceived intervention benefits of the intervention

Mean scores (n=21) for anticipated improvements to back/neck pain, mental health, and work productivity as a result of reducing SB in the intervention all scored an average of 4 (agree) at baseline (scored 1-5, 1 being strongly disagree, 5 being strongly agree). The mean score for the perceived intervention benefits to mental health remained at 4.0 (agree) at follow-up, indicating that participants ‘agreed’ that the intervention *would* benefit mental health, and further ‘agreed’ that it *did* benefit mental health at follow-up.

Mean scores for perceived benefit to work productivity and back/neck pain at follow up were 3.0. The score represents 'neutral' on perceptions of improvements of work productivity and back/neck pain after the intervention, which indicates a reduction in the perceived benefits of the intervention to productivity and neck/back pain, at follow-up.

5.7.10 Feasibility of trial-outcome measures

In total, 17 of the 21 participants met the criteria for minimum wear time (4 days) providing accelerometry data in the intervention period (81%), and 20 of 21 participants achieved minimum criteria for the control period (95%). The reasons for the missing data included, in the intervention period one participant was unexpectedly absent from the office, one device got wet and the data were lost, and two devices has software malfunctions and no data transferred. In the control period, one participant lost the device while travelling through the airport.

In the control period the majority of participants (15 of 21) collected data for more than ten weekdays in the control period. Four participants collected data for nine weekdays. One participant collected four days of data due to being unexpectedly absent from the office.

In the intervention measurement period, 12/17 participants collected ≥ 9 days of data, four collected eight days of data, and one collected six days of valid data.

The proportion breakdown of reasons for data not meeting minimum wear time criteria are outlined in Table 19.

Table 19 Reasons for not meeting minimum wear time criteria

Reason for not meeting minimum wear time	Number of days excluded (proportion of total exclusions)
Monitor removed before the end of monitoring period	18 (62%)
Airport travel	8 (28%)
Annual leave	2 (7%)
Device attached after day one of monitoring	1 (3%)
Total days missing	29 (100%)

5.7.11 Secondary outcome data

5.7.11.1 Sedentary behaviour/physical activity

Table 20 presents the data in each time period detailing the outputs from the ActivPAL3 data results showed a decrease in workday SB from 379.3 (SD 79.0) to 358.9 (SD 96.6) minutes per working day in the intervention period compared to the control period; thus an indicative reduction of workplace sedentary behaviour of 20.4 minutes-per-workday. Daily SB decreased from 634.5 (SD 102.5) to 588.8 (SD 107.8) minutes per day in the intervention group compared to the control group (45.7 minutes reduction in sedentary behaviour minutes in their overall day). In terms of physical activity (i.e. stepping) average total weekly PA increased by 9.9 minutes in the intervention period compared to the control period. Overall weekly standing was higher in the intervention period at 219.7 (SD 94.7) minutes per day compared to 196.5 (SD 52.0) minutes per day in the control period (i.e. 23.2 minutes increased standing per day).

Table 20 ActivPAL3 data on participants SB, standing, and physical activity

	Intervention (I) n=17	Control (C) n=20	Difference C-I
Work SB - minutes (SD)	358.9 (96.6)	379.3 (79.0)	-20.4
Total weekday SB	588.8 (107.8)	634.5 (102.5)	-45.7
Total weekend SB	498.9 (108.4)	507.7 (106.4)	-8.9
Work PA	48.7 (13.8)	48.5 (13.8)	0.3
Total PA	103.2 (29.2)	93.4 (24.3)	9.9
Total weekend PA	124.0 (38.7)	125.5 (36.1)	-1.5
Work standing	110.1 (72.1)	95.7 (36.2)	14.4
Weekday total standing	219.7 (94.7)	196.5 (52.0)	23.2
Weekend standing	239.4 (62.5)	229.3 (58.7)	10.1

5.7.11.2 Cycling activity and adherence to the protocol

Figure 24 graphically illustrates the daily pedalling times in minutes for each workday of the intervention. Compared with those in the control period, participants in the intervention group cycled an average 27.1 ± 10.23 minutes-per-workday in the intervention period. Overall, 67%

of participants engaged in >20 minutes of cycling per day, which equated to >60% of the intervention cycling goal.

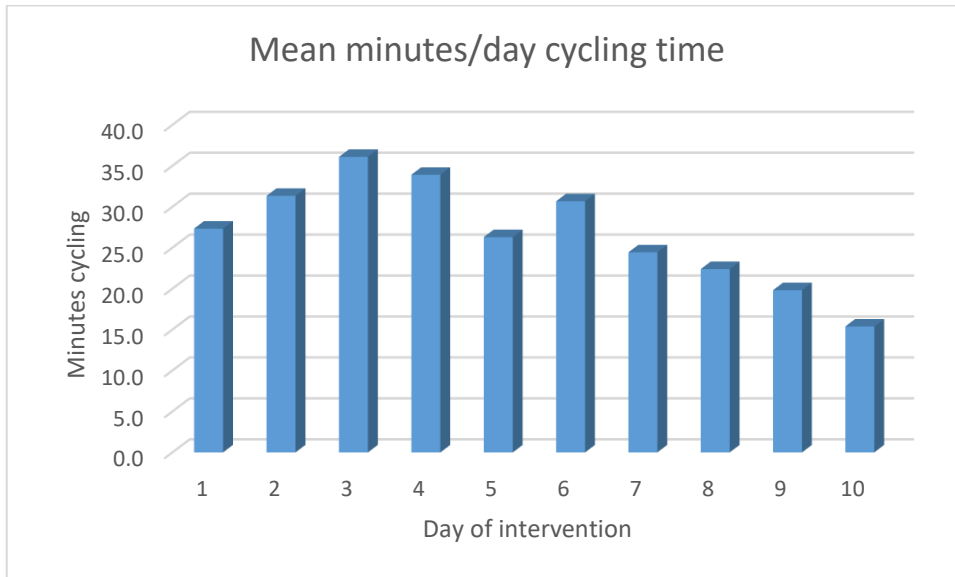


Figure 24 Minutes of pedalling time per day of the intervention

5.7.11.3 Ecological momentary assessment

Distribution of daily ecological momentary assessment activities within control and intervention periods was based on 1542 completed surveys. Of the potential 882 (6 notifications per day for 7 days), 788 were collected at baseline (89%). Of the 1764 notifications sent to participants over the control and intervention periods, 353 responses were collected in the intervention period (20.5%), with 441 responses in the control period (23%). Table 21 illustrates the breakdown of the distribution of response rates across each period and worksite.

Table 21 Breakdown of EMA response rates

RESPONSE RATE (%)	WORKSITE A	WORKSITE B	TOTAL
CONTROL	15	31	23
INTERVENTION	22	19	20.5
	18.5	25	43.5

Participants reported being engaged in significantly more physical activity in the intervention period (16.9%) compared with the control period (9.7%) as illustrated in Figure 25.

Participants reported being sedentary 80.8% in the intervention period compared with 81.1% in the control period. Participants responded to 12.5% of the EMAs in the intervention period as being currently engaged in using the under-desk machine (Figure 26).

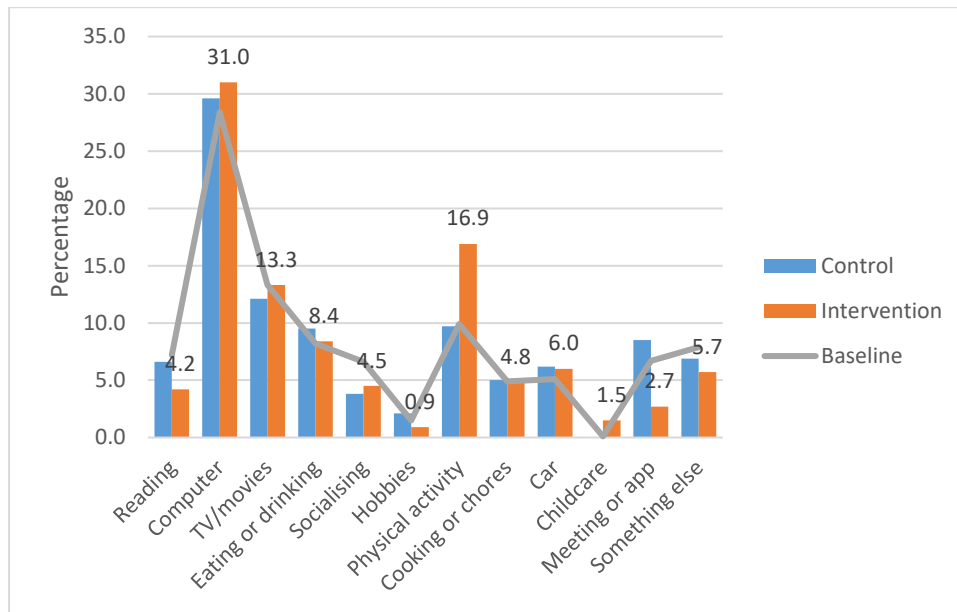


Figure 25 Distribution of daily ecological momentary assessment activities within control and intervention periods

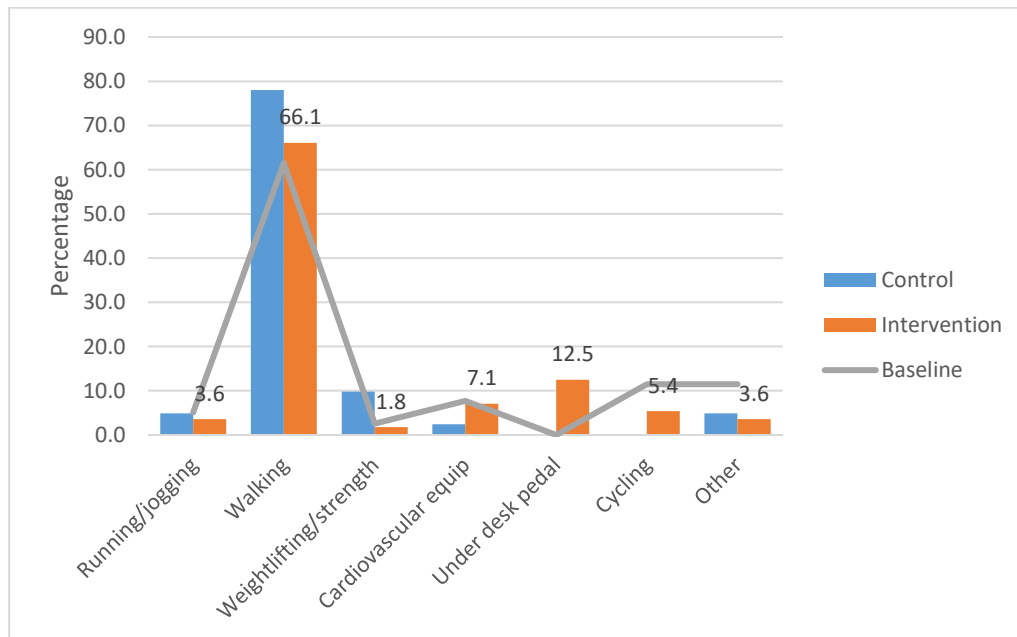


Figure 26 Distribution of daily ecological momentary assessment physical activities within control and intervention periods

5.7.11.4 UWES-9

Some group mean differences were observed within groups over the duration of the study for work engagement (Table 22). The group mean difference from the total work engagement scale showed a small increase from baseline to intervention period of 5.2%, and a small increase occurred from intervention to control periods (2.3% change). The group mean difference in the vigour subscale showed a notable increase of 11.3% from baseline to intervention period, and this increased by a further 5.3% in the control period. The group mean difference from the dedication subscale from baseline to intervention was an increase of 5.5%, with no difference in dedication between the intervention and control periods.

Table 22 Means and SDs in secondary outcomes across the intervention between intervention and control periods

		Intervention		Control
	N	Mean (SD)	N	Mean (SD)
Work engagement (total)	21	4.23 (0.8)	19	4.33 (0.8)
Vigour		3.94 (1.1)		4.16 (0.9)
Dedication		4.44 (0.8)		4.49 (0.8)
Absorption		4.32 (0.8)		4.35 (0.9)

5.7.12 Technical issues and adverse events

Throughout the study duration no serious adverse events were recorded. Two ActivPAL3 device malfunctions and one device battery did not hold the charge in the intervention period resulted in no transfer of data to the computer software. There were eight removals due to airport travel. On one of these occasions an ActivPAL3 was lost. One device was damaged by getting wet and resulted in lost data. Skin irritation was experienced by some participants who expressed that more dressings administered at the beginning of the intervention would have enabled their replacement more frequently. Two participants reported difficulty in correctly fixing the ActivPAL3 to the leg in the baseline period using the Tegaderm tape. One participant reported some discomfort and a minor skin abrasion when engaging in floor exercises due to the placement of the ActivPAL3. Irritation was experienced by one participant due to the Garmin watch. Two participants mentioned that some sweating was induced at the beginning of the intervention period.

5.8 Discussion

The aim of Study 3 was to conduct a cluster randomised controlled crossover pilot trial to examine the acceptability and feasibility of a gender-sensitised multicomponent intervention to reduce SB and increase LPA in professional men. Testing a set of feasibility objectives to ascertain if a future RCT is viable was a further aim of the study. The trial-related measures and study processes were overall acceptable to this target group as found in the qualitative component of the evaluation. The qualitative data highlighted several areas for improvement within the intervention, particularly with the ergonomic set-up of the pedal machine and the Garmin watch recording process, demonstrating that the intervention was somewhat acceptable to professional males. The implementation of the intervention was deemed somewhat appropriate, acceptable, and feasible in its aim by employees and managers. The methods and results did not significantly deviate from the published protocol for the study (684). However, it was decided between the submission of the protocol and the commencement of the pilot study that the 'introduction and briefing' session would be conducted as an 'education and knowledge provision behaviour change strategy'. On further reflection of the findings of Study 2, the education piece emerged as an important target for motivation and engagement in the intervention and was therefore developed to concentrate more on providing information on the consequences of prolonged SB to the participants.

Recruitment of clusters to this intervention was somewhat possible, with 40% of companies approached consenting to take part. Time restrictions were given by two of the companies that did not participate, which is likely reflective of many busy workplaces. Recruitment of professional men was possible, however, only 73.3% of the target sample outlined in the protocol were recruited to the intervention. Retention in the study was very good. In terms of outcome measures, the main trial related outcome data was sufficiently usable and collected at all time points in the study. However, the EMA had significant missing data, particularly in the intervention period. There were no serious adverse events reported, although slight skin irritation from the Tegaderm dressing used to hold the ActivPAL3 in place was noted.

In terms of trial related outcomes, the findings of the intervention suggest that the adoption of a gender-sensitised multicomponent approach could reduce workplace sedentary behaviour and increase light physical activity in professional men in the short term. Although not the primary purpose of the study and formal statistical testing was not carried out, total daily sedentary behaviour, and workplace SB were reduced in the intervention group compared to the control group. In terms of protocol adherence, just over two thirds of participants achieved more than 60% of their average daily cycling goal in the intervention period, although daily

cycling times reduced as the intervention progressed. Changes in self-reported activities included an increase in physical activity outcomes in the intervention, specifically an increase of self-reported pedal machine use. Perceived mental health improvements as a result of reducing workplace SB were reported. Slight musculoskeletal deterioration was reported at follow-up, which was as a result of the ergonomic set up of the pedal machine. In terms of work productivity, no changes were reported suggesting that the intervention did not have negative effects on work productivity. Changes in overall work engagement were minimal between the intervention and control periods. Vigour increased slightly from baseline to intervention suggesting a slight increase in levels of energy and resilience, as described within this construct. The objective to reduce SB by enabling light intensity physical activity by providing an under-desk pedal machine, individual level behavioural change strategies, and organisational support, the intervention was found to be appropriate, acceptable, and feasible from a manager and employee perspective.

5.8.1 Acceptability of trial-related assessments, study procedures and feasibility of measurement tools

The trial-related assessments and study procedures in the Cycle at Work intervention were overall acceptable to both managers and employees. The crossover design was acceptable in the professional workplace settings, although some intervention fatigue was expressed towards the end of the study period. The pen and paper questionnaire assessments were not excessively time-consuming or overly burdensome to participants. In terms of the ActivPAL3 measure, the majority of participants reported low burden and high acceptability in the qualitative evaluation. Missing data were low in the control period (95%), and in the intervention period (81%). Some discomfort while wearing the ActivPAL3 device was reported. Skin irritation was noted by some participants as a result of the Tegaderm dressing, previous studies using ActivPAL3 and these types of dressings have also reported minor issues of skin irritation (281,459). Participants in the current study suggested that a solution may be the provision of extra dressings at the outset of the study to enable more regular replacement. The dressing itself was difficult for some participants to correctly fix to their leg which resulted in missing data in the baseline period.

5.8.2 Evaluation of the intervention experience

The findings of the qualitative evaluation show that this multicomponent intervention to reduce SB and increase LPA was somewhat acceptable to both managerial and employees' participants in both worksites. The themes that emerged in the evaluation of Study 3 were organised in line with the socio-ecological model of sedentary behaviour (57). A range of influences, on different levels, i.e. intrapersonal, interpersonal, environmental, and organisational, that interacted to influence the intervention experience and behaviour change are mapped to the socio-ecological model in the following section.

5.8.2.1 Intrapersonal components

The primary intervention facilitator was awareness of the dangers associated with prolonged SB. This finding has been reported in many intervention studies concerned with SB (565,675,708). Educating participants can increase consciousness of their own SB and has been found to create shock about potential health consequences of prolonged SB. This is in congruence with a lack of knowledge of health risks associated with SB reported in the general population (638). This knowledge and awareness of participants' own levels of SB motivated an increase in PA and breaking up of prolonged SB. The weekly feedback received by participants on their own patterns and levels of SB, as well as how they compared with their team-mates highlighted further awareness. This type of feedback has been described as being visually impactful (611). In line with Brakenridge et al. (469), these minimally intensive approaches are felt to be valuable to participants, and important to utilise in future interventions.

As highlighted in Study 2, the important issue of the impact of the intervention on productivity was explored. Certain times of the working day were deemed more suitable to engage in cycling, for example, one participant noted that in the morning-time work tasks were prioritised. From an employee perspective, participants acknowledged a significant advantage in the complementation of cycling while conducting work tasks. Reading documents and speaking on the telephone were particularly suited to pedalling. Work performance was affected as cycling intensity increased, which resulted in some productivity issues. In congruence, Tronarp et al. (709) reported that light intensity cycling only slightly impaired work performance, compared to moderate intensity cycling which affected work performance more significantly.

The pedalling goal of >30 minutes per day for the intervention was deemed appropriate by participants. Several participants acknowledged that individualised goals, however, may be more effective and incentivising to engagement in the pedalling behaviours. This finding emerged as a result of piloting the intervention and highlights the value of qualitative evaluations where participants can reflect on certain aspects of the intervention and how changes can be made to be allow interventions to be more meaningful to them. This is advocated in a person-based approach (66). The use of personalised goals has been used in previous multicomponent workplace interventions of predominantly female participants (710). The use of technology in this intervention is well positioned to play a role in such a personalised approach in future interventions. Further technological developments may offer functionalities and opportunities for personalisation through the various activities on the online platform.

A sense of surprise was expressed by participants in terms of the ease of completing the goal of 30 minutes pedalling per day. This resulted in a perception of time moving quickly where significant bouts of cycling could be engaged in during a work telephone call. This demonstrates the efficiency of active sitting while continuing with the work tasks – an important construct in a workplace setting. In terms of health benefits, growing evidence has documented the improvements of a range of cardiometabolic risk factors associated with increasing light intensity PA (157,711–713). Engaging in just five to 30 minutes of LPA is associated with decreases in BMI, body fat and fat mass (164). Awareness of cardiovascular health as a result of daily PA using the intervention components was reported. Participants expressed an interest in continuing LPA using the pedal machine to improve cardiovascular health by elevating their heart rate in the longer term. Public health and health promotion campaigns seek improve men’s heart health, in particular prevention of cardiovascular disease (682). Accumulating PA and increasing the heart rate in a workplace setting may be used to target a reduction of the disease burden in men. Enabling employees to increase LPA in a way that is deemed easily achievable in their working day, has strong implications in terms of workplace health promotion and disease prevention.

Self-regulation in terms of achieving the goal set in the intervention was facilitator for some men. Others were not as motivated to meet their daily goals, which is not surprising as office employees likely differ in what motivates and encourages behaviour change (634). Some men acknowledged self-regulating strategies by being mindful and cognisant of their agreed goals and engaging this into personalised action. This behavioural change process reflects the ways in which individuals identify and evaluate personal goals, develop and implement strategies to

enact change, and regulate and strengthen patterns of behaviour (714). This can lead to sustained behavioural change and new ways of doing and being, and has been previously identified in women (715), and bank employees (675). Self-regulation approaches to self-monitoring, goal-setting and adaptive monitoring have been used successfully in previous evaluations to reducing SB (716,717). In line with the target population in the present study, being male has been found to result in more extensively used self-regulatory strategies, and significantly related to greater PA engagement (717). Previous studies have centred primarily on reducing sitting (675,718), and in community-dwelling older adults (716,717), whereas the present study found that self-regulation may be helpful to reduce SB and increase LPA in professional male employees.

A domino effect on PA outside of the intervention was reported as a result of participation in the study. Participants reported an increase in their own PA engagement throughout the day, as well as an observation of others increasing their daily activity compared with previous habits. Other strategies, such as having 'no lift days' (i.e. days that participants used the stairs instead of the lift), were described as being as a result of the study. Being part of the study also had an effect to 'energise' participants and re-inspire them to increase their activity. This knock-on effect of attending to other health behaviours, such as a 'wake-up call' to poor sleep behaviours, has been reported (676), and also as a general 'awakening' to improve health habits (560). This is important as it shows the positive effect of the intervention on daily PA, as well as other health behaviours. An accumulation of PA throughout the day is advocated in the new WHO PA and SB guidelines (294), that state that all movement counts towards overall PA levels and recommendations to achieve health benefits.

Furthermore, the findings of this research strengthen previous research highlighting the value of adopting a gender-sensitive approach to engage and retain men in health promotion interventions (552,633). The evidence provided by Study 3 adds to the literature by investigating previously untested intrapersonal gender-sensitive techniques in a workplace intervention to reduce SB, in particular, knowledge and awareness, and goal-setting. The findings build on growing evidence supporting recommendations on the importance of accounting for gender-related influences in the development and implementation of health promotion programmes for men.

5.8.2.2 Interpersonal components

At an interpersonal level, the social influence of the intervention was deemed a strong facilitator to increasing pedalling time. The mechanism of action - social influence - was targeted in this intervention using behaviour change strategies such as restructuring the social environment and social comparison (719). The observation of peers engaging in the intervention, was perceived as a strong 'catalyst' to increase PA. Observational learning refers to how individuals learn behaviours from observing others and their beliefs of how their behaviour is perceived, and is a construct of SCT (720). Co-participants' behaviour acted as a prompt to movement and 'triggered' pedalling activity. This appears to have been more than a simple prompt, as the importance of collegiality was expressed. A sense of peer pressure and social support encouraged PA. Employees learn and conform to the behaviour of the majority and are concerned about how behaviour outside of this norm is perceived, suggesting that observational learning is important to SB. O'Dolan et al. (675) reported that observational learning was an important construct to reducing SB in bank employees.

Social comparison using friendly competition was a key part of the intervention design and this strategy tapped into some participants' natural instinct to be competitive. Websites and mobile apps can provide a medium for social support and friendly competition in corporate team-based programmes where teams of male peers can compare their progress using a virtual platform (554,721). Competition can improve wear compliance of activity trackers (492), which was found in the present study where minimal removals of the watch were recorded. Employees used other PA information collected on the Garmin watch as scope for competition, such as the accrual of daily steps. Stephenson et al. (722) highlighted concerns using competition as a behaviour change strategy as those at the top or bottom of the scoreboard may draw unwanted attention. This did not emerge in the findings of the present study. Although some participants did not engage with the Connect platform, many found the strategies of self-monitoring, and social comparison via the competition element to be a 'driver of incremental activity' throughout the day - not only at work.

Social comparison at an organisational level in terms of being seen as a modern and forward-thinking workplace was also important. This wider community impression of the type of employer that an organisation is, has been previously reported (723), and is described as an advantage to be seen as a progressive and supportive working environment, and may be an effective strategy to recruiting employers to future intervention studies.

A sense of togetherness between participants was fostered within each worksite. Participants

enjoyed the 'buddy vibe' and was noted by both managers and employees. This togetherness and social support of others engaging in the intervention resulted in a reduction of self-consciousness. This was important in terms of normative behaviours, a concern outlined in Study 2, where employees did not want to be perceived as 'weird'. Some pressure in terms of social norms was perceived by participants in the study. Amusement from other employees not involved in the project, as well as comments centring on the pedal machine, were perceived by participants. However, participants were not deterred from their activity from this social pressure. Participants were comfortable in the intervention activity, and through a sense of shared activity, the behaviour was perceived as normative to them. This illustrates that within each worksite the requisite number of people were involved in the study to enable a group effect.

The intervention topic and components also provided an opportunity for social interaction throughout the worksites for many participants. Dutta et al. (630) reported an increase in 'social energy' and face-to-face interaction of employees using sit-stand desks, however, in the present study the relatively new topic of SB in general and the study in particular, were used as an interesting topic of conversation 'around the kettle'. The novelty of the pedal machine was a point of conversation that participants enjoyed. This was particularly expressed from a management perspective. A reason for this could be that in the social norms of the workplace, hierarchical structures may inhibit more relaxed conversation, and the intervention provided a shared topic that was common across work roles.

The strength of the influence of social environment reflected in the findings of this study is supported by the literature (427,566,567,622), and indicates that social relations are of the utmost importance in influencing men's behaviour. This can increase compliance to workplace interventions centred on physical activity (616), and SB as found in the present study. Furthermore, although in some workplace interventions poor social relationships may be a psychological barrier to participation, by contrast, reducing SB and increasing PA together with good colleagues in a positive atmosphere has been found to be a motivating factor for participation (623). As psychosocial work factors are modifiable through appropriate workplace interventions, the potential is available to harness these psychosocial factors to researchers' advantage, and to improve adherence to interventions by ensuring social support and a sense of 'togetherness' when implementing interventions. In the social workplace environment, in particular, the presence and actions of others has the potential to support or deter behaviours (451,655,724). Changing what is considered normal behaviour within a workplace setting is likely to be key to facilitating large-scale behavioural change to reduce SB

and increase LPA. This would involve cultural change not only in terms of individual behaviour, but just as important are the environment, policies, leadership, and individual beliefs.

The results of this research build on previous research advocating the incorporation of a gender-sensitive approach in recruiting men in health promotion interventions, especially at the social and interpersonal level (552,633). Study 3 adds to the literature by investigating previously untested gender-sensitive interpersonal techniques in a workplace setting to reduce SB and strengthens the argument for adopting a gender-specific lens in intervention development and implementation in behaviour change interventions.

5.8.2.3 Environmental component

The study highlighted several areas for improvement, in particular with regards to the ergonomic set-up of the pedal-machine. Participants expressed a sense of enjoyment in participating in the study, and of pedalling the under-desk machine in particular. This enjoyment was experienced, however, on the basis of a comfortable set up of the pedal machine within the participants' office workstation. Significant difficulties were reported in attaining a position to allow pedalling behaviours without knocking their knees on the desks, reflected in previous studies (484,725). Anthropometric measurements and variability from user preferences have been utilised, and recommended adjustable ranges of workstation settings for this type of pedal machine have been derived (637). Dimensions obtained from the worksites in the development phase, outlined that the height from floor to desktop had the adjustability required to use the Deskcycle™, however, participants found it difficult to overcome this in some cases. This is possibly as a result of the participants being male who tend to be taller, thus increasing the difficulty of the set-up. It was suggested that greater assistance is provided to participants to enable an ergonomic and comfortable position to be established for future studies using this device. Using height-adjustable desks with greater adjustability may allow more leg clearance space for cycling comfortably (726). Participants acknowledged that a time period was required to solve the issues with the pedal machine. Despite the barriers to pedalling, participants endeavoured to achieve their cycling goals, demonstrating resilience and perseverance.

The pedal machine elicited mixed findings in terms of musculoskeletal outcomes. Lower back pain was experienced by one participant when pedalling the machine, however, it was acknowledged that this was due to incorrect ergonomic set up. The problem was solved in this instance by turning to one side at the work desk to pedal and conducting work tasks such as

reading a document. Other participants experienced some reduction of musculoskeletal discomfort of the legs when using the pedal machine by increasing gentle leg movement. A reduction of neck and back pain was also described following the intervention period. Prolonged static sitting increases musculoskeletal issues such as low back pain (727). Replacing sitting with cycling, with the movement it creates, may assist in addressing some of the musculoskeletal issues with prolonged static sitting. A previous study reported significant increases in knee and ankle/foot pain using this type of under desk machine in mostly women (726). No reports of this type of pain or discomfort were noted in the present study. The findings are therefore of value to understanding musculoskeletal outcomes from using this pedal machine in males.

Using the pedal machine as a replacement at times when other types of PA were not feasible was observed by participants. For example, in times of inclement weather, when walking was not desirable, the pedal machine was used as an alternative. This finding has also been reported in previous studies (483). This highlights the benefit and convenience of this type of device in a workplace setting enabling new forms of occupational PA to overcome the frequently cited barrier of weather conditions to workplace PA (491,604,723).

5.8.2.4 Organisational component

Managers in particular placed value on the privacy element of the under-desk machine. A previous study found that participants self-reported feeling comfortable cycling in the presence of others (483), however, the participants were not described as professional, and were mostly female. This highlights the value of exploring themes qualitatively to enable in-depth exploration where differing viewpoints in different occupational roles may emerge. These findings highlight various elements of the intervention being potentially valuable to future specific target populations.

From a management perspective the intervention was deemed to not adversely impact productivity. Managers were conscious of how employees would negotiate participation in the intervention and how this may impact on the conduct of their work tasks. One manager discretely checked on the employees, and deemed the intervention to be acceptable, and not impacting negatively on work output. Light intensity cycling time is therefore achievable at certain times of the day and when conducting particular work tasks. These further compounds the premise of the suitability of the target of light intensity activity in the design of the intervention.

The Garmin Connect platform elicited mixed results, with interest and enjoyment of the statistics available to participants. The goal setting and self-monitoring elements were described as having value. The move bar on the Garmin watch prompted significant movement throughout the day and in the evening time. Participants described being prompted to engage in PA as a result of the move bar notifications. However, the technology of the process of recording pedalling time on the watch was a significant barrier. The burden of stopping and starting the recording on the watch was prohibitive to participants. Although this method was included in the intervention as a way of increasing participants' awareness of their pedalling behaviour, participant burden of this action was reported as not acceptable in the longer term. The fast-moving pace of technology development means that this process will likely be available in a simpler format for future trials.

The results from the implementation questionnaires demonstrated that the intervention was mostly viewed favourably by managers and employees. In terms of the acceptability of the intervention, the percentage of agree/completely agree responses ranged from 53% to 76% across all four statements. Defined by Proctor and colleagues (692) as 'the perception among implementation stakeholders that a given treatment, service, practice, or innovation is agreeable, palatable, or satisfactory, (pg. 67), perceived acceptability amongst participants was possibly influenced by the men's positive experience of the intervention and its associated benefits. This is slightly lower than previous findings in an intervention study to reduce SB in university students (67.9% to 72.6%) (728). As emerged in the qualitative feedback in Study 3, the enjoyable nature of the intervention was appreciated by the men, and the pedalling of the under-desk device was, in general, an acceptable method to reduce workplace SB. The reason for the slightly lower scores in the present study can be attributed to the set-up issues of the participants' workstations as highlighted in the qualitative barriers to the intervention.

In terms of the appropriateness of the intervention, there was a high level of agreement (58% to 76%). Appropriateness is defined as 'perceived fit, relevance or compatibility of the intervention or evidence-based practice for a given practice setting, provider, or consumer', (pg. 69) (692). The Cycle at work intervention was developed using a collaborative design process, whereby the views and opinions of the target population were actively sought in Study 2, to inform the intervention. The stakeholder contribution provided valuable insight and confirmed that the intervention components were context-appropriate in the workplace settings. The results are again slightly lower than previous studies (84.9%–93.4%) (728), which could be associated with set-up of the devices with the current desks in both worksites.

However, the highest frequency of disagree responses, were related to the feasibility statements, the highest being: 'The intervention seems easy to use' (38%). Feasibility is defined 'as the extent to which a new treatment, or an innovation, can be successfully used or carried out within a given agency or setting', (pg.69) (692). Consideration of the sometimes-uncomfortable set-up of the pedal machines for many participants can be said to have affected these responses. The results strengthen recent laboratory findings (637) regarding anthropomorphic considerations of desk clearance room required for comfortable use of the device, and highlight issues in a real-world setting. Despite this, the highest score (86%) of all statements across all three measures was 'The intervention seems possible'. It could be argued that this reflects the overall user experience of the intervention and its individual components as being positive, and with the noted issues considered and resolved in terms of the set-up and watch technology, future iterations may be possible and feasible.

Key physical outcomes such as chronic disease morbidity and mortality and their relationship with SB are of great importance to public health. These health indicators have been extensively summarised in the Physical Activity Guidelines Advisory Committee 2018 (11), however, they do not represent the full scope of human health and wellness. Until recently (145), no comprehensive review of the evidence has been undertaken on the relationship between SB and other important health indicators such as mental health, productivity and musculoskeletal effects of prolonged SB. Therefore, included in Study 3 was an investigation of how the men anticipated the intervention would impact on these health indicators, and furthermore, how they perceived the impact of participating in the intervention at follow up.

The mental health effect of the intervention was viewed favourably by the men, with agreement both that the intervention *would* benefit mental health, and further 'agreed' that it *did* benefit mental health at follow-up. This demonstrates the potential mental health and wellbeing benefits from this type of workplace intervention to reduce SB and increase LPA. These results strengthen the positive findings within the mixed evidence reported in a recent literature review investigating the effectiveness of workplace interventions on well-being (729). The findings also add to the literature suggesting the positive mental health impact of digital workplace interventions (730).

Participants rated the perceived benefit to work productivity as 'neutral' at follow up, compared to the anticipated positive improvement to work productivity prior to the intervention. Similar to the work engagement responses, the intervention did not produce a negative result. This is in line with previous studies have found that cycling workstations did

not reduce work productivity (731). Although the score in the present study did decrease from pre- to post intervention, the 'neutral' response represents that the intervention did not improve, nor did it reduce work productivity. This productivity result may be important as workplace cycling, compared with treadmill and standing workstations, allows employees to experience greater cardiometabolic gains, therefore it is important to maintain acceptable levels of productivity in work performance.

Similarly, the positive response to anticipated to improve back/neck pain as a result of the intervention reduced to a 'neutral' score. Although the reduction in scores reduced from pre- to post intervention time points, it can be argued that this may be interpreted to mean that although participating in the intervention did not improve neck/back pain, it importantly did not induce back/neck pain. The evidence is mixed regarding the association of musculoskeletal issues and prolonged stationary sitting (732,733). Similarly, conflicting results have been reported as to what impact, if any, strategies used in SB reduction interventions have on musculoskeletal symptoms, or in terms of participant comfort, or the health benefits associated with each strategy (339,418,734,735). The results of Study 3 add to the literature in terms of physical and mental effects, as well as work productivity, using the provision of a pedal machine in an intervention with professional men.

5.8.3 Recruitment and retention

Recruitment of professional men was possible, however, only 73.3% of the target sample outlined in the protocol were recruited to the intervention. This rate is significantly higher than reported in feasibility studies with similar aims (56%) of predominantly women participants (675). Retention in the study was very good (95%), also higher than retention rates reported in similar studies (86%) (675). This strengthens the assertion that initial contact with employers is the largest barrier to recruitment and could be improved by the education of the employers to the benefits of their employees participating in workplace SB reduction interventions. In terms of recruitment of increased numbers of worksites, as recruitment, rather than retention was the issue, future intervention studies may wish to consider using multiple sites so that the sample size may be increased.

These results strengthen the assertion that gender-sensitive interventions that target men may result in increased recruitment and retention rates to intervention studies, as mixed-gender programmes sometimes fail to energise men (680). Furthermore, the findings extend previous

findings where gender-sensitive programmes were found to be acceptable and feasible in rural workplaces (680), to highlight the potential of these type of interventions in urban locations.

5.8.4 Data completeness

The ecological momentary assessment (EMA) method in its current form may not be feasible due to the significant level of incomplete data. Some technical issues regarding the uploading of data files to the PIEL survey app were reported. Significant missing data in the intervention and control periods indicated that this EMA app may not be feasible for future studies without modification. The findings highlighted that the PIEL survey app may not have been entirely intuitive to participants. The use of participants' own smartphone introduced significant variability to technical issues that needed to be resolved by the researcher. This resulted in a substantial number of data files not being uploaded to the app, thus lost to the study.

From a participant response perspective, the EMA contributed to an awareness and insight into the men's high levels of SB. This sometimes-prompted movement, as the notifications acted as a reminder of participants' sedentariness. However, a strong sense of frustration was expressed due to the frequency of affirming sedentary behaviour in the surveys throughout the study period. This repetitiveness of responses may have resulted in some participants opting out or not responding to surveys. A second frustration, due to the nature of physical activity whereby participants did not carry their smartphones while being active, resulted in the inability of participants to demonstrate times of activity. The timeout period of twenty minutes for each notification, which was requisite for the 'momentary' aspect of the survey, was another source of frustration. Further challenges to using EMA included the high frequency of notifications, and the list of activities within each survey was not exhaustive. These challenges and limitations have been previously reported (247). However, the level of missing data in the present study was significantly higher compared to previous studies that reported high (>80%) compliance rates in older adults using EMA protocols (245,736,737). This may be due to the previous studies including older adults and not being conducted in a workplace setting which may, by its nature result in a higher burden to participants who are busy with work tasks. One of the studies employed four daily notifications as opposed to the current study's six notifications, which may reduce response burden (737). Engelen et al. (241) reported a 58% response rate in an academic workplace setting using four notifications per day over a 5-day period. The results are also considerably lower than the rates of >80% response rates mentioned previously. Providing participants with a separate smartphone

already loaded with the EMA protocol may also significantly reduce participant burden due to technical problems and software malfunctions (245,737).

Although a number of issues raised by participants are fundamental to the methodology of EMA - for example the time-out period – the participant burden of using this app resulted in significant missing data, particularly in the control period. Future studies should explicitly educate participants in the aims and objectives of EMA, that is, that EMA methodology is concerned primarily with contextual information regarding PA and SB. Ensuring that participants are aware that actual levels of PA and SB are recorded using the objective measures throughout the study duration may increase response rates and reduce negative reactions. Future studies could consider measuring affective states, behavioural cognitions, or the physical context, which as well as providing relevant data with regards to psychological affects surrounding SB, may be more interesting to participants to answer and result in greater compliance.

As highlighted by Goyder and colleagues (738), reporting of data completeness is an integral part of clinical trial and intervention reporting. Hence, the summary of data completeness is shown on a CONSORT flow chart from participants' enrolment, and at all time points in the study. To inform progression criteria, Avery et al. (739) advocate that assessing rates of completeness of outcome data is useful and important. The completeness of the main-trial related outcome data collected was very high in the intervention period (95%), and high in the control (81%). Overall, this would indicate a 'green' situation as per the stated progression criteria. In assessing the reasons for missing data using the ActivPAL3, it is determined that the issues could be resolved in a future trial. Given that the majority of removals were prompted by travelling through airports, ensuring that participants are aware that ActivPAL3 devices do not trigger security alarms could resolve non-wear periods as found in this study.

5.8.5 Evaluation of potential intervention effectiveness

The secondary aim of the study was to assess potential intervention effectiveness using accelerometry data to investigate if minutes spent sedentary, standing, and engaged in physical activity differed in the intervention period compared to the control period. At baseline, participants (n= 20) spent on average 10.33 ± 1.76 hours per day of their waking hours (mean \pm SD) engaged in sedentary behaviour. During working hours, the average duration of SB, the men engaged in was 6.72 ± 1.85 hours per working day. These indicative findings are significantly higher than findings reported Study 1 where total self-reported sitting

time 7.9 ± 3.35 hours per day, and overall workplace sitting was reported as 3.25 hours per day (SD 2.76); however, those in professional roles reported 8.29 (3.2) hours per day total sitting time. These findings strengthen the literature demonstrating that males (324), in desk-based or white collar employment have been engaged in dangerous levels of SB (323–325).

Although the present study was not powered to conduct inferential statistics, an indicative difference of -45.7 minutes per total weekday and -20.4 minutes per workday in sedentary behaviour was found in the intervention period compared to the control period. This is similar to a previous multicomponent intervention that reported 58.7 minutes reduction of daily SB with predominantly women (90%) using a pedal machine and technology by providing access to a motivational website (484). Similarly the current study finding of 27.1 minutes per day reported cycling time is in line with Carr et al. (484) participants who cycled 31.1 min/day. Importantly, the present intervention enabled an increase in workplace activity, without a compensatory decrease in PA for the remainder of the day. No differences in ambulatory PA were detected between the control and intervention periods measured using the activPAL3 device. This suggests that overall daily PA did not decrease as a result of pedalling the machine during the working day. The activPAL3 detects ambulatory PA, whereas the participants' cycling times were objectively measured using the Garmin watches, and uploaded to the associated website, Garmin Connect. This data was verified by the researcher to ensure constant cadence was achieved in each bout of pedalling (i.e. movement of the pedals was continuous in each recorded bout). This suggests that the LPA achieved in the intervention period, centred on the pedal device. A decline in cycling times from the first week to the second week of the intervention was however observed. The results from the qualitative data may somewhat explain this steady decline, with significant burden reported in terms of the recording of the cycling bouts by the participants using the Garmin watch. Although this method was used a self-monitoring technique, this was potentially overly burdensome in a busy professional workplace. Future studies would be required to provide improved automatic technology to the record bouts of cycling to allow participants to start and stop whenever it was suitable for them in their working day.

Danquah et al. (470) tested a multicomponent intervention targeting individual using workshops, texts and emails, environmental (e.g.. installation of high meeting tables) and organisational support to reduce SB by increasing standing. They reported that SB was reduced by 71 minutes (1 month follow up, -48 minutes at 3 months) per workday and replaced by 64 minutes standing time (43 minutes at 3 months follow up). In the present study, participants in the intervention group increased daily standing time by 23.2 minutes (+14.7 minutes

workday standing). The findings of Study 3 demonstrate that the Cycle at work intervention increased LPA (pedalling) to a potentially clinically meaningful level (27.1 minutes) and increased standing time without impacting on overall ambulatory PA levels.

Overall, in terms of protocol adherence, 67% of participants achieved more than two thirds of the daily cycling goal (>20 minutes), however, this reduced as the intervention period progressed. This finding is similar to adherence reported by Peterman et al. (663). The indicative findings suggest that a multilevel approach using behaviour change strategies with the provision of an under-desk pedal machine and ensuring organisational support may help to reduce workplace SB by increasing light intensity physical activity in professional men. This requires testing in a future trial of larger and more diverse populations to ascertain effectiveness outcomes.

Although significant levels of EMA data was missing, particularly in the control group, there were differences in types of self-reported PA between the intervention and the control groups. An overall increase of 25% PA was reported in the intervention period. This was divided between an increase of 12.5% in under-desk pedalling, 5.4% cycling, and 7.1% of the survey responses indicated cardiovascular equipment use. Although self-reported walking reduced by 16% in the intervention period, the overall increase of 25% of PA mirrors the objective findings of no overall important differences in PA between the periods. The use of the EMA provides interesting information on the categories of PA engaged in by participants that can be used to provide a broader understanding of intervention effects in terms of PA types. The EMA and objective measures did not differ greatly in terms of overall levels of PA between intervention periods and strengthens previous similar findings using EMA in workplace settings (241,740)

Despite a reduction in occupational SB in the intervention period, there were no changes observed in the trial-related outcome, work engagement. A recent study reported similar results where no changes in work productivity together with an decrease of workplace SB were found after six months (741). The authors pointed out that the intervention may not have had a positive effect on work engagement but reducing SB did not produce a negative effect on these work-related outcomes, i.e. less vigour, absorption, or dedication at work. It could therefore be argued that no changes in the measure can be interpreted as a positive finding, i.e. participants were equally engaged in their work, and did not experience workplace fatigue even though they were reducing their SB by pedalling. This is important because worker wellbeing (698), and in particular, onset on major depressive episodes among employees (742) can be predicted by work engagement. Shimazu and colleagues (743) demonstrated that work

engagement was related to a decrease in ill-health and to increases in life satisfaction and job performance. It may be optimistic to expect that a short-term intervention using a pedal machine would have a significant positive effect on work engagement outcomes. More important latent factors of an individual's occupation may produce a greater contribution to feelings of investment and/or enthusiasm in work, such as fair compensation or recognition of one's work, or result in fatigue due to unrealistic work demands causing stress, or a lack of support or control over one's work. However, long-term positive changes in work engagement have been associated with multicomponent interventions with the provision of sit-stand desks after six months (724). Conversely, multicomponent interventions that did not restructure the proximal environment of participants did not report significant changes in work-related outcomes (454,467). However, Torbeyns and colleagues (744) reported an increase in work engagement at 5-month follow up in a study using a bike-desk. This is important as it shows that the provision of bike desks in the workplace could not only contribute to improving employees' physical but also mental health.

The findings of Study 3 demonstrate similar work engagement outcomes when using a pedal device to reduce SB compared with other multicomponent studies using sit-stand workstations, but somewhat lower than the intervention using bike-desks. It is still therefore unclear whether meaningful changes in these work-related outcomes can be expected for interventions targeting reductions in SB by increasing LPA using a pedal device in a workplace setting. Testing Cycle at Work over a longer time frame is required to understand the long-term impacts of this intervention on work engagement.

5.9 Strengths and Limitations

The main strength of this study was the use of mixed methods evaluation using quantitative and qualitative data. The key advantage of this being the qualitative evaluation allowed for the exploration of important insights from a user perspective. For example, reasons why individuals did not answer the EMA prompts, were explored in the qualitative work. Another major strength was guidance by the socio-ecological model and incorporated behaviour change strategies used in the development and evaluation of the intervention. Objective measures of SB and PA were collected using a device-based instrument. By exploring the acceptability of a multicomponent intervention of professional men, including varying roles such as employees, managers, and managing partners, practical improvements to the

intervention were ascertained, which could be incorporated to inform the development of a fully powered cluster RCT.

The results of the pilot study should be interpreted in the context of several limitations, of note is the small sample size. The sample size target was also not met. The use of the waitlist crossover design had the benefit of participants acting as their own controls and reduced the between group differences. However, it is unlikely that the washout period negated the effects of the education regarding the dangers of SB, and thereby possibly impacted behaviour in the control period. It could be argued that participants who consented to participate were more motivated than the general population to reduce their sedentary behaviour, indicating selection bias. Overly positive feedback in the qualitative work may have been given from participants, due to researcher-participant relationships that evolved over the course of the study duration. However, given the many and various issues that arose in the evaluation indicate that this is not the case. Similarly, the use of participant reported outcomes for acceptability, feasibility and appropriateness data may have been answered in a biased manner, however, this is also is not thought to be the case given the modest scores. Although it was not possible to blind the participants and researchers due to the nature of the trial, the use of objective device-based outcome measures minimises researcher bias. A limitation was that there was not the requisite time available to return to the participants for feedback on the findings. Cluster randomisation was used to minimise contamination between groups, however, as found in the results of Study 3, neighbouring colleagues influenced behaviours; thus, it may not be that SB reduction was solely the impact of the intervention.

The findings enhance the knowledge base, and highlight the opportunities and challenges met in the process of conducting this research which may be of benefit to future investigators in this topic area.

5.10 Conclusion and Recommendations

The results of this study suggest that it is somewhat acceptable and feasible to implement a theory-led multicomponent gender-sensitised intervention to reduce SB and increase LPA in a workplace setting with professional men. The Cycle at work intervention has the potential to elicit change in SB and LPA, however, a larger RCT is required to confirm these findings. Any future trial of this intervention should consider the recommendations of this evaluation and carefully consider the ergonomic set up, the technology used to record the cycling bouts, and include a personalised approach before being used on a larger scale to reduce occupational SB.

Chapter 6 Discussion

6.1 Introduction and Main Findings

The high prevalence of sedentary behaviour and physical inactivity indicates a significant and widespread threat to population health (Chapter 2, Sections 2.7 & 2.8). When individuals engage in prolonged sedentary behaviour, alterations in metabolic pathways resulting in metabolic inflexibility occur independently of measurable changes in energy expenditure (15). Interventions can be effective to reduce sedentary behaviour (SB) and increase physical activity (PA) in highly sedentary settings such as office workplaces (52). This underlines the importance of enabling employees to reduce health risks through health promoting behaviours. The main aims of this PhD research were to investigate the prevalence and patterns of SB in an Irish adult cohort, and to test the acceptability and feasibility of a multicomponent intervention to reduce occupational SB in professional male employees and managers. In order to meet this aim, an evidence informed, iterative process was undertaken, which is displayed in Figure 27. The socio-ecological model informed and guided all stages of the research. The findings support the contention that the magnitude and direction of changes in behaviour depend on the interaction of the intervention with other influences on behaviour within the intervention context. Efficacy, therefore, is not straightforwardly inherent within behaviour change interventions. The evidence in this thesis, in line with the Medical Research Council guidelines for best practice in developing complex interventions (412,413), established the acceptability and feasibility of an intervention which aimed to reduce workplace SB by replacing it with light-intensity physical activity (LPA). The findings identified key methodological and implementation factors to be addressed prior to further effectiveness assessments in any definitive cluster randomised controlled trial.

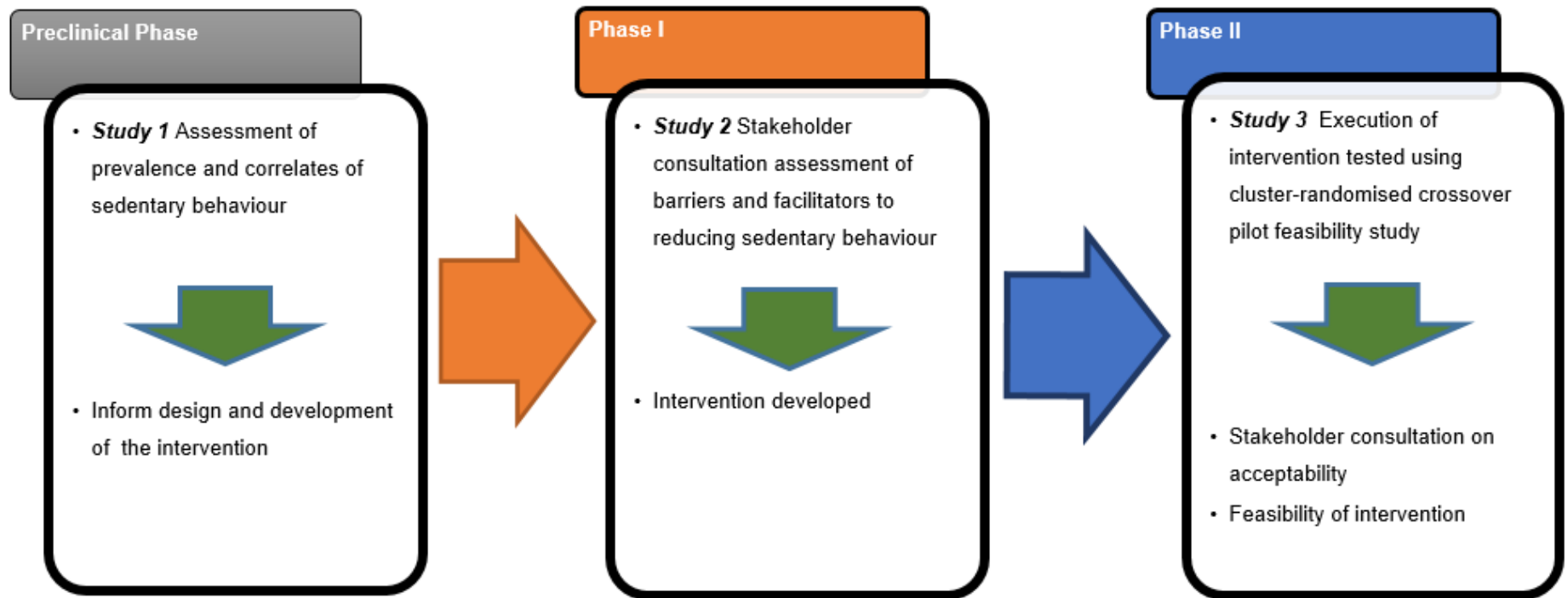


Figure 27 Studies involved in overall PhD research project

Detailed discussions, the rationale for conducting each of the studies, and the findings have been presented in Chapter 3 (Study 1), Chapter 4 (Study 2), and Chapter 5 (Study 3). The main results are outlined briefly in the following section, followed by an integrated discussion of the key findings, the strengths and limitations of the work, implications for practice and policy, considerations for future research, and conclusions.

Study 1 addressed Research Question 1 - what was the prevalence and correlates of domain-specific sedentary behaviour in Irish adults? The aim of the study was to provide evidence for the target population and setting for the intervention. The results, presented in Chapter 3, suggested that Irish adults spend worryingly long periods engaged in sitting behaviour, more than 7.5 hours per day. In investigating the contexts in which sitting time accumulates across the day, most sitting was accrued while working (195 ± 166 minutes per day). The strongest predictors of occupational sitting time were urban living (compared with those in rural locations) and those of higher socio-economic status (OR 1.96 [95% CI: 1.67-2.30, $p < .0001$], OR 2.20 [95% CI: 1.87-2.58, $p < .0001$], respectively). Those of male gender (OR 1.27 [95% CI: 1.08-1.50, $p < .0001$]), with higher educational attainment (OR 1.57 [95% CI: 1.33-1.84, $p < .0001$]), who engaged in low levels of physical activity (OR 1.55 [95% CI: 1.33-1.80, $p < .0001$]) and younger age-groups ($p < .0001$) were more likely to engage in long occupational sitting times.

Study 2 centred on the development of an intervention to reduce SB, and addressed Research Question 2 - what were the barriers and facilitators to reducing SB in the context of those most at risk? The study aimed to explore the perceptions of male employees, managers and managing partners to provide an understanding of the context-specific barriers and facilitators to reducing workplace SB. The most important barriers to reducing SB were the primacy of work, with a manager expressing that they *'have to get through your day's work right so that's the reality at the end of the day'*, and a concern regarding productivity, *'there's no incentive to me to get up and go and walk around the building because it's detrimental to my work'*. Entrenched, and the *'default habit'* of being sedentary were expressed by many participants, where *'by the nature of the work...the immediate mind-set is seat bound'*.

Powerful social and cultural barriers to reduce occupational SB included negative judgement of colleagues in terms of acting outside of group norms, for example, *'if you were in meeting like this and across this big table and try and stand, that just looks a bit weird'*. Being perceived as avoiding work emerged as a barrier, with employees acknowledging cases where individuals previously observed going out for a walk would be seen as *'taking liberties'* and *'a stigma'* may

be attached to this practice. Managers also expressed a requirement that employees be present in the office during working hours or may risk, *'the place is like a ghost town, it would look like a productivity problem'*. Being sedentary was the accepted normative behaviour in both worksites recruited to the study, *'we inevitably default to sit down because that's just what most people do'*.

Social support and modelling behaviour by management were deemed important enablers to the men's reduction of workplace SB. The managers supported their employees in health improvement endeavours, as it was expressed that management *'encourage us to do various things to achieve that and make us happier, if you're happier and you're healthier'*, a sentiment acknowledged by many employees.

Combining sedentary work with low intensity physical activity allowed the men to be observed at their workstation and to continue their work tasks, and was a strong facilitator to reduce SB that emerged in the findings, *'things you can do while you're at your desk, while still getting through your work, [I would] 100% be behind it'*.

Study 2 also addressed Research Question 3 - what were the perceptions and views of the target population of the components of a workplace intervention guided by the socio-ecological model of SB; and whether these components were acceptable and context-appropriate? The aim of this work was to ensure that the intervention was suitable for the specific contexts, and to engage the target group in the intervention development process. The under-desk pedal machine was deemed appropriate; *'it's a very good idea. It's very subtle'*.

The consensus overall was that the men were happy to take part in the study, that the intervention was context-appropriate, and was anticipated to be beneficial and effective to help reduce their workplace SB, and the measures were deemed *'not invasive in your life or in your working day and stuff like that so I can't see any barriers, I can only see benefits to be honest'*. The findings of Study 2 were used to inform Study 3.

The aim of Study 3 was to address Research Question 4; was a multi-component theory-led workplace intervention to reduce SB by increasing LPA, acceptable and feasible to professional males? Its primary aim was to address key design uncertainties, including the feasibility of recruiting eligible participants in terms of recruitment and retention, as well as the appropriateness, acceptability, and feasibility of the intervention. These outcomes were assessed qualitatively and quantitatively. Potential effectiveness of the intervention was

measured objectively using accelerometry data and using self-reported EMA data; cycling times were objectively measured using the Garmin watch. All measures and trial processes of the cluster randomised crossover design were deemed acceptable to this target group, as found in the qualitative component of the evaluation, although some intervention fatigue was noted towards the end of the study period. In terms of the feasibility outcomes, recruitment of clusters to this intervention was to some extent possible (40% of worksites approached were recruited). Recruitment of the professional men was possible, although only 73.3% of the target sample outlined in the protocol were recruited to the study. Of those recruited, retention was very good, with 95% of the men remaining in the study until the follow up measurements. In terms completeness of data, the secondary outcome measures pertaining to the main trial-related objective (activPAL3), and self-reported (UWES-9) outcome data were sufficiently usable and collected at all time points in the study. A large amount of EMA data were missing, and participants found this overly burdensome in its current format.

In evaluating the intervention, the qualitative data captured a sense of enjoyment from many participants who expressed that it was *'quite a nice thing to have done'* when pedalling bouts were achieved. However, this enjoyment was based on the comfortable ergonomic set-up of the pedal machine, which emerged as a major barrier to some participants' pedalling behaviour and in some cases, *'the set up too hard to overcome'* with participants experiencing *'banging knees on the desk'*. The main individual level facilitator to SB reduction was the awareness of the dangers associated with prolonged workplace SB as noted; *'general awareness and creating consciousness about how sedentary we are was definitely a good prompter to move or do something'*.

The sense of togetherness and *'buddy vibe'* was appreciated by those in both employee and management roles. Managers perceived that productivity was not negatively impacted as a result of pedalling in the intervention period, *'I have to say they were doing it as they were working'*. From an employee perspective some tasks were affected by pedalling, *'actually getting in and doing it was a challenge'*, although over time this appeared to be overcome, *'if you're doing it slowly you kind of can manage it'*.

The results of this study suggested that it was feasible and acceptable to implement a theory-led multicomponent intervention to reduce SB and increase LPA in a workplace setting with professional men. Various issues and considerations were highlighted that would need to be resolved in any future trial assessing effectiveness, such technological equipment improvements and assistance with the desk set up. The following section is a discussion and integration of the main findings of the research within the broader literature.

6.2 Discussion and Integration of Key Findings

In the discussion of Study 1, the risk factors associated with increased sitting times were discussed in the context of international research of prevalence, correlates, and domains of SB (Chapter 3, Section 1.4). The total sitting time of >7.5 hours per day was significantly higher than a previous report of 5 hours per day sitting time (366). Baseline objective measures of sedentary behaviour in Study 3 revealed high levels of SB engaged in by the professional men; 6.7 hours/day and 10.3 hours/day of occupational and total daily SB respectively. The findings of the research in this PhD strengthen previous evidence that males (323), and those in white-collar occupations and managers (366) engage in prolonged occupational sitting times and are at high risk of the associated deleterious health outcomes. In particular, males were 32% more likely to engage in longer total sitting, and 27% more likely to engage in longer occupational sitting times. This data suggests that professional male workers are an important target population at risk of serious health outcomes as a result of prolonged SB. The gender-focused research priority used in this PhD is supported by the World Health Organisation (583) 'Regional Committee for Europe Strategy on the health and well-being of men in the WHO European Region' as described in Chapter 5 Section 5.2.12.

Best practice recommendations for developing and evaluating complex interventions outlined by the MRC (412,413) advocate qualitative exploration to understand the specific barriers and facilitators to reduce workplace SB in the target population, to observe the real-life context of the intended intervention. Heretofore, a lack of evidence was available of the barriers and facilitators to reducing SB in professional men. To bridge this identified gap in the literature, Study 2 explored the views of male professional employees, managers, and managing partners with regard to workplace SB reduction. The participative approach used to inform the intervention tested in Study 3, engaged employees to develop a sense of ownership and commitment to change. The managers and employees were involved in the discussion of suggested strategies at the development stage of intervention planning, and this provided the men with an opportunity to give feedback and input to each of the intervention components, and to the study processes overall. This collaborative approach is likely to have contributed to participants' willingness to try using the under-desk pedal devices. In contrast, varying degrees of uptake have been reported where a top-down approach was adopted in which management decided to install a combination of electrically powered and manually operated sit-stand workstations for all employees in an office refurbishment, with little information provided on how to use the new desks (475). The successful uptake of environmental modifications (sit-stand desks) has been reported in a previous study using a collaborative

approach (571). This echoes with situations where researchers educated on the dangers of prolonged SB, and were supportive of sit-stand workstations, applied the intervention in a workplace with management support already in place (571,648). The findings of Study 3 strengthen the assertion that participatory approaches ensure a match between the target group and the strategies implemented to enable a reduction of SB with a replacement of LPA (683). The approach taken in this PhD research meant that the findings garnered from Study 2 were integrated to shape, inform, and confirm the design of the intervention to be tested in Study 3. This ensured that the components of the intervention were deemed acceptable and relevant to the key stakeholder (managers and employees) in each worksite, prior to the commencement of the pilot feasibility study. Participants could voice their opinions, in terms of what would work for them to reduce their SB, and this was observable to the managers and employees in the worksites by the incorporation of the findings to the final intervention design.

Multicomponent interventions using the socio-ecological framework

The design and evaluation of the Cycle at Work intervention were underpinned by the socio-ecological model (SEM). The findings strengthened evidence in support of the powerful influences on workplace SB that operate at an interpersonal, environmental, and organisational level, as well as the individual attitudes and behaviours. For example, the influence of group normative behaviours and perception of others were strong facilitators (or barriers) to reducing SB. Additionally, at an organisational level, management attitudes and modelling behaviours emerged as powerful facilitators to reducing occupational SB. The importance of targeting settings is acknowledged in the socio-ecological model, as behaviours tend to be embedded within certain contexts and within individuals' belief systems of appropriate and achievable behaviours (352,745). Although some authors (352) have acknowledged the impracticality of targeting all levels of influence and recommend focusing on two levels, the intervention in this PhD research targeted multiple important levels of influence. The findings provide evidence to support the utilisation of the socio-ecological model within behavioural change interventions as the themes that emerged of the important barriers and facilitators in Study 2, as well as the evaluation in Study 3, identified a range of influences on different levels that interacted to influence the intervention experience and behaviour change.

Results from Chapter 5 suggested that the multicomponent intervention using mHealth as a platform for targeting behaviour change strategies to prompt professional men to use the environmental strategy, a pedal machine, together with organisational support may maximise the success of these intervention methods. There is evidence to support the use of under-desk pedal machines used in conjunction with other behavioural intervention approaches (483,484), as well as recommendations on how to use them (637,667,725). As suggested in the qualitative data, behaviour change techniques that include self-regulatory strategies such as goal-setting and self-monitoring were useful facilitating factors to reducing SB in this population. Competition was a particularly valuable strategy to promote increased LPA and reduced SB in some of the professional men. However, a small minority indicated low interest in the social comparison BCT. This suggests that motivators to change behaviour likely differ between individuals. The findings are somewhat consistent with the masculinity-based literature centring on chronic disease prevention programmes which indicates the motivational appeal men place on group-based competition (746).

The inclusion of an organisational level target by recruiting management employees to participate in the intervention was successful to change the workplace cultural norms that moved away from an orientation of sedentariness, to new norms of LPA within the worksites. This further confirms the assertion by Healy et al. (45) that organisational support for reducing SB is essential for interventions to be successful. Furthermore, the results from this PhD research highlight that recruiting senior managers to participate in Studies 2 and 3, was a valuable strategy to create a supportive culture at the organisational level, which endorsed wellbeing values through modelling behaviour.

Social influence that included a sense of togetherness, fostered through the team-based component of the intervention, was described in Chapters 4 and 5 as a powerful behaviour change facilitating factor. The male-only groups within the broader workplace settings possibly supplemented this effect and was compounded by the requisite number of work colleagues in both worksites who participated in the intervention. The resulting group normative behaviour was sufficient to overcome self-consciousness and social judgement. The findings highlighted the importance of psychosocial work factors to working individuals. Importantly, the modifiable nature of these influences, through which appropriate strategies that ensure social support should be included when implementing workplace interventions. This further strengthens the argument for considerations to be made to foster and target social 'togetherness' by changing normative behaviours of cultural and social norms to improve the success of workplace interventions (61,676,677).

Findings from Chapters 4 and 5 showed that participants place priority on their work performance while in work, and do not want to be interrupted regularly by an intervention to reduce SB and increase LPA. Although the findings of Study 2 indicated that the components of the intervention were acceptable, results from Study 3 suggested a high user burden due to the requirement to manually record the pedalling bouts. Although this was incorporated into the intervention as a self-monitoring BCT, it was deemed excessively intrusive in the busy workplace settings.

Participants did not anticipate that the EMA would be burdensome, however, significant data were missing. Quantitative data provided information in terms of patterns of missing data, and the qualitative methods allowed further in-depth exploration of the users' experience of the EMA methods. Missing data were particularly high in the intervention period. The men experienced frustration due to the repetitiveness of the required response (i.e. their sedentariness), and this may have resulted in participants opting to not respond to surveys. The results of Study 3 provide contrasting findings to previous reports of high acceptability, feasibility and compliance of EMA methods in workplace settings (241,740). The level of missing data in the present study was significantly higher than previous studies reporting high (>80%) compliance rates in older adults using EMA protocols (245,736,737). This may have been due to the current study's professional workplace setting which, by its nature, have resulted in a higher burden to participants who are busy with work tasks. In one previous study, four daily notifications as opposed to the current study's six notifications, may have been a factor in the increased compliance (737). Engelen et al. (241) reported 58% response rate in an academic workplace setting also using four notifications per day over a 5-day period. Various considerations were made in Chapter 5 to improve the use of EMA in future trials in terms of technological and methodological advancements. These findings provide useful evidence and practical information in terms of EMA processes and survey content for future SB trials seeking to utilise this method. However, on reflection, where the aim is to collect useful data with the minimum burden for participants, it may be concluded that EMA is unsuitable for workplace intervention with professional men.

This section provided an integrated discussion of the findings of the studies in this thesis, including the performance of the socio-ecological theory as a framework for guidance throughout. The sections below describe the strengths as well as a critique of Studies 1, 2 and 3.

6.3 Strengths of the PhD research

Chapter 2 (Section 2.21) highlighted the importance of theory in developing and evaluation behaviour change interventions (413). A significant strength of this study was its grounding in a theoretical framework and the application of the socio-ecological model of sedentary behaviour (57), which provided guidance at all stages of the research process. This well-established model worked well with the Healthy Ireland dataset, guided the structure of the themes explored in Study 2, and framed the development of the multicomponent intervention tested in Study 3. The model represents a framework to examine a multitude of interconnected factors that influence behaviours. Highlighting, as well as providing an understanding of the important and many dynamic and interconnected influences of SB that transcend the individual to the social ecology, within which the individual operates and is impacted upon, is extremely valuable in building the characterisation of a behaviour. All of the studies in this thesis provided evidence to confirm that the intrapersonal, interpersonal, environmental, and organisational factors elucidated in the SEM were indeed important in the study of SB overall, and in particular, the context of occupational SB.

The strengths of Study 1 were: the generalisability of the results of a representative cohort, the comprehensive measure to calculate total sitting time, and the adoption of the socio-ecological model that extended the literature to provide an understanding of potential predictors of SB depending on the context.

The strengths of Study 2 included the provision of insights from the under-represented (in health promotion interventions) target population of professional males, and the involvement of key stakeholders - employees, managers and managing partners. Their voices provided a crucial understanding of the context-specific barriers and facilitators to reduce workplace SB, and an appreciation of the factors that motivate and encourage men's participation in intervention studies. Study 2 allowed the anticipation of issues, as well as a discussion of potential solutions, prior to the study commencement. Finally, the use of the socio-ecological model to structure the topic guide ensured a robust theoretical basis to the questioning that covered a wide range of behavioural influences.

In terms of the pilot feasibility study, this was the first to my knowledge to explore the acceptability and feasibility of a theoretically underpinned, gender-sensitised multicomponent SB intervention and associated evaluation, in a unique and challenging professional setting, recruiting a male-only sample. The study adopted a pragmatic approach to develop and implement a tailored multicomponent intervention in a real-life office setting and has real-

world applicability. Using best practice in the development and evaluation of the complex intervention in this PhD research, as recommended by the widely cited Medical Research Council Framework (413), was a major strength of this study. The mixed methods evaluation, engaging multiple important stakeholders to explore the acceptability and feasibility of the randomisation procedure, the recruitment strategy, data collection procedures, and intervention components has provided original knowledge to refine and justify the intervention. This will improve its likely effectiveness and sustainability if investigated in a future trial. Furthermore, the high retention rate suggested that the men were engaged in the study and committed to reduce their SB for the duration of the study period, although the study was short-term in design.

The thesis presents a formative, iterative and participatory approach to develop and evaluate an intervention to reduce SB in two workplace settings with those most at risk. A data driven process was adopted in this PhD research where each study informed and built on the next in a logical format. In particular, the participatory approach was a major strength in the development and evaluation of this intervention. This sequential formative testing and outcome evaluation enabled the end-users and stakeholders to inform the development process and ensured that the intervention was responsive to the users' needs and preferences and was context-appropriate. Target group input at the design stage contributed to the development of the intervention, and likely increased engagement and use of the under-desk pedal machines (571). At the evaluation stage, the qualitative findings highlighted practical and key considerations such as ergonomic set-up issues and the burden of manually recording the cycling bouts that would have arisen in a randomised pilot trial, so that they can be addressed prior to its commencement.

The gender-sensitive approach was a further strength of this study. Evidence suggests that health behaviours favoured by men differ from those of women (682). By recruiting urban workplaces and showing acceptability and feasibility in professional men participants, Study 3 demonstrated a gender-sensitive approach may be the most appropriate in targeting this group. Indicative results demonstrated that objectively measured total weekly SB was reduced by 228.5 minutes, and average cycling time summed to 135 minutes per week in the intervention period. The results suggest that gender-sensitised SB interventions may be a key development in men's health promotion and demonstrates potential for engaging this sometimes hard-to-reach group.

The often invisible and nuanced power of gender dynamics can inform how methodological decisions, as well as what is explored and found in qualitative data. This may be problematic due to the reinforcement of social norms (747). The behaviour change techniques employed in the study, as guided by the literature, sought to reinforce some traditional gender norms, however, it was not the aim of the researcher to reinforce structures of power, or unhelpful or undesirable stereotypical gender norms. While engaging in the process of self-reflection, it is noted that the men in the study may have behaved differently, or outcomes may have differed (positively or negatively), if the researcher was male (748). It is reflected and understood, within the findings of this PhD research, that pre-existing gender norms can unintentionally inform how, where and with whom, studies are conducted as well as how findings are interpreted (747). It is important that researchers remain self-critical and critical of well-worn methods and disrupt underlying inequities in research endeavours.

The cluster randomised controlled crossover pilot feasibility trial to target sedentary time as its main target, by replacement with light-intensity pedalling is among the first to be conducted and is a strength of the PhD research. The evaluation allowed assessment of key uncertainties to be investigated before a definitive cRCT. The cluster randomisation was used to minimise contamination between groups. This may, however, also mean that behavioural patterns in the intervention were influenced by neighbouring colleagues, which has been previously reported (675), rather than solely the impact of the intervention. The use of a valid and reliable objective measure of SB and PA, together with subjective ecologically valid measures of SB using EMA, allowed a fuller picture of participants' activity to emerge and provided complementary data when used collectively. Testing these methods from a user perspective informed significant improvements and considerations and may bolster data completion outcomes for future trials if these methods were to be employed.

Finally, the use of secondary analysis, focus groups, individual semi-structured interviews, and feasibility data produced an extensive and broad range of quantitative and qualitative data. The resulting integration of these methods demonstrates a further strength of this PhD research. Applying a pragmatic philosophy facilitated the selection of research methods emanating from different paradigms, which ultimately allowed the research aims and objectives to be met. In this PhD, the multistage mixed methods framework served to strengthen the rigour and enrich the analysis and findings of the thesis. This allowed the strengths of both qualitative and quantitative data to be combined, and a unified and fuller comprehension of the research problems to be achieved, beyond that of either approach alone.

6.4 Limitations of the PhD Research

The main limitation of Study 1 was the self-reported nature of the sitting-time measures in the Healthy Ireland survey, which may have led to issues of recall and social-desirability. Leisure-time and transportation sitting times were combined, and a lack of differentiation between weekdays and weekends (sitting patterns are different on weekends and weekdays) were further limitations in the study. Relevant measures such as BMI, and more detailed information on PA levels, as well as policy level correlates were not included in the data and precluded further examination of the relationship with and influence on SB in the study.

Study 2 presented several limitations. The strategies, as well as the barriers and facilitators that were generated in the focus groups and semi-structured interviews were, at times, based on hypothetical scenarios rather than lived experience. The education session also likely influenced the discussions. However, this was a necessary part of the study as it has been documented that insight and knowledge into the difference between SB and physical inactivity, and SB is a relatively new health risk factor is lacking in the general public (638). A convenience-based sample from two companies in Dublin was used, and it can be argued that, by taking part in the study, the participants were already motivated to reduce negative health consequences, and thus more interested to reduce their SB.

The results of the pilot study (Study 3) should also be interpreted in the context of several limitations. Although a cluster-randomised controlled trial with parallel groups was considered in this research, the crossover design was chosen as it had the benefit of participants acting as their own controls and reduced between-group differences. However, the education piece likely impacted on behaviour in the control period. The study design sought to minimise these effects through randomisation of the order (intervention in the first or second period), and implementation of a one-week 'washout' between periods to minimise carry-over effects. It is unlikely, however, that the washout period negated the effects of the education regarding the dangers of SB. Cluster-randomisation was used to minimise contamination between individuals, however, as found in the results of Study 3, neighbouring colleagues influenced behaviours; thus it may not be that the reduction of SB was exclusively from the impact of the intervention. Furthermore, the multicomponent nature of the intervention, comprising pedal machine, various behavioural strategies, and recruitment of managers to the study, meant that the impact of the individual components cannot be discerned.

Of note is the sample size target was not met. Males are acknowledged as a hard-to-reach population in the health behaviour intervention literature (554,585,749), however, the

recruitment rate (73%) achieved in this male-only sample, compares favourably with similar studies (56%) where mostly women were recruited in an open call (675). The recruitment strategies used to recruit the clusters resulted in two of the five worksites approached agreeing to take part in the study. This is comparable to other studies with similar aims, and the size was appropriate for this type of feasibility pilot study (620,675). Time constraints were given as a reason for not participating in two of the organisations, highlighting real-world time pressures on employees in the majority of organisations.

Due to the convenience sampling framework used for recruitment, it could be argued that participants who consented to participate were more motivated than the general population to reduce their sedentary behaviour, indicating selection bias. The managers initially approached had a key personal focus on health and were likely already receptive to workplace health improvements. The characteristics of those who declined to participate in the intervention were not collected, so selection bias could not formally be evaluated. Another limitation of the study was the use of samples across just two worksites in Dublin area, however, the purposive sampling did recruit the target population of interest. Although only two worksites were recruited, no major differences in the evaluation between the worksites were apparent, which suggests that the intervention is acceptable and feasible to professional males in real-world settings and warrants further evaluation.

Although it may be suggested that positive feedback in the qualitative work may have been given due to researcher-participant relationships that evolved over the course of the study duration, the many and various issues that arose in the evaluation would indicate that this was not the case. Similarly, the use of participant reported outcomes for acceptability, feasibility and appropriateness data may have been answered in a biased manner; this also was not thought to be the case given the lower feasibility scores representing the difficulties in some of the implementation aspects of the intervention. It was not possible to blind the participants and researcher due to the nature of the trial, however, the use of objective device-based outcome measures minimises researcher bias. It is also possible that being monitored impacted on behaviour (e.g. Hawthorne effect (750)). The work-related, and physical and mental health outcomes of the study were assessed by self-report questionnaires and may have been subject to reporting bias.

The activPAL3 device is a valid and accurate measurement tool to measure SB, and various PA intensities in free-living environments, is sensitive to postural change and reductions in sitting time, and is well established in SB interventions (751,752). Low levels of missing data were

observed in the study, and qualitatively, participants expressed acceptability of this measurement device for the duration of the study. However, the activPAL3 software is not a comprehensive data processing and analytical tool. To isolate periods of interest, i.e. time at work, requires significant and time-consuming processing of the data outside of the activPAL3 software (693). A manual approach (matching the activPAL3 generated data with self-reported sleep, wake and work times) was undertaken to analyse the important periods in this intervention study (work time and wake time), which was complex, time-consuming and a high burden process, thus a more useful, accurate and valid approach would be of great benefit for future research using these devices. Future trials evaluating effectiveness in larger samples may employ the use of an automated algorithm to reduce the researcher burden when processing and analysing data from activPAL3 devices (753); and to isolate periods of interest specific to the intervention, i.e. time spent at work.

There remains a lack of understanding surrounding the interaction between time spent in each behaviour, i.e. time spent sedentary or engaged in LPA, and the impact on health. Given behaviours are mutually exclusive across a finite 24-hour period, understanding the implications of the patterns and bouts of all health behaviours is important to further the research field of SB and PA (164). Due to the current lack of analysis guidelines, cut-points and gold standards, this is difficult to achieve and needs to be addressed in future research. A method known as compositional data analysis, a statistical technique that can be used to properly model the associations between movement behaviours and health outcomes, has been suggested (303,754). This approach constitutes a radical change to the way daily activity is conceptualised. Compositional analysis provides a paradigm by which optimum distribution of behaviours throughout the day are understood, thus enabling an integrated 24-hour guidelines for PA, SB and sleep which can be mapped across the life-course (289,303).

Engagement with the Garmin Connect website/app was not measured and is a limitation of Study 3. It is not known exactly how much and how often, if at all the participants attended to or engaged with the platform. The extent to which mHealth can deliver on the promise of demonstrable positive health outcomes depends on the successful utilisation by the users to this intervention component. User engagement and interaction needs to be measured to fully understand its effect on SB and LPA. Short et al. (755) recommend establishing the validity of, and conducting engagement measures across multiple settings and triangulating the data collected, such as qualitatively captured user experiences, and quantitative data such as questionnaires, in a complementary way may be important next steps to advance the field. This would allow a more thorough testing of 'contemporary models of user engagement and

hence, deepen the understanding of the interplay between intervention perceptions, usage, and efficacy across different settings', p.11.

Stationary indoor cycling is particularly difficult to accurately measure (270,281,756). As outlined in Chapter 5 there is a lack of commercially available devices that accurately detect under-desk cycling and provide the user with immediate feedback. Therefore, it was decided that the Bluetooth cadence sensor in conjunction with manual recording and uploading via the Garmin watch was necessary for this intervention. Measuring cycling times in this way facilitated self-monitoring to increase conscious awareness of breaking SB with LPA. However, this level of self-monitoring in an already time constrained environment where work takes priority invoked a burden that was too difficult to overcome. A possible solution would be a device that automatically detects cycling time and provides users with immediate feedback on how they are progressing with their daily goals, similar to activity trackers that provide continuous feedback on steps accumulated throughout the day (491). However, as indicated by Simons et al. (757), to create an automatically generated and tailored information would require considerable financial resources, as well as significant input and time from experts in computer science. Technology, and in particular mobile technology, is fast evolving and it would be anticipated that the development of suitable digital app/software be available in the near future, which could be adopted in future research.

A limitation in Study 3 was the technology and software used in the EMA method in the study which may have resulted in high levels of missing data. Although the notifications were described as having a prompting effect to remind participants of their sedentariness, the frustration experienced due to the repetitiveness of the responses led to significant missing data. As a result of the limited resources available in the PhD project, the PIEL Survey app was chosen as the delivery method of the EMA as it was freely available, could be downloaded onto participants' own smartphones which negated the need to purchase study-specific smartphones for each participant, and has been utilised successfully in previous studies (758,759). The PIEL Survey app somewhat lacked user intuitiveness, and as a result of participants using their own smartphones, led to a wide array of technological issues (e.g. problems with participants uploading data), which may have explained the high levels of missing data. However, in a busy workplace setting EMA methods may not be an appropriate approach due to

The MRC Framework's 'flexible, less linear nature' is highlighted as a strength in Chapter 2, however, in practice, a lack of clear guidance in particular areas presents a challenge for

researchers, with implications that could be far-reaching (67). Firstly, the terminology ‘pilot’ and ‘feasibility’ studies are sometimes used interchangeably in the MRC Framework, which has been highlighted in a number of publications as being unhelpful, and the need for a single nomenclature and associated aims are recommended (67,423). Secondly, the Framework recommends a thorough and embedded process evaluation is needed to identify implementation problems alongside an exploratory study, however the term process evaluation is not defined. Thirdly, in terms of progression criteria to a future evaluation study, the MRC guidance highlights that an iterative approach, acknowledging some movement between feasibility/piloting and intervention development may be required, however, no guidance is provided on under what conditions movement between the two stages should take place.

Due to the resource capacity and time constraints of a PhD, the short-term duration of the trial was a major limitation of this pilot study. Intervention engagement and cultural changes may dissipate over time. The intervention period in this study was conducted over two weeks. There is a need for health interventions to be implemented and measured over a long period. Many studies have investigated the efficacy of health interventions over short periods such as four, six, or 12 weeks, but these offer limited proof of methods which lead to sustainable behaviour change. Currently, little is known about the sustainable effects of interventions of longer than six months, and even fewer for 12+ months due to the resources required to conduct large scale RCTs (11). However, it is well recognised that adherence to lifestyle interventions drops off over time (760–762). Long-term behaviour change is required in organisations but must be sustainable over time. However, the results of this PhD research are important in guiding this important and rapidly emerging field, as the findings of Study 3 suggested a trend towards reducing the workplace SB and increasing LPA of professional men.

A limitation of the timeline in this PhD meant that the requisite time was not available to return to the organisations and establish if they would be willing to adopt the recommendations made in this thesis. This would be an important next step and be grounded in the research process undertaken in this PhD research. Future expansion of this research should consider the findings and recommendations of the evaluation and ensure that the issues raised in this pilot feasibility study inform the refinement of a future intervention and adaptation of the components. Potential future research directions that build on the approach and findings of this thesis are articulated in the following section.

6.5 Considerations for Future Research

The results of the three studies, individually and as a whole provide a valuable contribution to research in the development of interventions to reduce SB in office employees, in particular professional men, which have indicated a number of directions for future research, the most important of which are outlined below.

In terms of measurement of SB in large epidemiological studies, future studies should include measures of transportation and leisure sitting times separately, as these domains were combined in the questionnaire in the Healthy Ireland dataset in Study 1. Knowledge of patterns of SB in specific contexts are important to inform behaviour change targets. Furthermore, differentiation between weekdays and weekend days, and bout durations of sitting are important characteristics of SB and are required to better understand patterns of physical activity and sedentariness. In future epidemiological studies concerned with PA and SB, an important influence on behaviours highlighted in the outer ring of the socio-ecological model are policy level factors. Measures such as community- and street-scale urban design and land use policies have been found to positively support PA levels, but evidence is scarce, highlighting the need for these important influencing factors to be investigated in relation to PA and SB. Finally, while cross-sectional designs provide information on factors correlated with sitting, longitudinal studies are required to investigate true determinants of SB.

Results from this PhD research indicated that the office environment is a key consideration in the development of interventions to reduce SB in the workplace. A major issue however, with the men in this study, was the ergonomic set-up of the pedal machine with traditional-style desks. Involvement of an ergonomic expert may provide solutions to the issues raised in the study. For future interventions, the inclusion of women may not pose these issues to the same extent as they are generally not as tall as men, however, this would need to be at the forefront of considerations if using these devices for future trials. Notwithstanding the set-up issues, providing a mechanism for brief bouts of non-exercise activity thermogenesis (763) that is integrated into daily work routines, and appropriate for the built environment, warrants further investigation. Further research is needed to determine whether the pedal machine, combined with the mHealth component, significantly improve workplace SB following the considerations and adjustments suggested in the finding of the PhD research. The intervention design focused on targeting the professional male subgroup population in accordance with the gender-responsiveness recommendations made by the WHO (682). Testing the acceptability and feasibility in sometimes 'difficult-to reach' men in terms of health promotion and who engage in the longest sitting times was an important first exploratory step in this pilot

feasibility process. Following the acceptability testing of the Cycle at Work intervention in terms of men's engagement, and the provision of recruitment and retention information, it is important to now provide broader public health benefits. Although men's sitting times are longer, the intervention should now be expanded to include women because both men and women's sitting are in risk category (>7hours per day), to help prevent and reduce chronic disease risks on a wider scale. Future studies should recruit a larger sample of men and women and across different workplace settings (e.g. public sector) in order to be able to draw conclusions of effectiveness.

Measures of engagement with the mHealth technology in terms of the website/app, to provide an understanding of the frequency and duration of user engagement with this type of component and how it may impact on changing behaviours should be included in future studies. The triangulation of qualitative and quantitative data has been suggested as an important approach in investigating engagement with mHealth in intervention (755). Future studies would be recommended to include a wider range of engagement measurements and their thoughtful application to the study of engagement are encouraged, as opposed to the current heavy reliance on system usage data as the sole assessment of engagement.

The high burden of the PIEL survey resulted in significant missing data. Future trials may be more successful by providing participants with study smartphones preloaded with the EMA survey to reduce the technological issues and participant burden. Furthermore, it may be more appropriate and beneficial to use the EMA method to investigate psychological outcomes in terms of mood and state, which may reduce the survey content issues raised in Study 3 regarding the response categories in the measure. However, for future iterations of this current intervention, EMA was overly burdensome to participants in professional workplaces and would not be included in the measures used.

In this intervention, various components were implemented together (i.e. goal-setting, self-monitoring, social comparison) which makes it difficult to attribute outcomes to specific components of the intervention. It is important to provide evidence on which specific intervention elements led to positive behaviour change to further improve the effectiveness of the overall intervention. With the requisite funding, future studies may achieve this by applying smart study designs that could have multiple periods in which different combinations of intervention components are examined (764). N-of-1 designs (765) and multiphase optimisation strategies (MOST) (766) may be useful to understand the most effective components in the intervention.

Digital technology offers the ideal opportunity to personalise and tailor the content and strategies of an intervention to each participant or target population, which is essential to ensure interventions are responsive to users' needs and preferences (66,767). This is especially relevant as sedentary office employees' motivations and desires likely differ (634). In future, the most appropriate approach may be to offer a range or 'menu' of behaviour change strategies and outcomes for the goals targeted, where users can select their own components and tailor their intervention goals in line with how and when they want to reduce workplace SB. Gardner et al. (2017) recommend this approach and offered participants a selection of intervention techniques in a workplace intervention to reduce SB. This argument for individual preferences to be used in personalised intervention design in future studies is further strengthened in other health promotion studies in workplace settings (601,648,708). However, having no one intervention would make it difficult to identify the active ingredients in the intervention.

Using a collaborative approach acknowledges that reducing occupational SB is the responsibility of both individual employees and organisational management (571,648). Qualitative testing that includes management-level participants also has the purpose of eliciting buy-in, which is of utmost importance in determining if an intervention is to succeed (335). Future studies should note the value of including qualitative in-depth exploration of important stakeholders' perspectives to intervention development and evaluation, in conjunction with objective outcomes measures, and incorporate both important measures as part of intervention assessments.

Recruitment of the target sample in Study 3 was not met, however, retention was very good. Recruitment challenges are well-documented in health promotion studies (768,769), however, this study had the added challenge of recruiting the more difficult to reach male target population. As outlined previously, mixed-gender programmes may not engage men to participate in health promotion programmes (554); perhaps the male-only sample was a facilitating factor to the high retention rate in this pilot study. Future research could adopt this type of target-group specific approach to investigate its effect further. Further studies may wish to consider different strategies to maximise recruitment such as giving large-scale presentations to employees on the nature and purpose of the study. Multiple worksites across different regions may be considered to help achieve recruitment targets. Data on the potential differences in different work environments, as well as individual differences such as socio-demographic information on educational attainment and self-reported health status should be collected in this case.

A parallel group cluster randomised controlled design may be appropriate for future effectiveness trials, due to the unlikelihood that the washout period sufficiently removed the effect of the education piece received by participants. Longer-term follow up is important to understand how the effects of the intervention are sustained or dissipate. An important next step and grounded in the current research would be to contact the organisations who participated in this PhD research to see if they would be willing to adopt the recommendations mentioned.

In terms of the theoretical approach taken in this PhD research, the socio-ecological model provided a helpful framework to guide the intervention design in terms of the determinants of prolonged SB and the levels of influence that operate to promote and restrict certain behaviours at which to target. Several constructs used in the intervention closely matched Social Cognitive Theory, namely, knowledge of health risks, perceived self-efficacy, setting health goals, perceived facilitators and barriers, and social and structural impediments to change (440). The results of Studies 2 and 3 showed that these mechanisms were indeed relevant and important to the men in the study. Previous gender-sensitised studies have specifically targeted SCT constructs such as self-efficacy, outcome expectancies, development of skills (e.g. goal setting and problem solving), and building of social support to successfully increase PA in men, both internationally (552,770), and in an Irish context (589). Reciprocal determinism, and the importance of social and cultural norms is particularly relevant in a workplace setting in general and emerged as a strong facilitating factor in this research where colleagues' behaviour acted as a 'catalyst' to engage in the intervention. The sense of togetherness and social support of others engaging in the intervention resulted in a reduction of self-consciousness of pedalling behaviours and increased participation through observational learning. SCT recognises the importance of interactions between people, environments and behaviour that are dynamic and may continually change for an individual. The next iteration of this intervention would combine the socio-ecological model and an explicit underpinning, application, and integration of SCT to provide a more powerful approach to theoretically understand the mechanisms of change of occupational SB.

Finally, in terms of the MRC Framework, a single definition of exploratory studies throughout the guidelines would be favourable to reduce confusion that may emerge due to the interchangeable use of terms. Key issues of a lack of explicit guidance in terms of progression criteria has been highlighted as important and would be useful as a means of preventing biased post-hoc cases for continuation. Currently, there is a lack of clear information on devising progression criteria and processes for assessing if these have been sufficiently

achieved to inform the justification of a large-scale evaluation. Greater unanimity on the aims of exploratory studies, and how decisions should be made in terms of progression criteria to address uncertainties which may undermine a definitive intervention evaluation, is required.

6.6 Progression to a Definitive Intervention

The pilot study in this PhD research was of insufficient size to provide parameters required for estimating a sample size for a main cluster randomised trial (e.g. the intra-cluster correlation coefficient) with adequate precision, and too small to provide reliable estimates of rates for process measures such as recruitment or follow-up rates. This study has shown that as an important first step in acceptability and feasibility, this gender-sensitised intervention was interesting and acceptable to professional men, a difficult-to-reach group. Using the findings and subsequent learnings from this small pilot feasibility study, the following section will outline how the next step in the research process would be envisioned.

In terms of the intervention design and components, the main issues from the participants' perspectives were the pedal machine setup and the Garmin watch technology. In a future trial, an ergonomic expert would be recruited as part of the study to facilitate a comfortable desk setup to allow all participants to pedal with ease. Other types of PA tracker watches (i.e. Fitbit) that are popular with the general public and automatically record pedalling behaviours, would be used to target the individual level BCTs. The use of EMA would not be included as a measure of contextual information on SB and PA as this was found to be overly burdensome to participants in the busy workplace settings. The future intervention would be explicitly underpinned by Social Cognitive Theory, i.e. components incorporated to develop self-efficacy (i.e. confidence to perform PA and reduce SB), to focus on outcome expectancies (i.e. positive outcomes weighed against any negative outcomes), to develop skills (e.g. goal setting and problem solving) and to build social support.

The next stage of the research process, as outlined in the MRC framework for developing and evaluating complex interventions (65), is evaluation. A short-term pilot study would be required to provide estimates of sample size, and to test the improvements informed by this PhD research in males and females, and in public and private workplace settings. Following this, a full cluster randomised controlled trial would be required to test effectiveness of the intervention. This stage would incorporate three main activities and functions: 1) Assessing effectiveness, 2) Understanding change process, 3) Assessing cost-effectiveness. The primary outcomes of the trial would be to test effectiveness using objective devices (ActivPAL), i.e.

time spent in sedentary behaviour (minutes per 8-hour workday, minutes per total weekday), and time spent engaged in light-moderate physical activity (minutes per 8-hour workday, minutes per total weekday).

Secondary outcomes would include BMI and blood pressure, policy relevant measures - Quality-Adjust Life Years (QALYs) (771) using SF-12 (529), EQ-5D-5L (772) and Capacity Wellbeing using ICECAP-A questionnaire. Measures of resource use: work-engagement (698), presenteeism measured using the self-report instrument - World Health Organisation Health and Work Performance Questionnaire (HPQ) (773)- designed to estimate the workplace costs of health problems in terms of reduced job performance, sickness absence, and work-related accidents-injuries; and absenteeism reports from each worksite would be collected. Cost effectiveness analysis would be conducted to determine clinical and cost-effectiveness outcomes of a multicomponent workplace intervention to reduce sedentary behaviour in healthy adults (673).

6.7 Implications for Policy and Practice

[Requirement for a National Sedentary Behaviour Plan](#)

In the socio-ecological model of sedentary behaviour (57), the outermost ring of influences on behaviour is policy. The WHO 'Global Action Plan on Physical Activity 2018–2030' (GAPPA) (188) endorses the initiation, co-ordination and implementation of policies that encourage SB reduction, to enhance opportunities for whole populations to reduce SB by being more active, and develop environments where non-sedentary choices are provided. This report advocates the prioritisation and interlinking of “upstream” population-based policy approaches to promote PA and reduce SB with policy actions focused on “downstream” individually-centred interventions. As presented throughout this thesis, sedentary behaviour is distinct from physical activity with its own physiological mechanisms and outcomes, therefore warrants its own policy and implementation plan.

Woods and Mutrie (291), nearly a decade ago, advocated for the promotion of physical activity through national (and state and local) public policy. The accumulating evidence on the threats to health as a result of prolonged SB, highlights the need for public guidelines and national policy to provide legislation to support and enable individuals to break their sedentary time, particularly in highly sedentary settings such as office workplaces. The role of public health academics and researchers, in congruence with previous calls for physical activity policy (291), is to provide scientific information on the evidence base for why SB is an important public

health issue. Evidence on the prevalence of SB and physical inactivity in Ireland (and compared to other countries), advice on recommended minimum breaks of SB necessary to reduce the health effects of prolonged SB, and findings of interventions, in particular in at-risk settings are also required. The findings of this PhD research have implications for policy at international, national, and local levels.

The strategic objectives of the GAPPA, discussed in Chapter 2 (Section 2.12), form a universally applicable framework of a population-based response to increase PA and reduce SB. Key objectives include: targeting the most sedentary through the promotion of tailored workplace programmes, development and dissemination of national guidelines, strengthening national and institutional research and evaluation, and culturally and context-appropriate PA promotion where employers partner with government to provide fiscal incentives to reduce SB and increase PA. Within the 'Create Active People' objective, Action 3.3 advocates the promotion of the implementation of workplace health programmes aimed at increasing PA, reducing SB and promoting incidental PA during the work day for employees, in different occupations and settings, with a priority focus on the least active. The development and design of the research in this PhD directly aligns with this action and provides evidence on the acceptability and feasibility of a workplace intervention in the most sedentary, where relevance was ensured by employing a participatory approach.

Action 4.3 of the 'Create Active Systems' objective, aims to strengthen national and institutional research and evaluation, and in particular the application of digital technologies to reduce SB and increase PA. The component harnessing mHealth in this PhD research aligns with this action by testing the use of mHealth technology and its associated website platform, in terms of acceptability in a professional workplace. The findings suggest that this may be a useful strategy in interventions to reduce workplace SB and provides an important basis for further testing in a range of settings. Furthermore, aligned with Action 3.3, the institutional research and evaluation conducted in this exploratory PhD project, provides an important evidence-informed basis from which to build further trials to assess the effectiveness and the return on investment of this workplace health programme. The result of which would be to strengthen the evidence base and inform advocacy.

Action 4.5 within the strategic objective 'Create Active Systems', outlines investments needed to implement effective national and subnational action to increase PA and reduce SB. This action calls for multisectoral partnerships across all relevant sectors. The findings of this PhD research demonstrate the positive collaboration between the private organisations recruited

to the study and the researcher, working together with the joint aim of reducing SB to improve health and wellbeing of the employees. This provides some evidence of successful collaboration from which to build on future research that may be effective in reducing workplace SB on a larger scale. Joint investment from academic, workplace organisations and the government, with a shared aim to test and evaluate methods to improve worker health by reducing SB and increasing PA in the sedentary environment of the workplace, is recommended and may be possible as derived from the PhD findings.

The high prevalence of sedentary behaviour in Ireland reported in Study 1 suggests the need for an over-arching policy to effectively promote the reduction of SB in all areas of society. In the 'Create Active Systems' objective of the GAPPA, Action 4.1 outlines the need to strengthen guidelines and provide recommendations and an action plan on SB (and PA) for all ages. To ensure that as many people as possible are provided with an opportunity to reduce their SB, a national strategic planning process aimed at identifying policies, practices and initiatives that will have a collective effect of reducing population levels of SB is necessary. Study 1 identified that the Irish context in which the greatest risk of prolonged SB occurs is the workplace setting. As highlighted in the discussion of SB guidelines in Chapter 2 (Section 2.9.2), there is an extensive gap in the dissemination of relevant knowledge, and a lack of a strong and consistent evidence base. Recent guidance on physical activity and sedentary behaviour recommendations from the WHO (294) specifically outlines SB for the first time, however, Ireland does not have recommended guidelines on SB for the general population or specific at-risk groups (except for those who attend mental health services (292)). A criticism levelled at several national PA plans is their failure to provide a clear path and specific guidelines on sedentary behaviour (284).

In the current 'National Physical Activity Plan (NPAP) for Ireland' (185), no guidelines or recommendations on SB are outlined, although within Action Area 3, ref. 28 'Develop national guidelines on sedentary behaviour' is stated as a future action in the Plan. Although work on this has commenced as outlined in the Implementation Summary (290), guidelines and policy remain to be published. Availability of public health SB guidelines is a good indicator of a government's national SB policy, as it shows the government's commitment and intention to support the promotion of a reduction of SB. Monitoring levels of SB and PA are required to inform domestic policy and to meet Ireland's international reporting requirements. The findings of Study 1 outline the dangerous levels of SB engaged in by a significant proportion of the Irish population as derived from analysis of the Healthy Ireland survey. As outlined in Chapter 2 Section 2.4, chronic diseases are extremely costly in terms of the burden placed on

individuals and families, as well as in terms of population health and to the economy. Given that NCDs are largely preventable, and that men are more highly represented in the prevalence of chronic conditions and multimorbidity, targeting modifiable behaviours, such as sedentary behaviour is of upmost importance to reduce incidence and mortality rates.

The results provide detail to the view of behavioural patterns that reinforce and counteract inactivity, especially in a workplace setting. These findings, together with the overall evidence of acceptability and feasibility of the multicomponent intervention in a professional workplace setting, inform important elements that operate within a 'whole-systems approach' to reducing SB by increasing PA (328). The findings of the PhD research highlight how SB can be replaced by LPA in a real-world workplace setting with an at-risk population, from which to test further effectiveness.

The WHO report on 'Preventing Noncommunicable Diseases in the Workplace through Diet and Physical Activity' (52) states that a healthy workplace is one in which employees and managers collaborate to utilise a dynamic and iterative process to protect and promote health, safety and wellbeing of employees and the sustainability of the workplace. By considering all elements highlighted in the socio-ecological model: physical and psychosocial work environment, personal health resources, and participation in the wider community can lead to an increase in success of this approach. In Ireland, the 'National Healthy Workplace Framework' is currently being developed under the auspices of Healthy Ireland by the Department of Health. The Framework aims to encourage and support the development of health and wellbeing programmes in all places of employment across both public and private sectors (333). This is further strengthened by legislation in the public sector which requires all employers to have and report on a health and wellbeing programme. The findings of this PhD research provide an evidence-based insight into the roles of individuals, their environment and organisations that provides an important basis to further test an intervention in a larger pilot RCT, which can be translated into evidence in a scalable way to improve population health.

Given the typical workplace is highly sedentary in nature, and that employees and organisations have the authority to implement their own policies, this setting is ideal for targeting policy level workplace change. The implementation of the 'Cycle at Work' intervention has potential to reduce workplace SB, following the requisite amendments and adjustments outlined in the findings of Study 3, and following further testing of its effectiveness before large scale roll-out of the intervention. The multicomponent intervention including mHealth and under-desk pedals might be offered to employees and employees as

part of a wider culture of wellness that includes reducing SB and increases LPA throughout the working day. The findings relating to reducing SB and increasing LPA as a result of this intervention infer that this type of multilevel approach targeting the important influences of SB in professional men may play a role in facilitating behaviour change. As recommended in the 'Eight Investments That Work for Physical Activity' (328), a key consideration to enable sedentary employees to increase their PA and reduce their SB, is through a culture of wellness that is embedded in the workplace culture's strategic goals and aims. The workplace is a culture, or mini-system within a larger system, where a holistic or whole-of-workplace approach is recommended for successful health promotion, and where the employees are the end-users and champions for health and wellbeing promotion. The intervention strategies tested within this PhD research can be incorporated within a broader cultural change to promote PA and reduce SB, following future testing of effectiveness from a larger pilot RCT.

6.8 Conclusion

The findings described in this PhD thesis have demonstrated that implementing a multicomponent gender-sensitive intervention to reduce sedentary behaviour and increase light-intensity physical activity in sedentary professional males in a workplace setting is feasible and considered acceptable to participants. The findings presented within this thesis challenge the basic individual-level model to change behaviour by targeting the various and important influences on SB that operate on many dynamic levels, as guided by the socio-ecological model. The combination of components has the potential to garner behaviour change by reducing SB and increasing LPA, however, a larger RCT is required to confirm these findings. This thesis presents an evidence-based, iterative, and participatory approach to develop and test the acceptability and feasibility of a multicomponent intervention to reduce professional male employees' workplace SB.

The 'Cycle at Work' intervention was the first of its kind to be developed with the primary aim of reducing occupational SB using mHealth, a pedal machine, and organisational support in those most at risk, professional males, and extends the literature by demonstrating the acceptability and feasibility of a complex intervention in a real-world setting.

Future research would be subject to considerable improvements with the ergonomic set-up and watch technology, and evaluation of further iterations are required before being implemented as an initiative to reduce workplace SB. This thesis provides important exploratory findings, and key considerations for researchers to utilise in behaviour change

interventions to reduce occupational SB, detailing barriers and issues that should be attended to in future evaluations.

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Appendices

Appendix A - Published Baseline Paper

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BMC Public Health

RESEARCH ARTICLE

Open Access

Examining total and domain-specific sedentary behaviour using the socio-ecological model – a cross-sectional study of Irish adults



Gail Nicolson^{*} , Catherine Hayes and Catherine Darker

Abstract

Background: Sedentary behaviour (SB) has been linked with detrimental effects on morbidity and mortality. This study aims to identify the individual, social and environmental correlates of total sedentary behaviour and the contexts in which sitting time accumulates in an Irish adult cohort.

Methods: Cross-sectional analysis of data from 7328 adults of the nationally representative Healthy Ireland Survey. Ordinal regression analyses were used to examine participants' socio-demographic characteristics, lifestyle factors, physical and mental health status, perceived neighbourhood environmental factors, and their association with total daily sitting times and sitting times across the domains of occupation, leisure screen-time and transportation/leisure.

Results: Overall median of sitting time per day was 450min (7.5 h). Male gender, and living in an urban location were associated with increased total, occupational, and screen-time sitting ($p < 0.001$). Younger age was associated with increased total and occupational sitting times ($p < 0.001$), while being older was associated with increased screen-time and transportation/leisure sitting ($p < 0.001$). Insufficient physical activity levels were associated with increased sitting across all domains ($p < 0.001$). Higher socio-economic classification and education levels were associated with increased total, occupational, and transportation/leisure SB ($p < 0.001$), while lower socio-economic classification and education levels were associated with increased screen-time sitting ($p < 0.001$). Alcohol consumption was associated with screen-time and transportation/leisure sitting ($p < 0.01$), while smoking was associated with increased screen-time sitting ($p < 0.001$). Being married was associated with less screen-time ($p < 0.001$) and transportation/leisure sitting ($p = 0.02$), while those with a caring role had less total ($p = 0.04$) and screen-time sitting ($p = 0.01$). A significant negative association between neighbourhood attributes and total ($p = 0.04$), and transportation/leisure sitting times ($p < 0.001$) was found.

Conclusion: The results of this study provide a starting position for development of targeted interventions aimed at the most sedentary, such as males with sedentary occupations in higher socio-economic groups and education levels, those with insufficient levels of physical activity and who live in an urban location.

Keywords: Sitting, Sedentary behaviour, Adults, Ecological model, Correlates, Intrapersonal, Interpersonal, Environment, Occupational, Screen-time, Transportation, Leisure

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Background

Insufficient physical activity is defined as less than 150 min of moderate-intensity physical activity per week, or less than 75 min of vigorous-intensity physical activity per week, or equivalent [1]. At a global level, one in four adults are not sufficiently active [1]. Ireland has low levels of physical activity (PA) among adults in Europe (ranked 30th of 44 countries) [2], and just one third (32.6%) of Irish adults achieve the minimum level of activity of 150 min of moderate physical activity per week set by the National Physical Activity Guidelines [3]. Instead, people spend the majority of their time being sedentary [4, 5]. Sedentary behaviour (SB) is defined as any behaviour characterised by an energy expenditure of ≤ 1.5 metabolic equivalents (METs), while awake, and in a sitting, reclining or lying posture and is distinct from a simple absence of physical activity [6, 7]. SB has been reported to be a risk factor for a host of adverse health outcomes including the development of chronic diseases such as depression [8], type 2 diabetes [9], cardiovascular disease [10, 11], osteoporosis [12], some cancers [13, 14], as well as premature death and overall mortality [13, 15]. It has been estimated that having taken physical activity into account, adults who sit for more than 10 h per day have a 34% higher all-cause mortality risk; the risk appears to increase significantly when sitting exceeds 7 h per day [16]. To negate the risks associated with high levels of sitting, daily physical activity must exceed current recommendations of ≥ 60 –75 min of moderate physical activity per day; however those who achieve this level represent a very small proportion of adults [17]. Research into the prevalence and determinants of SB to identify the populations most at risk with longest sitting times, to explore the contexts in which most SB occurs.

The focus to date on factors that influence SB has mostly been directed at individual level factors such as biological, psychological and behavioural [18, 19], or socio-demographic factors in isolation with more distal contextual factors such as the built, social and economic environment overlooked in many studies [20]. The socio-ecological theory of health behaviour recognises that individual behaviours operate in, and are affected by environmental and policy contexts [21]. This conceptualisation of SB leads to explicit consideration of complex multiple levels of influence, i.e. intrapersonal (biological, psychological), interpersonal (social, cultural), organisational, community, physical environment, and policy [18]. The socio-ecological model (SEM) posits that simple cause and effect pathways of health behaviours are unlikely, and motivating or educating an individual to change their behaviour is likely to be restricted if their physical and socio-cultural environments do not enable and support the behaviour [22]. The SEM places the individual at the centre of an ecosystem, and provides a useful and integrative framework to achieve better understanding of the multiple

factors and barriers that impact SB. Central to the SEM, the 'behaviour settings' construct highlights the influence of particular contexts or domains in which behaviours occur [23]. Owen et al. [18] not only advocate this model of SB to understand the correlates of time spent sitting across different domains of leisure, transportation, and occupation, but also the necessity to identify and understand modifiable factors within these settings, to develop effective interventions and appropriate policies to address these. Early research on SB focussed heavily on TV viewing, however SB accumulates across many contexts during waking hours, including the workplace, transportation and domestic environments [18]. Various factors are likely to influence an individual's choice and/or risk of engaging in SBs, while built environments and social norms may encourage and reinforce time spent sitting [18]. Knowledge about the various levels and types of influences and contributors to SB may inform the development of multi-level interventions that offer an optimum level of success [21].

Systematic reviews assessing the available evidence on socio-ecological factors influencing SB across the life course; in youth [24], those aged 18–65 [19], and older adults [25] have provided information to map the domains of SB, as well as a conceptual approach to understand determinants of prolonged sitting time. Older females with low levels of physical activity, higher body mass index, who smoke and consume high levels of snack foods have higher total and leisure sitting times, whereas SB in the context of transport has been found greatest in higher income males [19]. These findings emphasise the necessity to focus on separate domains of SB. Socio-economic status is indicated to be the most consistent factor of all of the individual level factors associated with television viewing SB and occupational SB [19]. A recent review by Prince et al. [26] identified individual-level correlates; biological (i.e. age, gender, body composition and health status), behavioural (i.e. lifestyle, physical activity and sedentary habits), psychological (i.e. stress, mental health, attitudes and perceptions), and socio-economic factors (education level, employment status, and income) as important correlates of SB. The authors state that despite calls for the use of the SEM approach to look at determinants of SB, intrapersonal factors are the focus in the majority of studies investigating SB. Interpersonal factors such as marital status [27, 28], and family and caring duties [29] may be potential correlates associated with sitting time. At an environmental level, correlates of SB include physical environment and neighbourhood attributes such as safety and walkability [19]. Inconsistent and mixed results have been reported on the association between SB and perceived neighbourhood attributes such as open spaces [19]. Neighbourhood aesthetics have been found to be associated with overall sitting times [28] and women in

neighbourhoods with high walkability have been found to spend less time watching TV [30]. A correlation between living in an urban location and longer sitting times has been found in some studies [29, 31]. In a recent systematic review investigating the association between physical environment and weight status in adults [32], urban sprawl and land use mix, were found to influence weight status in the US only. Busschaert et al. [33] used a range of socio-ecological factors related to context-specific sitting times. However, this was a small ($n = 301$) cohort and the physical environment correlates used in the study focussed particularly on the close proximal environment. The neighbourhood environment access and characteristics as identified by Owen et al. [18] and the SEM, such as perceived aesthetics and open space availability that may influence SB [34] are also important to understanding SB. The present study includes a range of perceived neighbourhood attributes that may be associated with SB in a large generalisable sample, thereby adding to the knowledge regarding environmental factors as identified in the SEM.

One of the research priorities identified in Owen et al. (2011) is to gather evidence on all of the levels of influence on SB across different countries where environmental, social and cultural attributes may differ, to allow for the characterisation of a broader range of variation in individual, social and environmental correlates. Differences in sitting times have been reported in European contexts [35], in the US [36] and in Australia [37], whereas Matthews et al. [36] used objectively measured sitting time however contextual information on the domains in which the patterns of accumulated sedentariness occurred were not reported. An understanding of socio-ecological factors at each level, that are most relevant to specific populations, and how these factors may relate to each other in SB, is necessary if SB is to be successfully targeted in interventions. Loyen et al. [35] used the International Physical Activity Questionnaire (IPAQ) to determine SB. A breakdown of the separate domains in which sitting occurs was not used. In a study of Australian adults' sitting, [37] only two domains (occupational and leisure-time sitting) were assessed – other domains in which SB accumulates such as transport-related sitting were not included [38]. More accurate measures of total daily SB include the key domains that contribute to total sitting time: work, screen-time, leisure-time and transportation SB [18, 39]. TV viewing and occupational sitting time contribute to the majority of total amount of sitting accumulated throughout the day [40]. In recent years, mobile devices have enabled consumers to watch television programming at any time and location [41]. The use of smartphones and tablets, together with the streaming services have changed the way audiences view programmes. Transportation SB is

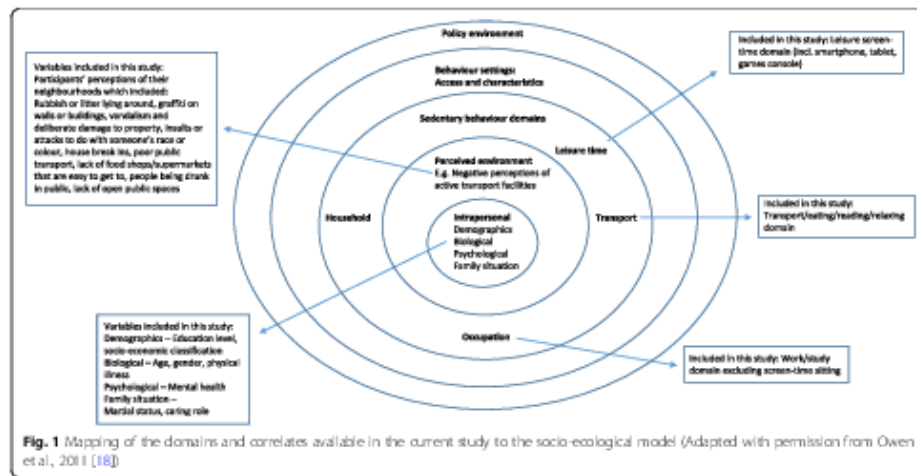
the context in which the least amount of daily SB accumulates, 60 min per day compared with 390 min and 120 min of occupational and TV viewing SB respectively [42], within the three domains used in the SEM. Television viewing has been found to be directly associated with all-cause mortality whereas time spent driving was not significantly associated with higher mortality in a large ($n = 13,284$) cohort of Spanish university graduates [43]. However, the higher educational levels of the participants in this study may have accounted for the lower than expected mortality rate observed; therefore the results may not be generalisable. Stamatakis et al. [44] assessed self-reported SB in the contexts of TV (including DVDs and videos) viewing; and sitting during non-work times, including reading and computer use. Participants who were in employment in this study were also assessed on average daily times spent sitting or standing while at work. Transportation SB was not investigated as a separate domain. It can be argued that although it is necessary to include transportation SB in overall daily measurements of SB, if the objective of interventions is to target the context in which most risk occurs, it may not be necessary to place transportation as a high-risk target for interventions to reduce SB. Transportation SB was included together with other leisure contexts of sitting (reading, relaxing, eating) in the present study. Although transportation SB is a separate domain outlined in the SEM, the data that is available in the present dataset can be usefully applied to the model to highlight sitting correlates in a population-level cohort. See Fig. 1 for a graphical illustration of how the present study has been mapped onto to Owen et al's [18] SEM.

Although some correlates of SB were examined in the previously mentioned studies [35, 37], it is of value to investigate the intrapersonal (psychological factors, risky health behaviours) and environmental factors (neighbourhood environment) that are emphasised by the SEM together in a large population-level study of adults with a wide-range of ages (18–97 years). The aims of this study were, to compare overall sitting between different individual, social, and environmental categories in a population-level study, and to identify individual, social, and environmental level correlates associated with sitting time across these domain-specific physical and social contexts where most sitting behaviours occur.

Methods

Study design

The sample comprised 7328 individuals aged 18 and older participating in the Healthy Ireland Survey (2016) [45]. This nationally representative survey is carried out on an annual basis. Data were collected by the market research company Ipsos MRBL. The provision of access to the data rests with the Irish Department of Health,



and is available to researchers fulfilling assessment criteria. The study uses the Irish postal service/Ordinance Survey Ireland's GeoDirectory as the primary sampling frame [46]. GeoDirectory is a complete database of every building in the Republic of Ireland. A two-stage equal-probability sample of addresses was drawn, and the sample was issued by Electoral Division clusters, each cluster comprising 20 addresses. The initial stage of the sampling process was to select a representative distribution of sampling points around the country. The use of a probability sampling approach ensures that the survey sample comprehensively represents the defined population. In adopting this approach every member of the defined population has a calculable chance of being included in the sample. Individuals in each household were randomly selected using a Kish Grid – a selection process used for random sampling [46]. Fieldwork was conducted between September 2015 and May 2016. Approval to conduct the original study was provided by the Research Ethics Committee of the Royal College of Physicians of Ireland. Informed consent, recorded electronically, was obtained from each participant prior to commencement of the interviews. Data collection was carried out by trained interviewers, and completed on a Computer Assisted Personal Interview (CAPI) basis. Sources, as well as reliability and validity of questionnaire instruments are provided elsewhere [46]. The response rate was 59.9%.

Ethical approval for secondary data analysis was granted by the Research Ethics Committee, School of Medicine, Trinity College Dublin (ref. 20180517).

Variables for analyses were selected a priori, guided by the SEM, and classified according to multiple levels of influence: [intrapersonal] (i) biological and demographic; (ii) psychological and emotional; (iii) behavioural; [interpersonal] (iv) social and cultural; and (v) environment. Variables measuring potential policy or organisational factors that may influence SB were not available in the dataset. This was due to limitations in the scope of the questionnaire given the broad range of topics that are covered in the Healthy Ireland Survey.

Dependent variable

Sitting time was assessed in minutes using the following measure,

I would now like to ask you a few questions about how much time you spent sitting down yesterday. It may be the case that yesterday was unusual in some way, but it is very important for this study that you answer these questions about yesterday rather than what you might consider to be a normal day:

- (a) Thinking of yesterday, how much time did you spend sitting watching TV or another type of screen such as a computer, tablet, Ipad, smartphone, games console, Kindle etc.? Please do not include any time spent in front of a screen for work or study purposes.
- (b) Thinking again of yesterday, how much time did you spend sitting while engaged in driving, eating, drinking, relaxing, reading etc. Please do not

include any time that you already mentioned at the previous question.

- (c) And again thinking of yesterday, how much time did you spend sitting whilst working or studying. Please do not include any time that you already mentioned at the previous questions.

For the current study, total sitting time was calculated by summing the values of (a), (b) and (c).

Intrapersonal correlates

Biological and demographic factors

Respondents provided information about their age, gender and physical health status. Physical health was measured by asking participants if they had any long-standing illness or health problem, i.e. problems which have lasted or will last for at least 6 months or more. Responses were a dichotomous 'yes' versus 'no'.

Socio-demographic variables included education level attained and socio-economic classification level. The original eight level education variable was re-classified for the current study into five simpler categories for ease of analysis (early childhood, primary education, lower secondary; upper secondary; tertiary, post-secondary, non-tertiary; bachelors or equivalent, masters or equivalent, doctoral or equivalent). This variable was dichotomised [early childhood, primary education, lower secondary; upper secondary versus tertiary, post-secondary, non-tertiary; bachelors or equivalent, masters or equivalent, doctoral or equivalent] in the regression models. Socio-economic classification was categorised in four levels (high-managerial, administrative, professional occupation; intermediate occupations; routine and manual occupations; not classified). This was dichotomised (high-managerial, administrative, professional occupation; intermediate occupations versus routine and manual occupations; not classified) for use in the regression models in the present study.

Psychological factors

The variable measuring psychological distress recorded the presence or absence of symptoms such as anxiety or depression using the instrument Mental Health Index-5 [74], a subscale of the Short-Form 36 questionnaire (SF-36) [46]. A cut-off point of ≤ 56 predicts disorder, and this was dichotomised to 'probable mental health problem' versus 'no probable mental health problem'.

Behavioural factors

Regarding physical activity, participants were asked, 'do you think you generally do enough physical activity?' Dichotomous responses of 'yes' versus 'no' were used in the analyses. Smoking behaviour was dichotomised in the present study into 'daily/occasionally' versus 'no'.

With regard to alcohol consumption, the AUDIT-C is an alcohol-screening tool that can help identify individuals who are hazardous drinkers or have active alcohol use disorders (including alcohol abuse or dependence) [75]. Dangerous alcohol consumption was measured by using questions on drinking behaviour that were scored on a scale of 0–12 (scores of zero reflect no alcohol use) and ranked on the AUDIT-C scale. This was included as a continuous variable in the regression analyses.

Interpersonal correlates

Marital status was recoded in the present study into two groups: married or civil partnership; versus single, widowed, divorced, separated. Participants were asked if they provided regular unpaid personal help for a friend or family member with a long-term illness, health problem or disability, to include caring responsibilities as a variable in the analyses. Dichotomised 'yes' versus 'no' were the response categories.

Environmental correlates

Questions regarding participants' perceptions of their neighbourhoods included whether they thought the following were 'a big problem', 'a bit of a problem' or 'not a problem': rubbish or litter lying around; graffiti on walls or buildings; vandalism and deliberate damage to property; insults or attacks to do with someone's race or colour; house break ins; poor public transport; lack of food shops/supermarkets that are easy to get to; people being drunk in public; and lack of open public spaces. For the purpose of this analyses, all questions were dichotomised as 'a big problem' and 'a bit of a problem' versus 'not a problem'. These questions were derived from questions used in the previous national survey of the lifestyle, attitudes and nutrition of people living in Ireland (SLAN) [76]. The variables were used as an interval/ordinal scale ('0 to 9 neighbourhood problems') in correlation and regression analyses.

Statistical analysis

Analyses were conducted using SPSS 25 for Windows (IBM Corp., Armonk, New York, USA). Data were weighted by Ipsos MRBI and details about this process are described elsewhere [46]. Missing data were very low for all of the variables (< 5%). Data were examined for normality via histograms, and kurtosis and skew statistics. Distribution was not normal and could not be improved through transformation therefore sitting times in all of the domains investigated in the study were categorised as ordinal variables. Ordinal regression analyses were executed using sitting times in the three domains (occupation, leisure screen-time and transportation/leisure) and total sitting time. Means, standard deviations and medians were calculated for sitting times within the

domains. Mean sitting times in terms of socio-economic classification were calculated to highlight how SB is distributed across the domains included in the study. Data on total sitting times were shown in terms of the various correlates included in the final models, to indicate the characteristics of those who engage in prolonged sitting. Multivariate ordinal regression analyses were executed to investigate associations between (i) biological and demographic; (ii) psychological, (iii) behavioural; (iv) social; and (v) physical environmental correlates with the dependent variables total sitting time, and the three domain-specific contexts of sitting. Separate binomial logistic regressions on cumulative dichotomous variables for each independent variable indicated that the assumption of proportional odds appeared tenable. Tests to see if the data met the assumption of collinearity indicated that multicollinearity was not a concern. *P*-values of less than 0.05 were considered statistically significant.

Results

The mean age of the 7328 participants was 51 years (SD \pm 17.8). Further descriptive characteristics are presented in Table 1 to address the first aim of the study. The median total sitting time of the sample was 450 min per day (IQR 290 min per day). The mean sitting time was 465.97 \pm 193 min per day.

Sitting time by domain specific context

Figure 2 shows the domain specific average sitting time in minutes per day, by socio-economic classification. Mean sitting time was highest in work/study domain (195 \pm 166), followed by screen-time sitting (184 \pm 122) and transportation/leisure sitting (139 \pm 95). Those in higher professional occupations had the longest sitting times per day in terms of both work/study sitting (230 \pm 161) and transportation/leisure sitting time (142 \pm 78), while those in routine/manual occupations had the longest leisure screen-time sitting (190 \pm 107).

Total sitting time

The strongest predictors of total sitting time were the intrapersonal factors of male gender, younger age, higher socio-economic classification and education levels, physical activity levels, having a long-term illness, and a probable mental health problem (Table 2). Having a caring role was associated with decreased sitting times. The environmental factors of living in an urban dwelling and increased neighbourhood 'problems' score were also associated with longer sitting times.

Work/study sitting time

Table 3 outlines results of regression analysis investigating the association between multi-dimensional correlates and occupational sitting. The strongest predictors of

occupational sitting time were male gender, younger age, higher socio-economic status and education levels, and low physical activity levels. Living in an urban location was associated with increased occupational sitting.

Leisure screen-time sitting

The results of multivariate ordinal regression to investigate the association of multi-dimensional correlates on leisure screen-time sitting (Table 4) showed that male gender, increased age, lower socio-economic and education levels, physical and mental health problems, insufficient physical activity, smoking, and alcohol consumption were associated with increased SB in this domain. Being single/divorced/widowed, not having a caring role, and living in an urban location were associated with increased leisure screen-time sitting.

Transportation/leisure sitting time

The results of multivariate ordinal regression to investigate the association of socio-ecological correlates on transportation/leisure sitting (Table 5) showed that an increase in sitting time was associated with older age, higher socio-economic and education levels, physical health problems, insufficient physical activity, not smoking, and alcohol consumption. Being single/divorced/widowed, and higher neighbourhood 'problem' scores were associated with increased transportation/leisure sitting.

Discussion

The aim of this study was to investigate the factors that are associated with sedentary behaviour, as well as the domains in which this behaviour accumulates in an adult population-level cohort. These factors were informed by the SEM, which takes into account the different levels of correlates - intrapersonal, interpersonal and environmental factors [18].

The results indicated worryingly high levels of overall sitting of >7.5 h per day in the Irish population, given the all-cause mortality risk associated with sitting for > 7h per day [16]. These levels are significantly higher than previous reports of 4 h per day of sitting time [35], and earlier preliminary findings reported in the 2015 Healthy Ireland Survey of 5.3 h per day [48]. A possible explanation could be differences in measures of sitting time used in the studies. The International Physical Activity Questionnaire short sitting question was used in both previous studies [35, 47], whereas total sitting time in the present study was calculated by summing the sitting times of the three domains measured. This may indicate a more accurate total sitting time as it captures SB separately for the most important daily contexts in which this behaviour occurs [18].

Table 1 Mean and standard deviation for total sitting in minutes/day, for intrapersonal, interpersonal, environment level influences

	N	Mean ± SD (Median)
Total sample	7328	465 ± 193 (450)
Age		
18–24	267	510 ± 179 (510)
25–34	467	480 ± 200 (470)
35–44	603	475 ± 201 (450)
45–54	447	477 ± 194 (480)
55–64	407	448 ± 187 (420)
65–74	203	392 ± 164 (370)
75–84	94	392 ± 165 (360)
85+	10	437 ± 140 (420)
Gender		
Female	1313	456 ± 193 (420)
Male	1185	477 ± 193 (480)
Long-standing illness		
No	1958	469 ± 194 (425)
Yes	538	477 ± 190 (450)
Education level		
<= Lower secondary	341	409 ± 185 (375)
Upper secondary	749	439 ± 187 (420)
Post-secondary course	442	458 ± 191 (420)
Bachelors or above	966	510 ± 193 (510)
Socio-economic classification		
Not classified	494	464 ± 185 (425)
Routine/manual	503	400 ± 174 (370)
Intermediate	633	460 ± 199 (420)
Higher managerial/professional	868	509 ± 193 (485)
Probable mental health problem		
No mental health problem	2310	469 ± 192 (433)
Probable mental health problem	188	506 ± 210 (480)
Physical activity levels		
Insufficient physical activity	1121	493 ± 200 (480)
Sufficient physical activity	1352	445 ± 185 (420)
Workplace activity		
Sitting	761	613 ± 167 (630)
Standing	281	366 ± 145 (360)
Mostly walking/moderate activity	553	370 ± 150 (360)
Mostly heavy labour/physically demanding	125	330 ± 140 (300)
Tobacco use		
No	2024	465 ± 193 (450)

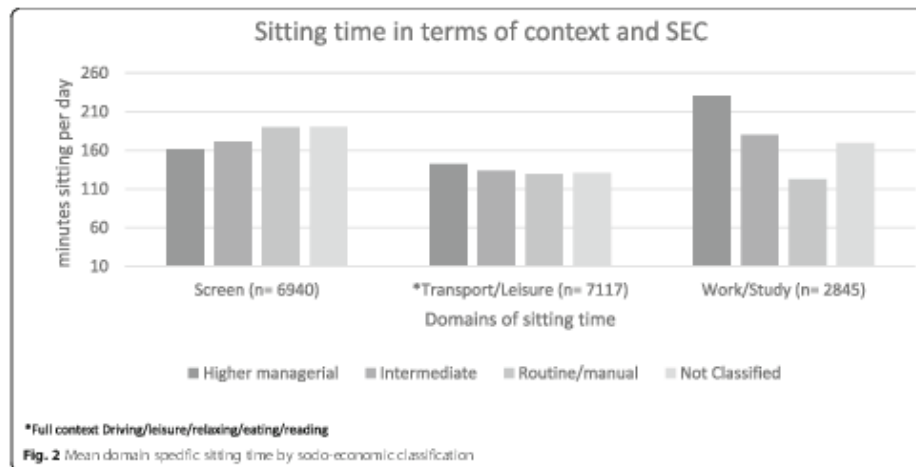
Table 1 Mean and standard deviation for total sitting in minutes/day, for intrapersonal, interpersonal, environment level influences (Continued)

	N	Mean ± SD (Median)
Yes	474	472 ± 196 (450)
Audit-C		
1–4	951	465 ± 196 (420)
5–8	275	483 ± 197 (480)
> 6	772	490 ± 186 (480)
Marital status		
Married/civil partnership	1366	456 ± 196 (420)
Not married/or in civil partnership	1132	478 ± 190 (480)
Caring Role		
No	2230	468 ± 194 (450)
Yes	268	448 ± 187 (420)
Neighbourhood attributes		
No Problem	893	456 ± 186 (420)
Some problems	1605	471 ± 197 (450)
Location		
Urban	1582	494 ± 191 (480)
Rural	916	418 ± 189 (390)

Highest sitting times accumulated for occupational sitting (> 3 h/day), in line with recently reported average daily occupational sitting [37], although somewhat lower than some previous studies [49–51]. The increase in desk-based occupations in recent decades has resulted in the workplace being a major contributor to sedentaryness [52, 53]. Leisure screen-time sitting (2.5 h per day) in this study was higher than previous findings which included TV/tablet viewing within their screen-time measure [33]. Transportation/leisure sitting times (2 h/day) was in line with previous reports of this combination of these sitting domains [50].

Those with low levels of physical activity were the most sedentary in terms of all of the sitting contexts investigated in this study. This is in line with previous studies showing an inverse relationship between PA and SB [29, 54–57].

In line with previous findings [34, 57] higher socio-economic classification and education levels were correlated with longer total sitting and occupational and transportation/leisure sitting times. This may be due to those with higher education attainment are more likely to be employed in more sedentary occupations. A recent review reported [19] that females who were older had higher total and leisure SB; however in our study males had significantly higher total, occupational and leisure screen-time SB. This is in line with studies that have found that total and



occupational sitting was highest in males [34, 37]. Contrary to other reports that males had higher motorised travel sitting, we found no association with gender and the transportation/leisure context of SB.

De Cocker et al. [48] found that being a younger male was associated with increased occupational sitting while in front of a computer screen. We found less occupational and total sitting as age increased, whereas in the contexts of leisure screen-time and transportation/leisure SB, an increase in sitting times as age increased was found. Although higher education attainment was associated with greater transportation/leisure sitting time and occupational sitting, those with lower education attainment were positively associated with leisure screen-time sitting. This inverse relationship between screen-time sitting and education confirms previously reported findings [44, 58, 59], and TV viewing has been well established as being associated with lower socio-economic position [44, 59–61]. These nuances in terms of correlates and drivers of sedentary behaviour highlight the need to focus on the separate domains of sitting. Smoking was not found to be associated with increased total or occupational sitting in this study, however being a smoker was associated with increased screen-time sitting. Previous studies have reported an association with smoking and leisure screen-time sitting [62], while other studies have found correlations with smoking and total sitting times in studies of women [29, 62]. We also found that transportation/leisure sitting was associated with not smoking, which may be explained by

the fact that smokers may leave their home to smoke outside.

Alcohol consumption was associated with increased leisure screen-time sitting and transportation/leisure sitting times. A recent review [19] found conflicting results regarding the relationship between alcohol consumption and SB, with three of the five studies included showing no association [29, 31, 64], while the remaining two studies found it to be positively associated with time spent sedentary in transportation [65] and to overall weekend sedentary time [63]. Relationships with alcohol are complex; this finding could be interpreted to mean that high risk drinkers sit more while in leisure screen-time viewing, possibly reflecting the recent culture of drinking more at home [66], while individuals who consume more alcohol in the transportation/leisure context may reflect a propensity for more sedentary leisure activities, such as reading or consuming alcohol while eating, further research is needed to investigate this.

Our study examined psychological factors associated with sedentary behaviour, and found that having a possible mental health problem was associated with increased total sitting times and leisure screen-time SB. This is in line with previous reports that individuals with major depressive disorders and comorbid depressive and anxiety disorders spend significantly more time in leisure SB while using the computer and TV viewing [65]. Recent reviews have found that SB is associated with increased risk of depression [67], and suggest positive associations between SB and anxiety risk [68]. The present study extends the research beyond screen-time SB and total SB by investigating associations between

Table 2 Results of multivariate ordinal regression on the contribution of various correlates on total sitting

N=1984	OR	CI	p-value
Gender			
Male	1.32	1.11–1.56	< 0.00
Female	1	Ref.	
Age ^a	0.99	0.98–0.99	< 0.00
Socio-economic status			
High	1.79	1.5–2.1	< 0.00
Low	1	Ref.	
Education			
High	1.43	1.21–1.68	< 0.00
Low	1	Ref.	
Long-term illness			
Yes	1.26	1.01–1.53	0.04
No	1	Ref.	
PWB-P			
No	0.73	0.53–0.99	0.04
Yes	1	Ref.	
Physical activity			
Not sufficient	1.70	1.46–2.01	< 0.00
Sufficient	1	Ref.	
Tobacco			
No	0.20	0.93–1.38	0.20
Yes	1	Ref.	
Audit-C ^a	0.99	0.99–1.06	0.18
Marital status			
Married/Cohabiting	0.87	0.72–1.01	0.07
Single/Divorced/Widowed	1	Ref.	
Caring role			
No	1.30	1.01–1.67	0.04
Yes	1	Ref.	
Location			
Urban	2.03	1.72–2.4	< 0.00
Rural	1	Ref.	
Neighbourhood ^a	1.05	1.00–1.10	0.04

^aContinuous variable**Table 3** Results of multivariate ordinal regression on the contribution of various correlates on occupational sitting

N=2172	OR	CI	p-value
Gender			
Male	1.27	1.08–1.50	0.00
Female	1	Ref.	
Age ^a	0.98	.97–.98	< 0.00
Socio-economic status			
High	2.20	1.87–2.58	< 0.00
Low	1	Ref.	
Education			
High	1.57	1.33–1.84	< 0.00
Low	1	Ref.	
Long-term illness			
Yes	1.15	1.33–1.80	0.16
No	1	Ref.	
PWB-P			
No	0.83	.613–1.13	0.23
Yes	1	Ref.	
Physical activity			
Not sufficient	1.55	1.33–1.80	< 0.00
Sufficient	1	Ref.	
Tobacco			
No	0.99	.95–1.04	0.68
Yes	1	Ref.	
Audit-C ^a	0.99	.96–1.03	0.68
Marital status			
Married/Cohabiting	0.96	.82–1.13	0.64
Single/Divorced/Widowed	1	Ref.	
Caring role			
No	1.20	.94–1.53	0.15
Yes	1	Ref.	
Location			
Urban	1.96	1.67–2.30	< 0.00
Rural	1	Ref.	
Neighbourhood ^a	0.99	.95–1.04	0.68

^aContinuous variable

psychological wellbeing and other domains of SB such as occupational and leisure-time SB. Few studies have investigated psychological factors, and although we provide support for previous findings [69–71], outcome measures vary making direct comparisons difficult.

In terms of interpersonal factors, previous studies investigating TV SB reported that increased sitting was associated with being single [27], whereas Xie et al. [64] found TV viewing time to be higher in married people. Uijtendwilligen et al. [63] found that those who were

married or living with a partner, were significantly less likely to be active compared to single women. We found an association between being married or in a civil partnership and lower leisure screen-time sitting and lower transport/leisure SB, in line with findings previously reported [28].

Mixed results have been reported in previous studies investigating physical environment correlates depending on the SB context. Higher total sitting times have been reported in women in urban areas compared to those

Table 4 Results of multivariate ordinal regression on the contribution of various correlates on leisure screen-time sitting

N = 5104	OR	CI	p-value
Gender			
Male	1.19	1.07–1.33	< 0.00
Female	1	Ref.	
Age ^a	1.02	1.01–1.02	< 0.00
Socio-economic status			
High	0.72	0.65–0.80	< 0.00
Low	1	Ref.	
Education			
High	0.78	0.70–0.87	< 0.00
Low	1	Ref.	
Longterm illness			
Yes	1.25	1.12–1.41	< 0.00
No	1	Ref.	
PW-P			
No	0.73	0.61–0.89	0.00
Yes	1	Ref.	
Physical activity			
Not sufficient	1.47	1.33–1.62	< 0.00
Sufficient	1	Ref.	
Tobacco			
No	0.81	0.71–0.91	0.00
Yes	1	Ref.	
Audit-C ^a	1.05	1.03–1.10	< 0.00
Marital status			
Married/Cohabiting	0.79	0.72–0.88	< 0.00
Single/Divorced/Widowed	1	Ref.	
Caring role			
No	1.25	1.67–1.47	0.01
Yes	1	Ref.	
Location			
Urban	1.28	1.16–1.42	< 0.00
Rural	1	Ref.	
Neighbourhood ^a	1.02	0.10–1.05	0.11

^aContinuous variable**Table 5** Results of multivariate ordinal regression on the contribution of various correlates on sitting while driving/eating/reading/relaxing

N = 5258	OR	CI	p-value
Gender			
Male	1.00	0.90–1.12	0.97
Female	1	Ref.	
Age ^a	1.01	1.00–1.01	< 0.00
Socio-economic status			
High	1.17	1.01–1.30	0.00
Low	1	Ref.	
Education			
High	1.34	1.21–1.50	< 0.00
Low	1	Ref.	
Longterm illness			
Yes	1.33	1.18–1.49	< 0.00
No	1	Ref.	
PW-P			
No	1.10	0.90–1.32	0.39
Yes	1	Ref.	
Physical activity			
Not sufficient	1.12	1.02–2.41	0.02
Sufficient	1	Ref.	
Tobacco			
No	1.15	1.01–1.30	0.03
Yes	1	Ref.	
Audit-C ^a	1.03	1.01–1.05	0.01
Marital status			
Married/Cohabiting	0.90	0.80–0.98	0.02
Single/Divorced/Widowed	1	Ref.	
Caring role			
No	0.95	0.81–1.11	0.50
Yes	1	Ref.	
Location			
Urban	0.99	0.89–1.10	0.82
Rural	1	Ref.	
Neighbourhood ^a	1.04	1.01–1.07	0.00

^aContinuous variable

living in a rural location [29, 31], however increased SB associated with transportation was shown in rural-dwelling participants in two studies [57, 72]. The present study found that living in an urban location was associated with longer total, leisure screen-time, and occupational sitting times.

O'Donoghue et al. [19], in a systematic review, reported mixed results in terms of sedentary behaviour and various neighbourhood and community attributes. In a study including data from the US, Australia and

Belgium, perceived aesthetics and proximity of destinations within participants' neighbourhoods were associated with higher total sitting [28], while Compennolle et al. [73] reported no association between objectively measured neighbourhood attributes and total SB. Our study further investigated SB within various contexts and self-reported neighbourhood attributes and found a positive association between total- and transportation/leisure sitting times and neighbourhood factors. This adds evidence to the assertion that environmental characteristics

related to perceived attributes of a neighbourhood may explain some of the variance in sedentary behaviour.

Our findings highlight the various and important correlates of sitting time in adults, as well as the physical and social contexts of where daily sitting time accumulates.

Strengths

The strengths of this study include the large population-representative sample of the Healthy Ireland Survey, and the ability to assess correlates of sitting which can operate in distinct ways across different contexts; the results can therefore be generalised. This study is one of the few to investigate many potential factors associated with prolonged sitting time, including psychological influences, interpersonal factors, and neighbourhood factors that may influence SB. The novelty of this study lies in the various contexts of sitting included in this study that provides a comprehensive measure to calculate total sitting time. The inclusion of smartphone and tablet screen-time SB in the leisure screen-time SB measure captures more contemporary screen-time SB habits. Using a socio-ecological approach the study extends our knowledge on sedentary behaviour accumulated across multiple domains.

Weaknesses

A limitation of this study is the use of self-report to assess sedentary behaviour. Self-report measures have limited validity due to issues with recall and social-desirability responses, however, there is consistency between self-report of SB and objective measures for most factors [19]. Transportation and leisure SB were combined in the present study, and although transportation SB may contribute the least to overall daily SB, it may be of benefit to investigate these domains separately. A further limitation in this study is the lack of differentiation between weekdays and weekend days in the Healthy Ireland Survey. Other characteristics of sitting such as prolonged bouts of sitting or sit/stand transitions were not captured. Body mass index and a breakdown of physical activity levels were not included in this dataset precluding important examination of these salient factors and their relationship with, and influence on, sedentary behaviour. Policy level factors were not available, which the SEM highlights as an important influence on behaviour. Finally, the cross-sectional design of this study provides information on factors associated or correlated with sedentary behaviour, thereby limiting causal inference and is subject to reverse causality.

Implications of findings for policy and future research

This study establishes factors that may help understand sitting behaviour in an adult population, and importantly

how these vary across specific domains of sitting, thereby providing valuable and relevant information for future development of effective interventions to reduce this damaging health behaviour. Males, with higher education and socio-economic classification levels, with a possible mental health problem, and those with insufficient levels of physical activity were the most likely to be sedentary. The domain in which most sitting was reported was occupational sitting, thus suggesting the workplace as a target setting for future interventions.

Subsequent research on SB will benefit from longitudinal designs that allow researchers to identify and predict determinants of sedentary behaviours, extrapolating them clearly from correlates. Surveillance using a combination of objective measures of sitting times including accelerometers/inclinometers, and contextual information obtained by subjective measures, would be preferable, however applying these on a large scale would be challenging. Homogeneity of outcome measures in future studies would be useful in terms of more in-depth analysis and provide more meaningful and useful conclusions. However, this evidence augments the Healthy Ireland survey findings and highlights the value of this data by enabling the application of the socioecological model to provide baseline information on important individual, social and environmental targets to incorporate into health promotion strategies and policy aimed at reducing sedentary behaviour.

Conclusions

Sedentary behaviour remains high in the Irish population with the average sitting time reported at > 7.5 h per day. Workplace sitting contributed the most to total sitting time. Males, with sedentary occupations, in professional roles and in urban locations were most likely to be sedentary, therefore it is important to direct future policy and interventions to these groups.

Abbreviations

AUDIT-C: Alcohol use disorders identification test; consumption; CAP: Computer assisted personal interview; IPAQ: International Physical Activity Questionnaire; METs: Metabolic equivalents; SB: Sedentary behaviour; SEM: Socio-ecological model; SF-36: Short form 36

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Authors' contributions

All authors contributed to the design of the work. GN carried out all statistical analysis, interpreted the data and produced the first draft of the manuscript. CD and CH supervised the direction of the project, and revised it critically for all important intellectual content. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

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analysis and interpretation of the data or in writing the manuscript. The views expressed are those of the authors and not necessarily those of the Dean of the Faculty of Health Sciences.

Availability of data and materials

The data that support the findings of this study are available from the Department of Health but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. The provision of access to the data rests with the Department of Health, and is available to researchers fulfilling assessment criteria.

Ethics approval and consent to participate

Approval to conduct the original study and to obtain informed verbal consent, recorded electronically, prior to commencement of the interviews was provided by the Research Ethics Committee of the Royal College of Physicians of Ireland. Verbal consent was obtained as opposed to written consent due to the administration difficulties pertaining to such a large population-level survey. Ethical approval for analyses was granted by Research Ethics Committee, School of Medicine, Trinity College Dublin.

Consent for publication

No applicable.

Competing interests

The authors declare that they have no competing interests.

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STUDY PROTOCOL

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A theory-based multicomponent intervention to reduce occupational sedentary behaviour in professional male workers: protocol for a cluster randomised crossover pilot feasibility study



Gail Helena Nicolson^{*} , Catherine Hayes and Catherine Darker

Abstract

Background: Prolonged sitting, a significant risk factor for increased morbidity and mortality, is accumulated mostly in the workplace. There is limited research targeting specific at-risk populations to reduce occupational sedentary behaviour. A recent study found that professional males have the longest workplace sitting times. Current evidence supports the use of multi-level interventions developed using participative approaches. This study's primary aims are to test the viability of a future definitive intervention trial using a randomised pilot study, with secondary aims to explore the acceptability and feasibility of a multicomponent intervention to reduce workplace sitting.

Methods: Two professional companies in Dublin, Ireland, will take part in a cluster randomised crossover pilot study. Office-based males will be recruited and randomised to the control or the intervention arms. The components of the intervention target multiple levels of influence including individual determinants (via mHealth technology to support behaviour change techniques), the physical work environment (via provision of an under-desk pedal machine), and the organisational structures and culture (via management consultation and recruitment to the study). The outcomes measured are recruitment and retention, minutes spent sedentary, and physical activity behaviours, work engagement, and acceptability and feasibility of the workplace intervention.

Discussion: This study will establish the acceptability and feasibility of a workplace intervention which aims to reduce workplace SB and increase PA. It will identify key methodological and implementation issues that need to be addressed prior to assessing the effectiveness of this intervention in a definitive cluster randomised controlled trial.

Keywords: Under-desk pedal machine, mHealth, Sedentary behaviour, Active sitting, Physical activity, Occupational sedentary behaviour, Socio-ecological model

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Introduction

Background and rationale

Prolonged periods of daily sedentary behaviour (SB) are associated with increased mortality, cardiovascular morbidity, diabetes [1–3], some cancers [4, 5], depression [6], and decreased self-rated health [7]. SB has been defined as any waking behaviour while in a sitting or lying position that expends ≤ 1.5 metabolic equivalents (METs) of energy expenditure (EE) [8]. Being sedentary for more than 7 h per day is associated with increased all-cause and cardiovascular mortality rates [3, 9]. Although high levels of physical activity (PA) may attenuate these relationships, 60–75 min per day of moderate physical activity (MPA), or 3.5 times the World Health Organization's (WHO) PA recommendations of 150 min of MPA per week, are required to eliminate the detrimental effects of SB [9]. Time spent in SB has increased rapidly in middle- to high-income countries in recent years and is set to continue to do so without intervention [10]. Given the detrimental health impact of prolonged and uninterrupted daily SB, this presents a serious public health concern.

The settings approach moves interventions upstream from defining goals and targets in terms of populations or individuals only, towards identifying goals that focus on changes in organisations, systems, and the environment [11, 12]. In this context, all of the opportunities for influencing health within a setting can be considered priorities for change, which can lead to maximised health gain [13]. The WHO includes the implementation of multicomponent interventions in a workplace setting to target physical inactivity as one of their 'best buy' recommendations for the prevention and control of non-communicable diseases [14].

Working adults spend more than 7.5 h of their day being sedentary, and when individual, social, and environmental factors are controlled for, professional males with high levels of education and who live in an urban location have the longest sitting times [15–17]. High levels of occupational SB are associated with depression and anxiety [18], increased BMI [19], and risk of heart failure [20], mortality in men [21], colorectal cancer [22], pancreatic cancer [23], lung cancer in women [23], and breast cancer in women aged younger than 55 years [24]. Reducing workplace SB is important to curtail the physical and mental health risks associated with prolonged SB [6, 25–27]. Individuals in private offices sit more and engage in more prolonged sitting than those in public office spaces suggesting that this group may be at increased risk of the associated health outcomes [28].

Given the strong reinforcing and restrictive properties of the physical and social environment of the office workplace, allowing workers to continue with their favoured or required task (e.g. computer work), while breaking up prolonged SB may be most acceptable and effective in terms of workplace interventions to address SB [29]. Studies examining sit-stand workstations have

enabled the break-up of prolonged SB by replacing some SB with standing; however, standing does not provide the metabolic benefits of light physical activity (LPA) [30]. A recent study employing a data compositional approach showed that standing (and SB) was associated with increased body mass index (BMI), body fat, and fat mass [31]. Standing for long periods may indeed be detrimental to cardiovascular health and has been associated with an increase in the risk of ischemic heart disease and varicose veins [32]. Rempel and Krause [33] suggest that advising sedentary employees to increase standing time at work should not be recommended, and maintain that if the basis for a reduction in SB is to improve cardiovascular health, promotion of increased standing is misguided. Results from studies using treadmill desks [34] and activity-permissive workstations [35] suggest that combining simultaneous, low-intensity PA with sedentary practices could increase daily caloric expenditure and reduce cardio-metabolic risk factors. 'Active sitting' as opposed to 'reduced sitting' may be preferred in workplace interventions where the choice of employees and/or employers may be to remain seated [36]. Furthermore, combining PA with sedentary activities could reduce time-related costs of PA—a frequently cited barrier to regular PA in adults [37].

The socio-ecological model of SB emphasises the importance of intervening at the many levels influencing behaviour in the workplace and includes organisational structures, the physical and social interpersonal environment, and intrapersonal factors [38]. Multicomponent interventions have been most successful in reducing workplace SB [39], while interventions that involve environmental restructuring (e.g. activity-permissive workstations) have shown the largest reductions in daily SB [40]. Cycling workstations with resistance (i.e. 20–30 Watts) can increase EE by twice the amount of METs compared with standing workstations [41]. The feasibility of using under-desk portable pedal machines to reduce SB has been reported in laboratory settings [42, 43] and in studies predominantly of women [44]. Some productivity issues while cycling in work, i.e. accuracy of computer mouse dexterity [45] or typing performance [43], have been reported; however, cycling does not impair reading comprehension or speed of computer mouse use. These productivity issues were inversely related to cycling speed, whereby cycling at a high cadence is likely to result in considerable trunk movement, providing a less stable base for upper limb movements and hence potentially impairing the task performance [43, 45]. Cycling in work has been found to increase arousal and reduce boredom significantly more than standing workstations [46] and may be capable of increasing short-term memory and attention more effectively than standing or treadmill workstations [47]. The rationale for providing sedentary employees working in professional environments

with pedal machines at work is to allow participants to engage in light-intensity activity (i.e. active sitting) that can be performed for long periods throughout the day without causing perspiration, a previously reported barrier to workplace PA [48, 49].

Ensuring relevance and individualisation are effective basic methods in health interventions, and this is traced especially to social cognitive theory (SCT) [50]. The core determinants of health behaviour in SCT are knowledge of health risks, perceived self-efficacy, outcome expectations, health goals, perceived facilitators and barriers, and social and structural impediments to change. In a recent review of behaviour change techniques (BCTs) used in SB reduction interventions among adults, the most frequently used intervention functions were enablement (i.e. facilitating reduction in SB), education, and environmental restructuring. The most commonly used (and also most promising) techniques were setting behavioural goals, providing unspecified forms of social support, and addition of objects to the environment [51].

Contemporary technological advances in digital tools such as mobile phones, the Internet, and wearable technology provide a platform to intervene on an individual level to change behaviours. A systematic review and meta-analysis of interventions using computer, mobile, and wearable technology to reduce SB reported a mean reduction of 41 min per day in interventions that used these tools. The most frequently used BCTs were prompts/cues, self-monitoring of behaviour, unspecified social support, and goal-setting [52].

Mobile health (mHealth) technology has rapidly gained popularity in the general population. mHealth technology includes wearable PA monitors and trackers that connect to smartphone applications (apps). These apps allow individuals to manage their own health and wellbeing at a relatively low cost and offer potential to tailor interventions to the needs of individuals or specific groups. A recent review to investigate the use of mHealth in interventions found reasonable evidence that mHealth may be an effective and feasible method to increase PA, with some evidence for effectiveness in reducing SB [53]. Studies using mHealth to promote PA and reduce SB in the workplace found significant reductions in sedentary time in women [54], where the outcomes were increasing daily steps [55, 56], or reductions in computer use as a proxy for SB [57]. Team-based competition as opposed to individual monitoring has been found to increase compliance with wearing activity monitors [53].

Adopting a participatory approach to intervention development and evaluation of an intervention's acceptability and feasibility benefits the development of effective interventions [58, 59]. Pretesting the participants' knowledge, beliefs, and circumstances and using this information as a basis for intervention development creates relevance [60]. For interventions to be acceptable, feasible, and effective,

participant involvement provides important information on the individual, organisational, and cultural contexts into which SB reduction strategies must be embedded.

The present study

This study operationalises the Eldridge et al. [61] definition of a randomised pilot study, i.e. those studies in which the future RCT, or parts of it, including the randomisation of participants is conducted on a smaller scale. Feasibility outcomes which 'might be interviews to ascertain the acceptability of an intervention' are also investigated within Eldridge et al.'s feasibility study description [61].

Previous research attests to the potential efficacy of combining pedal machines and motivational behaviour change strategies. However, to our knowledge, no studies have combined BCTs of goal-setting, social comparison, self-monitoring, and prompt/cues in a multicomponent intervention using mHealth technology, an ergonomic under-desk portable pedal machine, as well as targeting organisational support by recruiting management staff to participate, in a male-only sample. Pilot work can aid in the design of future trials with continuous outcomes by providing estimates of population SD, evidence of potential for intervention effectiveness, and quantification of feasibility in the form of recruitment and retention rates [62]. This paper outlines the protocol for a randomised pilot study which will employ a cluster randomised controlled wait-list crossover design.

Aims and objectives

The study aims to:

1. To conduct a randomised pilot study to test a set of feasibility objectives to ascertain if a future RCT is viable
2. To investigate the acceptability and feasibility of a multicomponent intervention to reduce SB by promoting active sitting and LPA in professional male office workers

The objectives of this study will test the feasibility and viability of the intervention in a future larger trial by reporting recruitment and retention rates, and potential intervention effectiveness by ascertaining if participants in the intervention period differ in occupational and overall SB and PA (including cycling time) compared to the control period. This will be addressed by collecting accelerometry data, which will provide information on minutes spent sedentary, standing and moving. The objectives also include an investigation of the acceptability of the intervention using semi-structured interviews and focus group data which will explore participants' views of acceptability and usefulness and their expectations and experiences of the study. The study will measure intervention acceptability, appropriateness, and feasibility using a questionnaire

administered to participants immediately post-intervention [63].

Methods

Design

Intervention development process

This intervention was developed using guidance from the Medical Research Council (MRC) [64, 65] and encompasses three distinct phases. The first preclinical stage was a literature review of workplace interventions to reduce SB and the application of socio-ecological theory to the design of the current intervention.

Phase I involved the identification of intervention components and the underlying mechanisms by which the outcomes will be influenced. The development of the intervention followed the principles of the integrated approach of socio-ecological theory: a method that emphasises the need to consider multiple levels of influence on behaviour. Qualitative testing and the adoption of a participatory approach through focus groups and semi-structured interviews with both employees and managers have been conducted to help understand the relevance of the intervention components as well as potential barriers to behaviour change.

This protocol outlines phase II of the approach that tests the acceptability and feasibility of an intervention to reduce workplace SB to develop an optimum intervention, as well as feasibility objectives to test the viability of a future trial. The dominance of progression criteria has been noted as relatively crude and somewhat binary assessments of acceptability and feasibility (e.g. [53]). Assessing the acceptability and feasibility of complex interventions in terms of what works, for whom and under what circumstances, and aiming to refine hypotheses about potential mechanisms of action and how these might vary by context has been suggested as more appropriate to better develop interventions [66] and can be integrated to the MRC framework [65, 67]. By exploring the views of those involved by collecting rich qualitative data, as well as contextual exploration, enables optimisation of intervention design or how to adapt to different contexts prior to a full RCT. Piloting the processes of a full RCT such as randomisation and assessing qualitative data provides insight without biasing outcome measurement, e.g. Hawthorne effect, and can assist in hypothesis refinement.

The intervention comprises the provision of the following components: (1) an under-desk portable pedal machine (DeskCycle2; 3D Innovations LLC, Greeley, CO, USA), (2) Garmin Forerunner 35 activity tracker, and (3) access to a Garmin Connect application (app) and website (Garmin.com). The organisational-level component will be targeted by recruiting management staff to the study, thereby garnering support for employees to participate in the pilot study.

The intervention will communicate the key message: 'cycle at work'. As highlighted from prior qualitative work, the determinants goal-setting, self-monitoring, and social comparison will be included using BCTs provided within the Garmin Connect app/website. Gender-sensitised interventions that recognise men's interests and tailor health promotion efforts for this specific group have been found to be more effective in increasing physical activity [68, 69]. Social comparison will be used as a strategy to focus on the masculine ideal. By engaging men in PA, this draws upon as well as provides opportunities to garner masculine capital by affirming competitiveness and/or striving for physical prowess [68, 70]. Social comparison will be targeted by providing weekly feedback of each team's progress. Participants will also be prompted to move every 60 min of accumulated SB using the 'move' prompt on the Garmin Forerunner 35 wrist-worn device.

Figure 1 shows an overview of the study timeline. The intervention and control arms will be conducted over 14 days each. The active intervention will involve the use of an under-desk pedal machine to interrupt SB every hour and accumulate ≥ 30 min of cycling time during the working day. There will be a washout period of 1 week between the intervention and control arms. The washout period is used as there is a possibility that the effect of a treatment/intervention in one period may carry over into the next period [71]. These are known as carryover effects. Unless both carryover and period effects are known to be negligible, a crossover design loses its advantages. In order to ensure negligible carryover effects, there is a need to have sufficient washout periods between intervention periods. In circumstances where a participant suffers any adverse outcome such as pain or discomfort while taking part in the study, they will be advised to immediately discontinue participation in the study and to contact their doctor.

The study protocol has been registered at the International Standard Randomised Controlled Trial Number (ISRCTN11584275).

The Standard Protocol Items: Recommendations for Intervention Trials reporting guidelines were used to guide the preparation of this pilot study protocol [72].

Participants

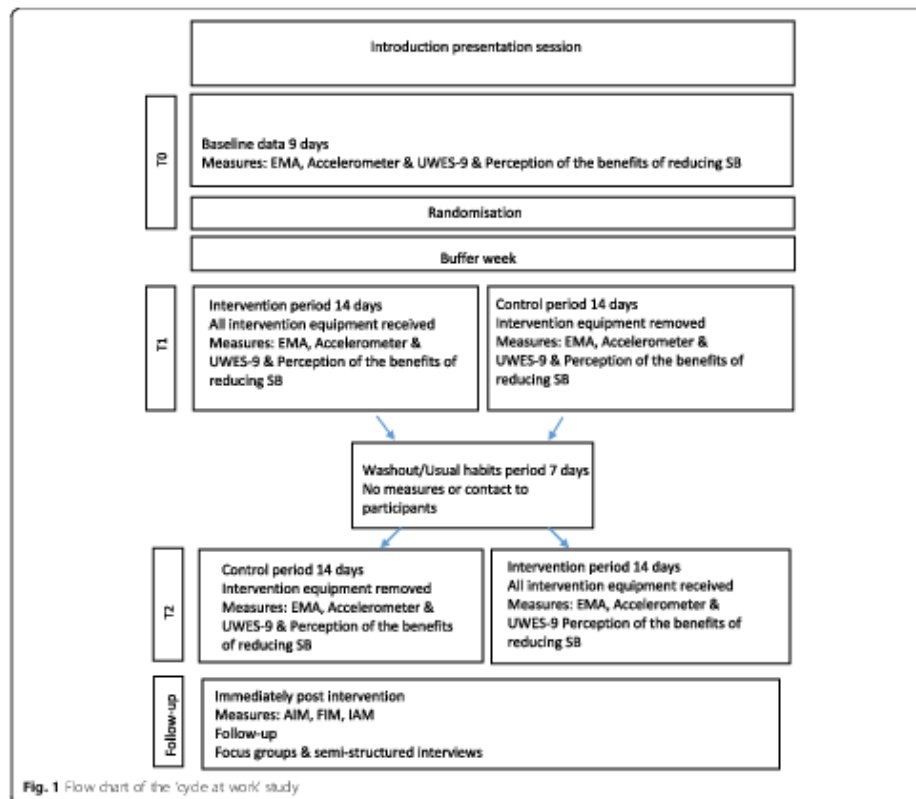
Participants will be office-based employees from two professional companies in Dublin, Ireland.

Inclusion criteria

- Males who spend most of their working week performing desk-related activities

Exclusion criteria

- Have limitations with or **contraindications** to physical activity as indicated by the Physical Activity Readiness Questionnaire [73]



- Do not have a personal desk
- Females
- Age under 18 years
- Employees who plan to be absent from the workplace for more than 2 days during the study period
- Employees who are involved in another programme or intervention to reduce behaviours

Randomisation

Following baseline assessments, worksites will be randomised to the intervention or control arms of the trial. Simple cluster randomisation will be determined by a statistician not associated with the project, who will use randomisation software to allocate each worksite to begin with either the intervention or control period.

Allocation concealment

Participants will not be advised of their group allocation until after baseline assessments have been made. The allocation concealment mechanism is important to reduce selection bias as it prevents foreknowledge of the period (control/intervention) in which participants are enrolling, which negatively affect recruitment [74].

Blinding

Due to the nature of the study, neither the participants nor the research team will be blinded to group assignments.

Setting and context

The proposed randomised pilot feasibility study will be conducted in two private-sector professional organisations in Dublin, Ireland (a legal firm and an online medical education provider). The sites have been chosen to

target professional males as outlined in the introduction as those with the highest risk of prolonged SB.

Management approval has been obtained for employee recruitment, for permission to make environmental changes in the office setting, and for study contacts to occur during work-time. All participants will provide written informed consent before inclusion in the study.

Selection and recruitment

Convenience sampling has been used to recruit the organisations who have been involved in the development of this pilot study. The organisations were initially approached through the lead researcher's personal networks. Purposive sampling will be used to recruit eligible participants in the companies via an email sent by a contact within each company. Participants in this study will include members of management and managing partners as well as employees.

Sample size

No formal sample size calculations are produced for this pilot feasibility study. The sample size is pragmatic and chosen based on resources. Thirty male desk-based workers will be recruited to the feasibility trial. A sample size of $n = 30$ is conventionally deemed adequate for pilot studies as it permits collection of sufficient useful data while minimising research costs [75].

Focus groups comprising separate management and employee participants in each worksite will be recruited (four in total) for intervention evaluation purposes. This is appropriate in qualitative research of this kind, with diversity of sampling (i.e. all stakeholder groups) more important than numbers of focus groups [76].

Procedure

An open call will be given to all staff who meet inclusion criteria, regardless of area/department to take part in the research. When preliminary agreement to the study has been obtained, the lead researcher will meet potential participants at their workplace, where they will be provided with a consent form, participant information leaflet (PIL), and a verbal explanation of the study. Participants who are interested in taking part in the study will be asked to consider the consent form and PIL for a 24-h period. Arrangements to meet all participants who are willing to participate will then be made, and they will then sign the consent form. The Physical Activity Readiness Questionnaire (rPARQ) health screening tool [73] will be administered to participants at the information/briefing stage to ensure participants' physical capability to safely participate in the study.

Following the baseline period, all participants will be provided with a report via email on their weekly SB and PA derived from their baseline accelerometer data. Participants randomised to the intervention group will then

be shown by the lead researcher in a face-to-face session at their workplace on the correct use of the intervention equipment. The goal of cycling 30–40 min/day (i.e. ≥ 5 min/h for 8 h) has been chosen as the minimum amount of exercise break to fractionate SB [31]. The Garmin watch is paired with a Bluetooth cadence sensor on the pedal machine and will record minutes of cycling upon start and stop buttons pressed by participants. The completed activity will transfer wirelessly via Bluetooth to a smartphone application (Garmin Connect) or to the website on participants' workplace computer using a wire. The watch has a 'move bar' that visually appears and provides a sound and vibration alert after 1 h of inactivity. Additional segments appear every 15 min of inactivity thereafter. The move bar is reset by engaging in a small amount of physical activity (i.e. work short distance, record stationary cycling). The Garmin platform does not allow the setting of SB goals, but does allow cycling-time goals. Prior to the intervention commencement, all participants will be assigned teams formed within sites (e.g. managers versus employees, or a mix of roles), which will target the social comparison behaviour change strategy. The Garmin platform allows self-monitoring of participants' own time spent in SB, PA, and cycling, and participants will be encouraged to visit the site regularly. A weekly email from the researcher will provide encouragement and feedback on participants' activity progress. For logistical and practical reasons, there will be a buffer week after randomisation. This is to allow the researcher to attend the workplaces to deliver the pedal machines and Garmin watches.

Control arm

Participants in the control arm will be informed that they have been randomised to a delayed intervention that will begin after 3 weeks and will be asked to continue their normal workplace habits. All measures collected in the intervention group will be collected in the control arm.

Assessments

At baseline, participants will wear the thigh-based accelerometer (activPAL3) monitor for 24 h/day, for nine consecutive days (and 14 days each for control and intervention arms). All device removals will be documented in a wear diary. Prior to being attached to the participant, the device will be set to record at 20 Hz. The activPAL3 will be set to start recording at 0001 h on the day after the participant receives the device. Each device will be attached to the anterior aspect of the midline of the right thigh using a nitrile sleeve and waterproof Tegaderm dressing. Sleep, sedentary time, standing time, physical activity (i.e. stepping time (minutes) (cadence ≥ 100 , duration > 1 min)) will be derived from the activPAL3 data. An acceleration threshold has been developed (unpublished data)

to identify under-desk cycling, i.e. cut-point threshold acceleration exceeding 375.0 (sum of vector magnitude), while seated (recorded as SB by activPAL), and in bouts lasting ≥ 5 continuous minutes. Only cycling that occurs within self-reported working hours will be analysed and then quality-checked by comparing to user-entered Garmin recorded cycling time. Sedentary time and standing time will be calculated using the postural function of the monitor through the associated software (activPAL v8.10.8.75).

Contextual SB information will be measured using self-report via Ecological Momentary Assessment (EMA). The use of EMA has been recommended to collect ecologically valid and context-specific outcome data alongside objective measures in studies [77, 78]. EMA involves repeated sampling of participants' current behaviours and experiences in real time and in their natural environments. This is useful to specify the type of activity or contextual factors (e.g., physical, social, temporal, affective) surrounding these behaviours which are important factors to consider when developing interventions and that cannot be provided by objective measures [79]. EMA has been reported as a valid and reliable measure of SB and PA in adults [80] and for use in a workplace setting [81]. Each day, six notifications will appear on participants' own mobile smartphones at random times between 8 am and 10 pm, using the application PIEL Survey (pielsurvey.org, v1.2.4.2). The notifications are scheduled at random times to obtain a representative sample of participants' activities over the course of their study participation. The questions have been found to be valid and feasible [82].

Work engagement will be measured at baseline, post-control arm, and post-intervention arm using the Utrecht Work Engagement Scale (UWES-9) [83]. The perceived benefits of reducing SB in the workplace will also be assessed at these time points using a questionnaire devised by the research team. Immediately upon finishing the study, participants will be asked to complete a questionnaire to assess the acceptability, appropriateness, and feasibility of the intervention [63].

Focus groups and semi-structured interviews will be carried out within the 2-week post-intervention follow-up. An interview schedule has been designed based on existing literature. The interview schedule for the focus groups will be guided by Orsmond et al. [84]. The schedule will be pre-piloted on a small number of employees within the author's place of work, within the Discipline of Public Health and Primary Care.

Pilot outcomes

Trial-related outcomes will be explored within the focus groups and/or semi-structured interviews which includes:

- Acceptability of the assessments and burden by the users—from a management and employee perspective
- Acceptability of the study procedures by the users—from a management and employee perspective

Recruitment and retention

- Number of people recruited to the study recorded by the researcher at the beginning of the study
- Number of dropouts in the study will be recorded

Feasibility of measurement tools

- Missing data from questionnaires. This information will be recorded by the researcher in a separate report at the end of the study.

Potential intervention effectiveness Trial-related outcomes will be assessed at baseline (before randomisation) and throughout the control and intervention periods:

- SB and PA measured using ActivPAL3 accelerometers:
 - SB in minutes during working hours (workplace SB) and all waking hours (total SB)
 - PA in minutes during working hours (workplace PA) and all waking hours (total PA)
- Context-specific SB measured using EMA with notifications of survey completion sent six times a day at random times throughout the baseline, control, and intervention arms
- Work engagement will be measured at baseline, post-control arm, and post-intervention arm using the UWES-9 [85] using pen and paper
- Perception of the benefits of reducing workplace SB will be assessed using the 3-point questionnaire at baseline and immediately post-intervention using pen and paper

Feasibility outcomes

The following quantitative measures will be used [63]:

- Intervention appropriateness measure (IAM)
- Acceptability of the intervention measure (AIM)
- Feasibility of the intervention measure (FIM)

Evaluation of participants' perspectives of the intervention will be assessed via focus groups and/or semi-structured interviews using the following themes:

- Experience of using the under-desk pedal machines, including factors perceived as affecting the pedal machine, issues (e.g. contextual, practical, individual,

or others), and adverse consequences (e.g. work, health, or otherwise related)

- Experiences of the mHealth intervention components (e.g. Garmin watch)
- Organisational-level and management perspectives on using the pedal machine
- Acceptability of the overall intervention by the users, from a management and employee perspective

Progression criteria

As pilot studies are usually too small to estimate parameters required for estimating a sample size for a main cluster randomised trial (e.g. the intra-cluster correlation coefficient) with sufficient precision, and too small to provide reliable estimates of rates for process measures such as recruitment or follow-up rates, these are not calculated in the present study [86]. This study is an exploratory study and progression criteria should not be judged as strict thresholds but as guidelines using, for example, a traffic light system with varying levels of acceptability [86, 87]. We will decide whether or not to proceed to a fully powered RCT using the following assessment principles and progression criteria:

- **Green:** indicates that we have met a criterion or we are within 10% of our stated progression targets
- **Amber:** indicates that we are within 20% of our stated progression target, in which case we will critically review reasons for this and assess whether major changes to study methods are likely to realise significant improvements
- **Red:** indicates that we are more than 20% from our target, in which case we will not, in the absence of clear extenuating circumstances, consider progression to a full trial

Progression criteria include protocol non-adherence and outcome data.

Protocol adherence criterion Green— $\geq 80\%$ of participants engage in $> 60\%$ of their cycling goal

Amber—60–79% of participants engage in $> 60\%$ of their cycling goal

Red— $< 60\%$ of participants engage in $> 60\%$ of their cycling goal

Retention progression criterion Green— $\geq 80\%$ of participants provide main trial-related outcomes (SB/PA) at T2

Amber—60–79% of participants provide main trial-related outcomes at T2

Red— $< 60\%$ of participants provide main trial-related outcomes at T2

Data analysis

Descriptive analysis will account for the recruitment and retention. Quantitative analyses will be carried out using Statistical Package for the Social Sciences V.25 (IBM Corp., Armonk, New York, USA). Descriptive statistics (e.g. daily mean SB and PA in minutes, SD) will be provided for all questionnaire data, from the EMA information, and overall SB and PA as derived from the objective measure.

Participant experience of acceptability and satisfaction with the intervention, as well as trial-related processes, will be assessed using analysis of the focus groups and semi-structured interviews. Transcriptions of audio-recorded interviews will be analysed using thematic analysis [88]. At each stage, findings will be verified and discussed in order to assess the accuracy of the interpretation, promote reliability, and ensure rigour [89]. The main analysis of this study will include thematic analysis, and no software package will be used to analyse the data.

Discussion

This paper describes the design of a cluster randomised wait-list crossover pilot feasibility trial that will test pilot outcomes which will ascertain if a future larger-scale RCT is viable. Acceptability and feasibility outcomes of this theory-led multicomponent intervention to reduce SB in professional males will also be discussed. The design builds on previous developmental work in the participating work-sites. The current study, to our knowledge, will be the first study to target professional males using an intervention that combines an under-desk pedal machine; the utilisation of mHealth to target specific BCTs such as self-monitoring, social comparison, and goal-setting; and recruitment management staff to the study. This unique combination of components aims to reduce SB and increase LPA during participants' working day. The design of the study has been underpinned by the socio-ecological theory acknowledging that an understanding and subsequent targeting of the intrapersonal, interpersonal, physical environmental, and cultural-level factors are likely to be required to achieve the greatest changes in behaviour [38].

Office workers are one of the largest occupational groups in high-income countries and are sedentary for a large proportion of their day; therefore, reducing their SB could have important public health implications by reducing this risk factor associated with chronic disease and mortality [15]. Reallocating just 30 min of SB, sleep time, or standing time with LPA has been found to beneficially affect body composition, including BMI and fat mass [31]; therefore, restructuring the physical environment to enable LPA is an important strategy.

The current randomised pilot feasibility study is designed to inform subsequent refinement of intervention content, in terms of acceptability and feasibility of the intervention components and measures, so that the format

may be suitable for real-world implementation and evaluation in a future definitive trial. Its primary purpose is to address key design uncertainties, including the feasibility of recruiting eligible participants, as well as the appropriateness, acceptability, and feasibility of the intervention. The qualitative component of the study will allow for exploration of any issues surrounding the acceptability of the under-desk pedal machines, as well as the mHealth component from the perspectives of the users, which will include employees and management. It will also allow for exploration of the study procedures and assessment methods.

By assessing the potential effectiveness outcomes of SB and PA, and work engagement, and the perceived benefits of reducing workplace SB, the current pilot feasibility study will clarify the design of a future larger trial that will extend the current knowledge regarding the effectiveness of this type of multicomponent intervention to reduce occupational SB.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s40814-020-00716-9>.

Additional file 1: SBRT 2013 Checklist: Recommended items to address in a clinical trial protocol and related documents.
Additional file 2: Ecological momentary assessment.
Additional file 3: Focus group schedule.
Additional file 4: Participant information leaflet and consent form.
Additional file 5:

Abbreviations

SB: Sedentary behaviour; METs: Metabolic equivalents; EE: Energy expenditure; PA: Physical activity; MPA: Moderate physical activity; WHO: World Health Organization; LPA: Light physical activity; BMI: Body mass index; SCT: Social cognitive theory; BCT: Behaviour change technique; MRC: Medical Research Council; iPARQ: Physical Activity Readiness Questionnaire; BAA: Ecological Momentary Assessment; UWES-9: Utrecht Work Engagement Scale; IAM: Intervention appropriateness measurement; AIM: Acceptability of intervention measurement; FWA: Feasibility of intervention measurement.

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Authors' contributions

All authors contributed to the design of the study. The manuscript was drafted by GN with contributions from CD and CH. All authors read and approved the final manuscript.

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Availability of data and materials

Not applicable—protocol paper.

Ethics approval and consent to participate

Ethical approval has been obtained from the Research Ethics Committee of the School of Medicine, Trinity College Dublin, reference number 20190701, on the 18th of September 2019. Informed consent will be obtained for all participants before data collection and randomisation.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Appendix C – Ethical Approval (a)



Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin
Ollscoil Átha Cliath | The University of Dublin

23rd January 2019

Att: Ms. Gail Nicholson

Re: New Application 20180517 (amendment requested of application 20171107)

Title: To ascertain multi-level determinants of sedentary behaviour in the Healthy Ireland Survey.

Dear Ms. Nicholson,

Further to a meeting of the School of Medicine Research Ethics Committee held in June 2018, we are pleased to inform you that the amendment to the above project was approved by our then Chairperson, Dr. Laure Maignol, on the 5th June 2018, and now as per this letter.

Applicants must submit an *annual report* for ongoing projects and an *end of project report* upon completion of the study. You will find these forms on the School of Medicine Research Ethics website.

It is the responsibility of the researcher/research team to ensure all aspects of the study are executed in compliance with the General Data Protection Regulation (GDPR) and Data Protection Act 2018.

Yours sincerely,

Dr. Tadhg Stapleton,
Chairperson,
School of Medicine Research Ethics Committee.

An tOllamh Michael Gill MD FRCO MRCPsych
Ceann Scoil an Leighis

Dr. Alex McKee
Riarthóir na Scoile

Scoil an Leighis
Institiúid Eolaíochtaí Bithleighis Choláiste na Tríonóide
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Appendix D – Ethical Approval (b)



Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin
Ollscoil Átha Cliath | The University of Dublin

29th April 2019

Application no.: **20190205**

Re: EXPLORING THE BARRIERS AND FACILITATORS TO SITTING IN A SEDENTARY WORKPLACE

Dear Ms. Gail Nicolson,

Your application has been reviewed by the School of Medicine Research Ethics Committee (REC) and we are pleased to inform you that the above project has been approved.

Please note that documents submitted for GDPR purposes within your ethics application are approved by the REC from an ethical perspective only and this approval does not confirm GDPR compliance. Where a Data Protection Impact Assessment (DPIA) is required please submit the DPIA to the Data Protection Office (DPO) and seek comment from the DPO prior to commencing your study.

It is the responsibility of the researcher/research team to ensure all aspects of the study are executed in compliance with the General Data Protection Regulation (GDPR), Health Research Regulations and Data Protection Act 2018.

Yours sincerely,

Dr. Tadhg Stapleton,
Chairperson,
School of Medicine Research Ethics Committee,
Trinity College Dublin.

An tOllamh Michael Gill MD FRCO MRCPsych
Ceann Scoil an Leighis

Dr. Alex McKee
Riarthóir na Scoile

Scoil an Leighis
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Appendix E- Email inviting workplaces to participate



Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin
Oíscóil Átha Cliath | The University of Dublin

Dear Gatekeeper (Name will be inserted here),

My name is Gail Nicolson and I am a PhD candidate with Trinity College Dublin. I am inviting your workplace to participate in a research study entitled: "Exploring males' perspectives of the barriers and facilitators to reducing sedentary behaviour in a workplace setting". The intention is to gain an understanding of the perspectives of employees and managers in relation to daily routines and patterns of sitting. I am also interested in exploring their opinions on potential strategies that could support them in reducing sedentary behaviour in the workplace.

The study will involve completing basic demographic information and taking part in a focus group. Two focus groups will be conducted in your workplace – one comprising of employees and the other of managers. Each focus group will involve participation of 6 to 8 people.

I would very much appreciate if you could inform potentially interested participants about this study, and we can arrange a time and location of your choice to further discuss the study and answer any questions. At that point, I will provide participant information leaflets and consent forms that I will go through with people interested in taking part. A period of seven days will then be provided for reflection and for each person to read the consent forms and information leaflets. After seven days, I will then arrange to meet with those who are willing to participate. Both the participants and the researcher will then sign the consent forms.

The opinions of individuals in the specific workplace context are very important. This will give us an understanding of the strategies that could reduce and interrupt workplace sitting. Participation in the study is of great importance in our bid to understand appropriate ways to support individuals and organisations to reduce sitting in the workplace.

Thank you for your time.

Kind regards

Gail Nicolson

Public Health and Primary Care

Trinity College Dublin
Institute of Population Health
Russell Centre
Tallaght Cross
D24 DH74

Phone (01) 896 3739



SITTING DISEASE

COSTS TO EMPLOYEE HEALTH AND FINANCIAL
COSTS TO BUSINESS

SITTING IS THE NEW WORKPLACE HAZARD

-  COSTS TO SMALL BUSINESS 6490 MILLION PER YEAR
-  INCREASED RISK OF COLON CANCER - DIABETES - HEART DISEASE - RESULTS IN 70,000 DEATHS PER YEAR
-  ASSOCIATED WITH POOR PRODUCTIVITY - LACK OF CONCENTRATION - INCREASED ABSENTEEISM & PRESENTISM
-  MEN HAVE HIGHEST LEVELS OF SITTING IN THE WORKPLACE

THE BRIEF

 A RESEARCHER FROM TRINITY COLLEGE DUBLIN WILL WORK WITH YOU TO SET GOALS AND STRATEGIES TO HELP BREAK UP PROLONGED SITTING SPECIFIC TO YOUR WORKPLACE

TEST STRATEGIES TO REDUCE PROLONGED SITTING TIMES IN A PILOT STUDY THAT WILL RUN FOR 6-8 WEEKS

INVITATION TO YOU AND YOUR EMPLOYEES TO BE INVOLVED IN A PILOT STUDY

-  PARTICIPATE IN A FOCUS GROUP (DURATION OF 45-60 MINS EACH) WITH 4-8 MALE EMPLOYEES AND MANAGEMENT STAFF TO DEVELOP STRATEGIES TO REDUCE SITTING IN YOUR WORKPLACE
- MALE STAFF WILL RECEIVE STATE-OF-THE-ART EQUIPMENT TO HELP REDUCE SEDENTARY BEHAVIOUR AT WORK - WHICH WILL BE TESTED OVER 6 TO 8 WEEKS

BENEFITS OF WORKPLACE WELLNESS

- SAVE €5.17 FOR EVERY EURO INVESTED IN HEALTH AND WELL-BEING
- REDUCE ABSENTEEISM & PRESENTISM
-  ATTRACT AND RETAIN TALENT
- IMPROVE STAFF FATIGUE AND PRODUCTIVITY
- REDUCE SICK LEAVE BY 25.3%
- DECREASE STAFF COMPENSATION COSTS BY 49.3%

Appendix G - Participant Information Leaflet (a)



Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin
Ollscoil Átha Cliath | The University of Dublin

“Exploring males’ perspectives of the barriers and facilitators to reducing sedentary behaviour in a workplace setting”

Research Team

Gail Nicolson, Professor Catherine Darker and Professor Catherine Hayes

We are inviting you to take part in a research study. Before you decide that you want to take part, it is important for you to understand why it is being done and what it will involve. Please take your time to read the following information before deciding to take part. If you have any questions or do not understand any of the information, you can ask the research team. Their details are at the end of this information sheet.

What is the aim of this research?

The aim of the research is to undertake a focus group(s) to explore the barriers and facilitators to sitting in a workplace setting. This will provide evidence for the development of a pilot study to reduce sedentary behaviour in your workplace.

Who is organising the research?

The study is being conducted by Gail Nicolson as part of her PhD project to test an intervention to reduce sedentary behaviour in the workplace. The PhD is funded by the Dean of the Faculty of Health Sciences, Trinity College Dublin.

Can I take part in this study?

We are looking for men aged 18 or over with sedentary occupations and who would like to be part of this study. We would like to hear the views of both employees and managers.

How many people will take part in the research?

Six to eight men who are employees and are employers within the workplace will take part in the study.

What are the possible risks to taking part in the study?

There are no risks to taking part in this study.

What are the possible benefits of taking part in this study?

It is hoped that you would benefit from taking part in this study and is an opportunity to contribute your knowledge to the understanding of the barriers and facilitators to prolonged sitting in a workplace context.

Do I have to take part?

You do not have to take part in this study. You may decide if you would like to take part. You are free to refuse to take part in the focus group, refuse to answer any of the questions or leave the focus group at any time. You are free to withdraw from the study at any time and your details will be deleted if you decide to withdraw or request that your information is deleted.

What will happen if I take part?

If you decide to take part, you must sign a consent form. We will then ask you some questions about yourself such as your age and education level. There is also a short questionnaire (3 questions) on your sitting time over the past seven days. This should take about 2-3 minutes. We will then convene in a place suitable to you to begin the focus group. The focus group will include 6-8 of your fellow co-employees to discuss sedentary behaviour and your views on ways to reduce it in your workplace. The discussion will be audio-recorded and will take 30 - 40 minutes. The recording will be sent to a transcriber who will put it into writing word for word. Your name or any identifying information will not be included in the transcript and the audio recording will then be destroyed. Your information will not be disclosed to anyone outside of the research team. You can request a transcript of the interview.

What will happen to the information that I provide?

We will keep all of your information confidential. Your name and contact details will only be seen by the research team. We will then replace your name with a code and store your name separately from your other information (data). Only the researcher will hold the key to the code. The researcher will enter the information that you provide on a password-protected computer using the code. The data will then be analysed by the researcher. Trinity College Dublin is the Data Controller. This means that the College controls and is responsible for the keeping and use of your personal information. The transcriber is the Data Processor - that is they process your data. They must only process your data on the instructions of the Data Controller. The responsibilities of the Data Processor include the necessity to keep personal data secure from unauthorised access, disclosure, destruction or accidental loss. The Data Processor will destroy the audio recording when it is transcribed. Your data will not be used in future unconnected research without your consent. If you would like to have more information about how your data are protected please ask for the Privacy Notice. You can ask for a copy of the Privacy Notice from Gail Nicolson (details below). In line with Trinity College Dublin Data Protection guidelines all data will be stored securely for ten years. Your information will be destroyed securely after that time.

If you need to make a complaint, you can contact the Data Protection Officer at dataprotection@tcd.ie.

What will happen to the study results?

The results of the study will be used in the development of an intervention to reduce prolonged sitting times in a workplace setting. Research results may also be published in a journal or presented at a conference. Your information will not be linked to you in any way.

Has this study been approved?

The study has received ethical approval from Research Ethics Committee of the School of Medicine at Trinity College Dublin.

Further information: If you would like any further information, or have questions about the study and your participation in the focus group, you can contact Gail Nicolson on 01-8963739.

Appendix H - Participant Consent form



Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin
Oíscail Átha Cliath | The University of Dublin

Interview Participant Consent Form

Exploring males' perspectives of the barriers and facilitators to reducing sedentary behaviour in a workplace setting

PhD Candidate: Gail Nicolson, Trinity College Dublin.

Tel: 01-8963739 Email: nicols@tcd.ie

Primary supervisor: Dr Catherine Darker, Trinity College Dublin.

Tel: 01-8968510 Email: Catherine.darker@tcd.ie

Secondary Supervisor: Dr Catherine Hayes, Trinity College Dublin.

Tel: 01-8961385 Email: hayesc9@tcd.ie

If you would like any more information about the study or if you have any further questions, please refer to the attached participant information leaflet or contact the research team. Please initial each box to confirm that you have read, understood and agreed to each of the points of the form.

I confirm that I have read and understood the attached Participant Information Leaflet. I have had the opportunity to think about the information and to ask questions. The research team has answered any questions that I have had.

I agree to take part in the research study.

I agree that my personal details will not be shared with anyone outside of the research team. A professional transcriber will have access to the data I provide, and will sign a legally binding Data Processing Contract governing the data processing as outlined in Article 28 of the General Data Protection Regulation (GDPR). I understand that my data will be anonymised i.e., my name or personal details will not appear, prior to any publication of the results. I understand that I can get a copy of the Privacy Notice from the researcher if I want to find out more about how my data are protected.

I agree to my data being stored securely for ten years after the study ends, by Trinity College Dublin researchers.

I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. I understand that if I withdraw from the study, any data collected from me can still be used unless I state otherwise. I understand if I need to make a complaint, I can contact the Data Protection Officer at dataprotectionofficer@tcd.ie.

I agree to be part of a focus group and understand that information will be audio-recorded and put into writing word for word by a transcriber, and the voice recording will then be destroyed.

(Please print name of participant here) Date

(Please sign here)

Researcher's name
signature

Date

Researcher's
signature

Appendix I - Occupational Sitting and Physical Activity Questionnaire



1. How many hours did you work in the last 7 days? _____ hours
2. During the last 7 days, how many days were you at work? _____ days

Example:

Jane is an administrative officer. Her work day involves working on the computer at her desk, answering the phone, filing documents, photocopying, and some walking around the office. Jane would describe a typical work day in the last 7 days like this:

Sitting (including driving)	90 %
Standing	5 %
Walking	5 %
Heavy labour or physically demanding tasks	0 %
Total	100 %

3. How would you describe your typical work day in the last 7 days? (This involves only your work day, and does not include travel to and from work, or what you did in your leisure time)

a. Sitting (including driving)	_____ %
b. Standing	_____ %
c. Walking	_____ %
d. Heavy labour or physically demanding tasks	_____ %
Total	_____ %

Make sure
this adds up
to 100%

Scoring:

Minutes sitting at work per week = Item 1 * Item 3a

Minutes sitting per workday = (Item 1/Item 2) * Item 3a

Similar calculations can be done for standing, walking, and heavy labour.

Appendix J – Interview Schedule Mapped to the Socio-ecological Model



I would like to thank you all for taking part in this focus group today.

Housekeeping:

1. Recording
2. Phones off
3. Just to remind you that everything you say here will be confidential to the research team, and when we write up the findings no identifying information will be with anything that you have said.
So for example Mark here would be Sean in the write-up and in terms of the company it will be described in broad terms such as private professional company in a Dublin location.

So what we would like to do is understand more about sedentary behaviour in this worksite and that is why your views are important, and from there we will incorporate that information into the design of a pilot study to reduce sedentary behaviour that is relevant to you.

And finally, just to say that I will available to speak afterwards on a one-to-one basis to anybody who feels constrained to speak in the focus group.

So just to help the transcriber differentiate between the voices could we just go around the table and if everyone could say their name and their favourite colour.

Ok thank you for that so we'll get started now.

Part 1

The topic of the study is sedentary behaviour or sitting.

<p>What are your experience of/thoughts on workplace sitting? <i>What is known, if anything, about the association between prolonged sitting and mental and physical health?</i> <i>Do you think you have a good understanding of the importance of reducing prolonged sitting in terms of health?</i> <i>Are there physical enablers that may encourage you to sit less, for example musculoskeletal problems associated with prolonged sitting?</i> <i>Are there any physical barriers for you or people in this worksite to moving more – such as disability or health?</i> <i>Would you think that a lack of understanding of the importance of reducing prolonged sitting on health would be a barrier to moving more?</i> <i>Would you feel like you would prefer to remain seated? Is it something that concerns you?</i> <i>Do you feels a sense of motivation to sit less? Does that help you to sit less?</i></p>	<p>Individual level</p>
---	-------------------------

<p>What are the social influences such as work team relationships, peer/manager views and opinions on reducing sitting at work? <i>Do you have supportive colleagues, others trying to reduce sitting? Please consider any social influences such as What are the norms in your office? Is it the norm to break up sitting regularly? What would your colleagues think?</i></p>	Social influence
<p>How does the office environment effect your sitting habits? <i>What is the environment like that you work in? Are there barriers/enablers to reducing sitting related to this? Centralised printers, green space?</i></p>	Environmental level
<p>How do the views/opinions of management influence sitting? <i>How might the organisation hinder you from sitting less?</i> To employees only: How does the organisation influence your sitting habits? <i>How could they support you more in reducing your daily sitting in work?</i> <i>How important is it that they give you support/permission to take part in an intervention?</i></p>	Organisational level

Part 2

As you may be aware various components may be used as tools to reduce workplace sedentary behaviour. These include technology such as activity trackers, mobile phone apps and websites, and restructuring your desk to enable movement.

Show participants the under-desk pedal machine

What are your first impressions of the under-desk elliptical machine? Would this device enable you to reduce your sedentary behaviour? Is it appropriate for this worksite/ your own personal desk?

What do you think would be a benefit/harm of this type of strategy?

Show and invite participants to use elliptical

What do you think about the use of smartphone apps and activity trackers to break up sitting time? *What factors would stop you/allow you to use a smartphone app in this particular worksite?*

Show participants Garmin watch and describe how it will be used in the study

What are your views or opinions on competition/goal setting – i.e., competing either against yourself or as a team?

What do you think of workplace challenges? What you think about physical activity social media platforms such as Gamin Connect/Strava? Would you use one every day?

Show participants activPAL device and demonstrate how to wear

What are your impressions of wearing this device? Do you have any concerns/questions?

Show participants EMA PIEL Survey on smartphone

How would you feel about answering notifications throughout the day using the PIEL Survey?
Do you have any concerns/questions?

Close: Is there anything else that we didn't talk about today that you think is important for us to know? Is there anything you would like to add?

Summary: Summary of session and main points.

Thank you very much for your time and valuable contribution to the study.

Appendix K - Consolidated criteria for reporting qualitative studies (a)

No. Item	Guide questions/description	Reported on Page #
Domain 1: Research team and reflexivity		
<i>Personal Characteristics</i>		
1. Interviewer/facilitator	Which author/s conducted the interview or focus group?	142
2. Credentials	What were the researcher's credentials? E.g. PhD, MD	142
3. Occupation	What was their occupation at the time of the study?	142
4. Gender	Was the researcher male or female?	
5. Experience and training	What experience or training did the researcher have?	142
<i>Relationship with participants</i>		
6. Relationship established	Was a relationship established prior to study commencement?	142
7. Participant knowledge of the interviewer	What did the participants know about the researcher? e.g. personal goals, reasons for doing the research	141
8. Interviewer characteristics	What characteristics were reported about the interviewer/facilitator? e.g. Bias, assumptions, reasons, and interests in the research topic	102
Domain 2: study design		
<i>Theoretical framework</i>		

9. Methodological orientation and Theory	What methodological orientation was stated to underpin the study? e.g. grounded theory, discourse analysis, ethnography, phenomenology, content analysis	141
<i>Participant selection</i>		
10. Sampling	How were participants selected? e.g. purposive, convenience, consecutive, snowball	141-142
11. Method of approach	How were participants approached? e.g. face-to-face, telephone, mail, email	141-142
12. Sample size	How many participants were in the study?	142
13. Non-participation	How many people refused to participate or dropped out? Reasons?	
<i>Setting</i>		
14. Setting of data collection	Where was the data collected? e.g. home, clinic, workplace	142
15. Presence of non-participants	Was anyone else present besides the participants and researchers?	142
16. Description of sample	What are the important characteristics of the sample? e.g. demographic data, date	145
<i>Data collection</i>		
17. Interview guide	Were questions, prompts, guides provided by the authors? Was its pilot tested?	143-144
18. Repeat interviews	Were repeat interviews carried out? If	NA

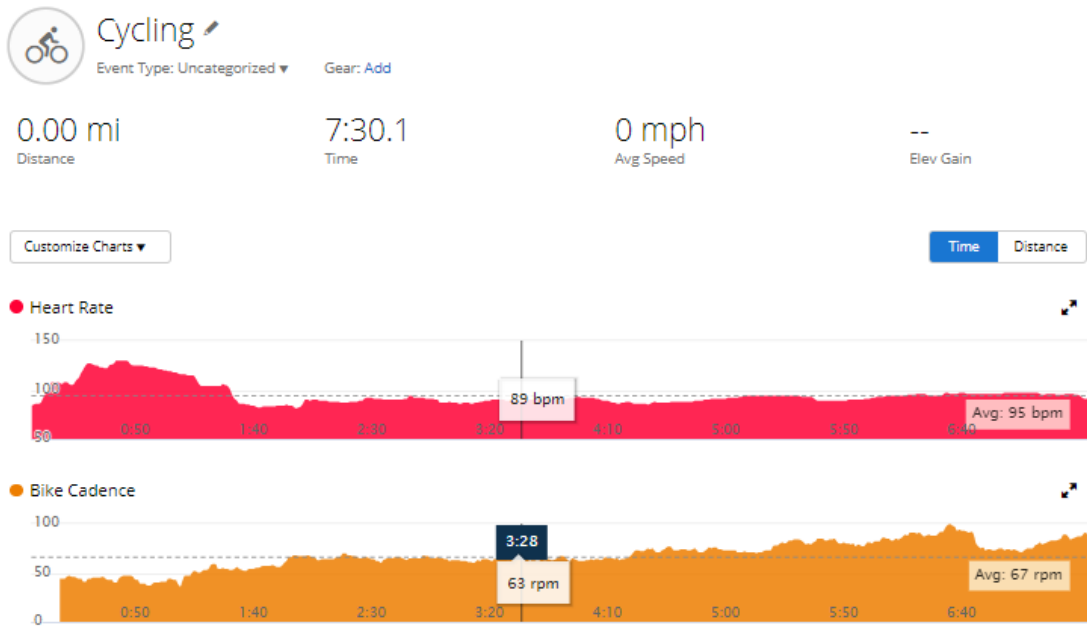
	yes, how many?	
19. Audio/visual recording	Did the research use audio or visual recording to collect the data?	142
20. Field notes	Were field notes made during and/or after the interview or focus group?	144
21. Duration	What was the duration of the interviews or focus group?	145
22. Data saturation	Was data saturation discussed?	142
23. Transcripts returned	Were transcripts returned to participants for comment and/or correction?	143
Domain 3: analysis and findings		
<i>Data analysis</i>		
24. Number of data coders	How many data coders coded the data?	144
25. Description of the coding tree	Did authors provide a description of the coding tree?	
26. Derivation of themes	Were themes identified in advance or derived from the data?	144
27. Software	What software, if applicable, was used to manage the data?	144
28. Participant checking	Did participants provide feedback on the findings?	
<i>Reporting</i>		
29. Quotations presented	Were participant quotations presented to illustrate the themes/findings? Was each quotation	146-183

	identified? e.g. participant number	
30. Data and findings consistent	Was there consistency between the data presented and the findings?	146-183
31. Clarity of major themes	Were major themes clearly presented in the findings?	146-183
32. Clarity of minor themes	Is there a description of diverse cases or discussion of minor themes?	146-183

Appendix L – Garmin Forerunner 35



Appendix M – Garmin Connect Platform



Appendix N – Deskcycle2™



Appendix O – Participant Information Leaflet

Appendix O – Participant Information Leaflet



Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin
Ollscoil Átha Cliath | The University of Dublin

Pilot study to test the acceptability and feasibility of a theory-led multicomponent intervention to reduce sedentary behaviour in the workplace

Research Team

Gail Nicolson, Dr Catherine Darker and Dr Catherine Hayes

We are inviting you to take part in a research study. Before you decide if you would like to take part, it is important for you to understand why it is being done and what it will involve. Please take your time to read this information sheet before deciding to take part. If you have any questions or do not understand the information, you can ask the research team. Their details are at the end of this information sheet.

What is the aim of this research?

The aim of the research is to undertake a pilot study to investigate if a multicomponent intervention to reduce sedentary behaviour in a workplace setting is acceptable and feasible.

Who is organising the research?

The study is being conducted by Gail Nicolson as part of her PhD project to test a pilot intervention to reduce sedentary behaviour in the workplace. The PhD is funded by the Dean of the Faculty of Health Sciences, Trinity College Dublin.

Can I take part in this study?

We are looking for men aged 18 or over with sedentary occupations, who are physically healthy to engage in light-moderate physical activity, and who would like to reduce their sedentary behaviour in their working day.

How many people will take part in the research?

We would like thirty people to take part in this pilot study.

What are the possible risks to taking part in the study?

There are minimal risks to taking part in this study.

What are the possible benefits of taking part in this study?

Participants in this study are contributing to the understanding of the acceptability and feasibility of an intervention to reduce sedentary behaviour in a workplace setting. People taking part will potentially reduce their daily sedentary behaviour and may thereby benefit from taking part in the study.

Do I have to take part?

You do not have to take part in this study. You may decide if you would like to take part. You are free to withdraw from the study at any time, and if you change your mind and withdraw from the study your details will be deleted if you so wish.

What will happen if I take part?

If you decide to take part in the research, you must sign a consent form. We would like to see if an intervention to reduce sedentary behaviour at your workplace is acceptable and feasible, and also if it can help reduce your sedentary behaviour and increase your physical activity. Before you take part we will give you a questionnaire to make sure that you are physically able to take part in this study.

- Firstly, to get your baseline daily activity information we will ask you to wear a thigh-worn accelerometer to measure your sedentary behaviour and physical activity for 24 hours a day for 9 days. From this information we will provide you with a graph illustrating a breakdown of your sedentary behaviour and physical activity for the week. We will also ask you to download an app that will notify you 6 times a day every day to complete a short survey (each survey takes approximately 10 to 15 seconds to complete) to help us to gain real-time information about activities throughout the day. The questions ask what you are doing right before the notification went off – such as if you are working on your computer, reading or engaging in physical activity.
- Next, your worksite will be randomised to start the study either in the control period or the intervention period.
- If you are in the control period, this means that you will not receive the intervention components (i.e., under-desk pedal machine, Garmin watch) but you will continue to wear the accelerometer and you will be sent the notifications asking about your daily activities. At the end of each week the researcher will come to your workplace to upload the accelerometer data onto a laptop. The control periods and intervention periods will take place over 14 days each. In between the control and intervention periods will be what is called a 'washout period/usual habits' for 7 days where you have no measurements taken and you will not be contacted by the researcher.
- Alternatively, your worksite may begin with the intervention period, followed by the control period depending on the randomisation. In the intervention period, you will receive an under-desk pedal machine (Desk-Cycle™) to use, as well as a wrist-worn physical activity tracker (e.g. Garmin Forerunner 35) so that you can track your daily use of the pedal machine and monitor your activity using the associated app/website (e.g. Garmin Connect). You will take part in a challenge to cycle at your desk every day and upload your activity to the website where you can see yours, and others in your worksites' progress. The activity tracker will also prompt you to move every hour that you have been sedentary, and by engaging in some physical activity such as a short walk or uploading a cycling activity, you will clear this 'move bar'.
- In summary, there is a 9-day baseline measure period, and you will then be in either the intervention period or the control period (14 days each); with a 7-day washout period in between; followed by whichever period you did not receive. At the end of the baseline, control and intervention periods, we will ask you to complete a questionnaire on your work engagement. This questionnaire takes approximately 5-10 minutes to complete.

- At the end of the study, we would like to know how you found the study and what were your experience and thoughts of participating. We would like you to complete a short questionnaire (takes about 5 minutes to complete) on whether you thought that the intervention was acceptable, feasible and appropriate. We would also like you to take part in a focus group to tell us about your experience of being in the study. We will convene in a place suitable to you to carry out the focus group. The focus group will consist of 6-8 of you and your fellow co-employees to discuss your views on the pilot study in your workplace. The discussion will be audio-recorded and will take 30 - 40 minutes. The recording will be sent to a transcriber who will put it into writing word for word. Your name or any identifying information will not be included in the transcript and the audio recording will then be destroyed. Your information will not be disclosed to anyone outside of the research team.

What will happen if I suffer pain/discomfort at any time during the study period?

If you suffer any pain/discomfort at any time during the study, please discontinue all aspects of the intervention immediately and contact the research team using the contact details at the bottom of this leaflet. You should also contact your GP if you feel that you would like further advice.

What will happen to the information that I provide?

We will keep all of your information confidential. Your name and contact details will only be seen by the research team. The information (data) collected from the accelerometer will be uploaded to a secure laptop that is password encrypted. The accelerometer device only collects data on your activities such as lying, sitting, and standing and stepping in minutes per day. Your name will not be attached to any of this data and each information file will have a code when uploaded. The PIEL Survey app is only used to collect the survey data and send you notifications. The PIEL Survey app does not use a remote server or database. Your data is stored on your own phone. At the end of each study period you will email your data file, using the secure email account on your device to the researcher.

The questionnaires used in this study will be completed using pen and paper and your name will not be attached to them. All completed questionnaires will be stored in a locked bag during transportation to the researcher's place of work, where they will be stored in a locked cabinet. We will replace your name with a code and store your name separately from your other information. Only the researcher will hold the key to the code. The researcher will enter the information that you provide on a password-protected computer using the code. The data will then be analysed by the researcher. Trinity College Dublin is the Data Controller. This means that the College controls and is responsible for the keeping and use of your personal information. The transcriber of the focus group data is the Data Processor - that is, they process your data. They must only process your data on the instructions of the Data Controller. The responsibilities of the Data Processor include the necessity to keep personal data secure from unauthorised access, disclosure, destruction or accidental loss. The Data Processor will destroy the audio recording when it is transcribed. Your data will not be used in future unconnected research without your consent. If you would like to have more information about how your data are protected please ask for the Privacy Notice. You can ask for a copy of the Privacy Notice from Gail Nicolson (details below). In line with Trinity College Dublin Data Protection guidelines all data will be stored securely for ten years. Your information will be destroyed securely after that time. If you need to make a complaint, you can contact the Data Protection Officer at dataprotection@tcd.ie.

What will happen to the study results?


The results of the study will be used in the write-up of the researcher's PhD thesis. Research results may also be published in a journal or presented at a conference. Your information will not be linked to you in any way.

Has this study been approved?

The study has been approved by the Research Ethics Committee of the School of Medicine at Trinity College Dublin.

Further information: If you would like any further information, or have questions about the study and your participation in the focus group, you can contact Gail Nicolson on 01-8963739.

Appendix P – Template for Intervention Description and Replication

Item number	Item	Primary paper (page or appendix number)
		
	BRIEF NAME	
1.	Provide the name or a phrase that describes the intervention.	217
	WHY	
2.	Describe any rationale, theory, or goal of the elements essential to the intervention.	217-218
	WHAT	
3.	Materials: Describe any physical or informational materials used in the intervention, including those provided to participants or used in intervention delivery or in training of intervention providers. Provide information on where the materials can be accessed (e.g. online appendix, URL).	217, Appendices L, M, N
4.	Procedures: Describe each of the procedures, activities, and/or processes used in the intervention, including any enabling or support activities.	217, 223
	WHO PROVIDED	
5.	For each category of intervention provider (e.g. psychologist, nursing assistant), describe their expertise, background and any specific training given.	223
	HOW	

6.	Describe the modes of delivery (e.g. face-to-face or by some other mechanism, such as internet or telephone) of the intervention and whether it was provided individually or in a group.	223
WHERE		
7.	Describe the type(s) of location(s) where the intervention occurred, including any necessary infrastructure or relevant features.	217
WHEN and HOW MUCH		
8.	Describe the number of times the intervention was delivered and over what period of time including the number of sessions, their schedule, and their duration, intensity or dose.	223
TAILORING		
9.	If the intervention was planned to be personalised, titrated or adapted, then describe what, why, when, and how.	n/a
MODIFICATIONS		
10.†	If the intervention was modified during the course of the study, describe the changes (what, why, when, and how).	n/a
HOW WELL		
11.	Planned: If intervention adherence or fidelity was assessed, describe how and by whom, and if any strategies were used to maintain or improve fidelity, describe them.	234
12.†	Actual: If intervention adherence or fidelity was assessed, describe the extent to which the intervention was delivered as planned.	276

** **Authors** - use N/A if an item is not applicable for the intervention being described. **Reviewers** – use '?' if information about the element is not reported/not sufficiently reported.

† If the information is not provided in the primary paper, give details of where this information is available. This may include locations such as a published protocol or other published papers (provide citation details) or a website (provide the URL).

‡ If completing the TIDieR checklist for a protocol, these items are not relevant to the protocol and cannot be described until the study is complete.

* We strongly recommend using this checklist in conjunction with the TIDieR guide (see *BMJ* 2014;348:g1687) which contains an explanation and elaboration for each item.

* The focus of TIDieR is on reporting details of the intervention elements (and where relevant, comparison elements) of a study. Other elements and methodological features of studies are covered by other reporting statements and checklists and have not been duplicated as part of the TIDieR checklist. When a **randomised trial** is being reported, the TIDieR checklist should be used in conjunction with the CONSORT statement (see www.consort-statement.org) as an extension of **Item 5 of the CONSORT 2010 Statement**. When a **clinical trial protocol** is being reported, the TIDieR checklist should be used in conjunction with the SPIRIT statement as an extension of **Item 11 of the SPIRIT 2013 Statement** (see www.spirit-statement.org). For alternate study designs, TIDieR can be used in conjunction with the appropriate checklist for that study design (see www.equator-network.org)

Appendix Q - Consolidated Standards of Reporting Trials



CONSORT 2010 checklist of information to include when reporting a pilot or feasibility randomised trial in a journal or conference abstract

Item	Description	Reported on line number
Title	Identification of study as randomised pilot or feasibility trial	210
Authors *	Contact details for the corresponding author	
Trial design	Description of pilot trial design (e.g., parallel, cluster)	218
Methods		
Participants	Eligibility criteria for participants and the settings where the pilot trial was conducted	219
Interventions	Interventions intended for each group	223-224
Objective	Specific objectives of the pilot trial	211
Outcome	Pre-specified assessment or measurement to address the pilot trial objectives**	224-228
Randomization	How participants were allocated to interventions	231
Blinding (masking)	Whether or not participants, care givers, and those assessing the outcomes were blinded to group assignment	231
Results		
Numbers randomized	Number of participants screened and randomised to each group for the pilot trial objectives**	236
Recruitment	Trial status [†]	
Numbers analysed	Number of participants analysed in each group for the pilot objectives**	236
Outcome	Results for the pilot objectives, including any expressions of uncertainty**	236-271
Harms	Important adverse events or side effects	275

Conclusions	General interpretation of the results of pilot trial and their implications for the future definitive trial	293
Trial registration	Registration number for pilot trial and name of trial register	210
Funding	Source of funding for pilot trial	vii

Appendix R – Ethical Approval (c)



Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin
Ollscoil Átha Cliath | The University of Dublin

18th September 2019

Att: Gail Nicholson

Application No: 20190702

Title: Pilot study to test the acceptability and feasibility of a theory-led multicomponent intervention to reduce sedentary behaviour in the workplace.

Dear Ms. Nicholson,

Your application has been reviewed by the School of Medicine Research Ethics Committee and we are pleased to inform you that the above project has been approved.

Applicants must submit an *annual report* for ongoing projects and an *end of project report* upon completion of the study. You will find these forms on the School of Medicine Research Ethics website.

It is the responsibility of the researcher/research team to ensure all aspects of the study are executed in compliance with the General Data Protection Regulation (GDPR) and Data Protection Act 2018.

Yours sincerely,

A handwritten signature in blue ink that reads 'Tadhg Stapleton'.

Dr. Tadhg Stapleton,
Chairperson,
School of Medicine Research Ethics Committee.

An tOllamh Michael Gill MD FRCO MRCPsych
Ceann Scoil an Leighis

Dr. Alex McKee
Riarthóir na Scoile

Scoil an Leighis
Institiúid Eolaíochtaí Bithleighis Choláiste na Tríonóide
152-160 Sráid an Phiarsaigh
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Professor Michael Gill MD FRCO MRCPsych
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Appendix S - Email to Gatekeeper

Dear Gatekeeper (Name will be inserted here),

My name is Gail Nicolson and I am a PhD candidate in Trinity College Dublin. I am inviting your workplace to participate in a research study entitled: "Pilot study to test the acceptability and feasibility of a theory-led multicomponent intervention to reduce sedentary behaviour in the workplace". The intention is to gain an understanding of whether an intervention to reduce sedentary behaviour in your workplace is acceptable and feasible.

The study is a wait-list crossover design and will take place over 8 weeks. Initially there will be a 9-day period where each participant wears a thigh-worn accelerometer for 24 hours a day that measures baseline information on sedentary behaviour and physical activity. Six notifications will be sent to you on your phone at random times throughout the day asking you to answer a short (10-15 seconds) survey on your activity at that moment. You will also be asked to fill in a short questionnaire on your work engagement. Following this, the study will begin.

This type of design means that your worksite will be randomised to begin the study with either a 2-week intervention period or a 2-week control period (where no intervention is given but measurements of sedentary behaviour and physical activity are taken). Between the intervention and control periods is a 'washout period' for 7 days where no measurements are taken and contact from anyone involved in the study will occur. At the end of the study, we would like to carry out focus groups to gather information on how acceptable and feasible the intervention was to the participants involved. This will involve 6-8 participants who took part in the study and will take 30-40 minutes.

I would very much appreciate if you could inform potentially interested participants about this study, and we can arrange a time and location of your choice to further discuss the study and answer any questions. At that point, I will provide participant information leaflets and consent forms that I will go through with people interested in taking part. A period of 24 hours will then be provided for reflection and for each person to read the consent forms and information leaflets. After 24 hours, I will then arrange to meet with those who are willing to participate. Both the participants and the researcher will then sign the consent forms.

Reducing sedentary behaviour in the workplace is important in terms of reducing the risks associated with this damaging health behaviour. The opinions of individuals in the specific workplace context are very important. This will give us an understanding of whether the strategies used in this pilot are acceptable and feasible in your workplace. Participation in the study is of great importance in our bid to understand appropriate ways to support individuals and organisations to reduce sedentary behaviour in the workplace.

Kind regards

Gail Nicolson

Public Health and Primary Care

Trinity College Dublin
Institute of Population Health
Russell Centre
Tallaght Cross
D24 DH74
Phone (01) 896 3739

Appendix T - Participant Consent Form (Pilot Feasibility Study)



Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin
Ollscoil Átha Cliath | The University of Dublin

Pilot study to test the acceptability and feasibility of a theory-led multicomponent intervention to reduce sedentary behaviour in the workplace

PHD Candidate: Gail Nicolson, Trinity College Dublin.

Tel: 01-8963739 Email: nicolsg@tcd.ie

Primary supervisor: Dr Catherine Darker, Trinity College Dublin.

Tel: 01-8968510 Email: Catherine.darker@tcd.ie

Secondary Supervisor: Dr Catherine Hayes, Trinity College Dublin.

Tel: 01-8961385 Email: hayesc9@tcd.ie

If you would like any more information about the study or if you have any further questions, please refer to the attached participant information leaflet or contact the research team.

Please initial each box to confirm that you have read, understood and agreed to each of the points of the form.

I confirm that I have read and understood the attached Participant Information Leaflet. I have had the opportunity to think about the information and to ask questions. The research team has answered any questions I have had.

I agree to take part in the research study.

I agree that my personal details will not be shared with anyone outside of the research team. A professional transcriber will have access to the focus group data I provide, and will sign a legally binding Data Processing Contract governing the data processing as outlined in Article 28 of the General Data Protection Regulation (GDPR). I understand that my data will be anonymised i.e., my name or personal details will not appear, prior to any publication of the results. I understand that I can get a copy of the Privacy Notice from the researcher if I want to find out more about how my data are protected.

I agree to my data being stored securely for ten years after the study ends, by Trinity College Dublin researchers.

I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. I understand that if I withdraw from the study, any data collected from me can still be used unless I state otherwise. I understand if I need to make a complaint, I can contact the Data Protection Officer at dataprotectionofficer@tcd.ie.

I agree to be part of a pilot study and understand that survey information that I provide will be confidential to the research team and the focus group will be audio-recorded and put into writing word for word by a transcriber, and the voice recording will then be destroyed.

_____	_____	_____
(Please print name of participant here)	Date	(Please sign here)
_____	_____	_____
Researcher's name	Date	Researcher's signature

Appendix U - Physical Activity Readiness Questionnaire

Physical Activity Readiness Questionnaire

NAME Date of Birth Age:

Please tick appropriate box

YES NO

Has the study procedure been fully explained to you?

Any information contained herein will be treated as confidential

1. Has your doctor ever said you have heart condition and that you should only do physical activity recommended by a doctor?

2. Do you feel pain in your chest when you do physical activity?

3. In the past month, have you had chest pain when you were not doing physical activity?

4. Do you lose your balance because of dizziness or do you ever lose consciousness?

5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?

6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?

7. Do you know of any good reason why you should not do physical activity?

- If you have answered **NO** to all questions then you can be reasonably sure that you can take part in the physical activity requirement of the study.

I declare that the above information is correct at the time of completing this questionnaire

Date/...../.....

Please Note: If your health changes so that you can then answer YES to any of the above questions, tell the researcher. Consult with your doctor regarding the level of physical activity you can conduct.

Appendix V - Doctor Statement of Safety

To whom it may concern,

I have answered yes to a question on the Physical Activity Readiness Questionnaire (e.g., Q6. I am currently taking prescribed drugs for my blood pressure or heart condition). I have consulted my doctor and they have stated that it is safe for me to participate in this research.

Name: _____

Signed: _____

Date: _____

Appendix W – Programme Logic Model

Inputs	Activities	Outputs	Outcomes – Short term	Outcomes-Intermediate	Outcomes – Long term
<p>Partnership Management support, approval and participation</p> <p>Resource/Materials Intervention programme to reduce sedentary behaviour/increase physical activity</p> <p>Materials for Cycle at Work intervention (Garmin watches, Pedal machines)</p> <p>Assessment tools (ActivPAL devices, EMA electronic surveys, questionnaires)</p>	<p>Activities Present education session on risks of prolonged workplace SB</p> <p>Implement Cycle at work intervention facilitated by researcher</p> <p>Goal-setting of >30 minutes per day reduction of SB by replacing with LPA – pedalling</p> <p>Self-monitoring SB/LPA using Garmin platform</p> <p>Social comparison of team-mates progress using Garmin platform</p>	<p>#Participants recruited</p> <p>#Workplaces recruited</p> <p>#Participants retained</p> <p>#Workplaces retained</p> <p>Acceptability and feasibility of intervention</p> <p>Acceptability and feasibility of trial procedures</p>	<p>Psychosocial - Increased awareness/knowledge of consequences associated with SB and benefits of increasing PA at work</p> <p>Motivation to reduce SB and increase PA in work</p> <p>Address barriers to reduce SB and provide facilitators to increase LPA in work</p> <p>Social - Increased camaraderie and support from colleagues</p> <p>Organisational - Improved support for reducing workplace SB by pedalling at work from employees and management</p>	<p>Decreased total/workday sedentary time</p> <p>Increased workday PA</p> <p>Increased work engagement</p> <p>Change in workplace culture/social norms</p> <p>Organisational change/support</p> <p>Decrease in musculoskeletal symptoms</p> <p>Improved mental health</p> <p>Improved work productivity</p>	<p>Sustained decrease SB/Increase LPA in workplace</p> <p>Sustained improved work engagement</p> <p>Improved cardiovascular health (using markers such as BMI, waist circumference, blood pressure)</p> <p>Sustained change in workplace culture</p> <p>Increased Health Related Quality of Life</p> <p>Decreased presenteeism/abstenteeism</p> <p>Sustained improvement of mental health, of musculoskeletal symptoms, of work productivity</p>

Appendix X - Interview Schedule (Pilot Study)

Introduction

Before the focus group begins:

Thank participants for taking part.

Explain the nature of the research to the participants (i.e., research questions, why their perceptions are important, what the data will be used for). Explain that the researcher will make themselves available to speak on a one-to-one basis to any participants who feels constrained to speak in the focus group.

Housekeeping:

1. Recording
2. Phones
3. Consent forms (confidentiality, anonymity).

Ask participants to sign consent forms, which will be countersigned by the researcher. (Participants have been given a 24-hour period of reflection prior to commencement of the focus group).

Schedule for focus group

Introduction and the framing and guidelines of the focus group. We would like to know about your experience (satisfaction, perspectives) of the pilot study and in particular regarding the following aspects:

(a) Acceptability of intervention components

To start, could you tell me what you thought of the intervention, overall? *What was your experience of it?*

What did you think of the individual components of the intervention? What was your experience of using the elliptical machine? How did you find wearing the Garmin watch? What about the challenge aspect of the intervention?

What are your thoughts on the measures used within the study? How did you find wearing the ActivPAL?

What are your thoughts on the ecological momentary assessment? The number of messages throughout the day – too many? Was it acceptable to you? Were there any other outcomes of using this that you were not expecting?

(b) Randomisation

What are your thoughts on the randomisation aspect of the study? Did it affect your participation in the study?

(c) Appropriateness of the intervention

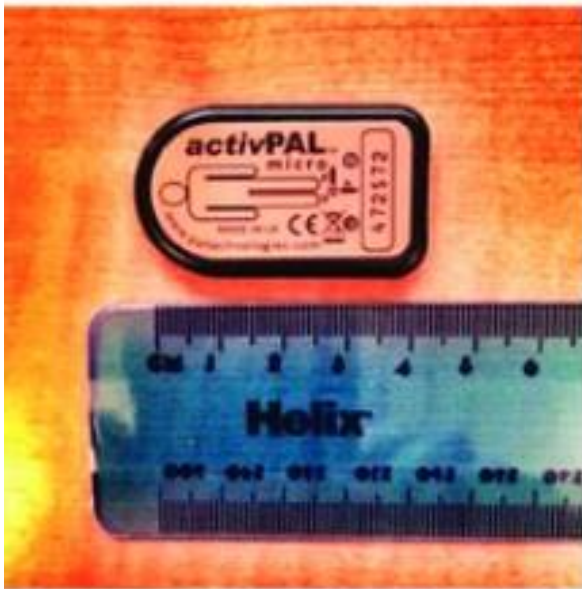
Do you think that the intervention was appropriate in terms of its objectives? Do you think the components used in the intervention were appropriate in enabling you to reduce your workplace sedentary behaviour?

(d) Effectiveness of the intervention

Do you think that the intervention was effective in its aims? Did the intervention achieve its goal in reducing your workplace sedentary behaviour?

- (e) Barriers to reducing workplace sitting not addressed by the intervention
Were there factors that impeded you taking part in the intervention that we did not take into consideration? *Was there a factor that stopped you taking part in the intervention as much as you would have liked?*
- (f) Other benefits/harms of the intervention
Were there other benefits or improvements that you felt because of the intervention?
Were there disadvantages taking part in the intervention?
- (g) Suggested improvements to the intervention
What do you think would improve the intervention going forward if it was run on a larger scale? *What would you change if you were to take part again in the intervention?*

Appendix Y - activPAL3



Appendix Z – activPAL3 Instructions and Wear Diary



ID Number: _____

Thigh Monitor Instructions

How do I wear the monitor?

- The Thigh Monitor is attached directly onto the skin and positioned on the front of the thigh, roughly 1/3 of the way between hip and knee with the stick man standing up (see picture).
- Please wear the monitor for the duration that the researcher asks you.
- Please wear the Thigh Monitor continuously (24 hours/day)
- The Thigh Monitor can be worn during sleep and is water resistant (to 1m) so you can wear it whilst showering and bathing but please do not wear it in the swimming pool in case it falls off.
- The adhesive patch that sticks the Thigh Monitor to your skin may last up to 7 days but to avoid skin irritation to may want to change the adhesive patch



Note: The Thigh Monitor will emit a green flash every 6 seconds. This is an indication that it is working and recording data.

How do I change the adhesive patch?

- Remove the Thigh Monitor from your thigh (note that this may cause some slight discomfort) and peel the adhesive patch off the Thigh Monitor. The monitor is covered in a waterproof sleeve and wrapped in one adhesive patch—please make sure that these remain on the monitor when you do this.
- With an alcohol prep pad provided in your Activity Monitor Pack, thoroughly wipe down the monitor and the area of your leg where the Thigh Monitor was attached.
- Position the Thigh Monitor in the same spot as previously on your thigh (or on the other thigh if you have had a slight irritation), ensuring that the stick man on the front of the Thigh Monitor is standing up (head facing upward).
- Peel the backing off an adhesive patch and place it over the Thigh Monitor. Press the patch onto your skin, peel back the top layer of the patch and smooth out the air bubbles and wrinkles as much as possible to ensure that the Thigh Monitor is firmly secured to your thigh.
- If you require assistance re-attaching your Thigh Monitor, or if you experience any skin irritation whilst wearing it, please call 086 8251011

What else do I need to do?

- It is important that you fill in the Daily Log on the following pages every day for the 9 days while you are wearing the monitor.
- This helps us to look specifically at the data from when you were awake.

Returning your Thigh Monitor and Daily Log

- After you have worn your Thigh Monitor for 9 days, along with this completed Daily Log, the

researcher will collect both from you.

How to fill in the daily activPAL log

- The log is divided into 9 days. Please complete each question for all of the 9 days. Please try and be as accurate as possible—record the exact times if you can, or at least to the nearest 5 minutes of your estimated times.
- Start by writing the **date** in the top row.
- Then record the time that you **woke up** and the time that you actually **got out of bed** (these times may be the same for some days). We ask for these two times because people sometimes spend time in bed before going to sleep or getting up and we are interested in distinguishing between actual sleeping time and time in bed before sleep or once awake, for example going to bed and watching TV for an hour before going to sleep.
- If you **remove the device** for longer than 10 minutes during the day please note down the time that you removed the device, the time that you re-attached it and the reason why you removed the device. This is particularly important as we cannot tell from the data if you are lying down or whether you have removed the device and are just not wearing it (the data looks the same when we look at it).
- Then record what time you **got into bed** to go to sleep and the time that you actually **went to sleep** time. (i.e., the estimated time that you fell to sleep not the time that you got into bed). This is important as the monitor cannot tell the difference between asleep and awake times, and we are only interested in your activity while you are awake.
- Please record your sleep time first thing in the morning when you wake up along with your wake time.
- There is also a space for you to make **comments**. It is useful for us to know if you have had any skin irritations, accidentally worn the monitor upside down or any other information that you think we should know.
- Once you have completed your 9 days of wear please return this log along with your thigh monitor to our research team in the envelope provided by our research team.

If you have any questions please contact Gail Nicolson Ph: **01 8963739 / 086 8251011**

ID Number:

Day and Date	Time woke up	Time got out of bed	Did you remove your monitor for >10 mins today?	If removed, record time of removal and reason why	Time got into bed	Time went to sleep	Other comments
Day 1 17/12/2018	07:00am	07:15am	Yes No	Time off: 18:00pm Time on: 18:45pm Reason: Swimming in the sea	21:45pm	22:10pm	Slight irritation on right leg so put monitor on left leg
Day 1 Date:			Yes No				
Day 2 Date:			Yes No				
Day 3 Date:			Yes No				
Day 4 Date:			Yes No				
Day 5 Date:			Yes No				
Day 6 Date:			Yes No				
Day 7 Date:			Yes No				
Day 8 Date:			Yes No				
Day 9 Date:			Yes No				

Appendix AA –Participant information sheet for PIEL Survey

Thank you for agreeing to be part of our research project into reducing sedentary behaviour in your workplace.

Your participation is essential to further understanding this important subject.

The survey is to be conducted using the PIEL Survey app. You should find it intuitive to use but some important information is provided here to make sure that you do not have any problems.

It is extremely important that you do not stop the survey or delete the PIEL Survey app unless we confirm that you can do so.

If you have questions or problems, please contact Gail Nicolson by phone: 01 896 3739 / 086 8251011

Setup Survey

Download the app

The app is available at these two locations, depending on your phone type. Please tap the link on your mobile device. You will be taken to the store. Then install the PIEL Survey app. It is free.

You will notice on the first installation that a "Welcome" survey will appear. This survey is not related to our research survey but is a sample from the app developer. Please tap on it and start the survey as a way of exploring the app. You can then delete it if you wish.

Import Survey

We will send you a survey by email. You can open this in the app by tapping on the downloaded file and selecting the option to open it in the "PIEL Survey".

Activate and Run Survey

Simply tap on the imported survey and you will see that it is selected. On 16th October please tap the green button at the bottom of the screen to start the survey.

A placeholder screen will show, giving the name of the survey and the completion date.

Wait for survey

There is nothing to do for the moment, the app will notify you when a survey is due.

We ask that you remember a few things:

it is extremely important that you do not disable notifications for the PIEL Survey app while a survey is running.

If you enable "Do not disturb", please exclude the PIEL Survey app if possible or remember to turn off "Do not disturb" when no longer needed.

Please keep your device charged and nearby with the volume at a level that you can easily hear.

Make sure the volume for notifications is sufficient to be noticed. Do not mute your device for prolonged periods.

Note: Android phones

Owners of some Android phones may require 3 further steps to allow notifications to be received. If during testing, you are not receiving notifications, please verify these steps.

Disable battery optimization for the PIEL Survey app.

Lock the PIEL Survey app in "Recent apps".

Do not close the PIEL Survey app during the survey period. It must remain in the background. If you accidentally close it, just reopen it.

If you are unsure of these steps, please see some examples on the [support website](#).

Completing a survey

Notification

The survey will run for 9 days. It will run from the 16th of October to the 25th of October.

When you receive a notification, you can tap on the notification to start the survey or simply open the app.

You will be required to complete the survey within 20 upon receiving the notification.

If you miss a scheduled survey, don't worry, the schedule will continue and you can answer the next survey.

Just answer as many surveys as you can.

Answering questions

Answering questions is easy. You must answer a question to be able to move forward, either by swiping or tapping "Next". You can always move backwards and modify answers.

You can put the app in the background during a survey then continue it again after a delay but if you close the app, you will terminate the current survey.

Once the survey is opened it will expire in 10 minutes.

Sending Data

The PIEL Survey app does not ever send out your data during a project. You are in total control of your data.

At the end of all the scheduled surveys, you will receive an alert asking if you want to send you data to us. Please choose to email the data immediately. It will be sent using your own email account directly to us.

A failure of sending the email will not delete the data and you can resend it later.

While this approach provides a high level of protection of your data, it's extremely important that you DO NOT delete the data or the app until we have confirmed that we have received your data and that you can delete your copy.

Appendix BB - Ecological Momentary Assessment

Screenshots of the EMA messages

Screen 1

Screen 1 Cont.

Screen 2

The image displays three screenshots of the EMA application interface. Each screen has a yellow header with a question and a blue asterisk indicating a single-choice question. Below the question are several white buttons with rounded corners, each containing a text option. At the bottom of each screen are navigation buttons: 'Back', a progress indicator (e.g., '50% done'), and 'Next'.

- Screen 1:** Question: "What were you doing just before this notification went off?". Options: Reading, Using computer, Watching TV/Movies, Using smartphone/tablet, Eating/Drinking, Socialising, Doing Hobbies.
- Screen 1 Cont.:** Question: "What were you doing just before this notification went off?". Options: Watching TV/Movies, Using smartphone/tablet, Eating/Drinking, Socialising, Doing Hobbies, Physical Activity/Exercising, Other.
- Screen 2:** Question: "What type of physical activity/exercise?". Options: Running/jogging, Walking, Weightlifting/strength training, Using cardiovascular equipment, Elliptical machine, Other Cycling, Other.

Screen 3

Screen 4

The image displays two screenshots of the EMA application interface. Each screen has a yellow header with a question and a blue asterisk indicating a single-choice question. Below the question are several white buttons with rounded corners, each containing a text option. At the bottom of each screen are navigation buttons: 'Back', a progress indicator (e.g., '66% done'), and 'Next'.

- Screen 3:** Question: "What was this OTHER activity?". Options: Cooking/Chores, In a car, Childcare, Attending meeting/appointment, Something else.
- Screen 4:** Question: "Were you SEDENTARY while doing this activity?". Options: yes, no.

Appendix CC - Checklist for Reporting Ecological Momentary Assessments

Title	1	Include ecological momentary assessment in title and key words	Location
Introduction			
Rationale	2	Briefly introduce the concept of EMA and provide reasons for utilizing EMA for this study or topic of interests (e.g., to examine time-varying predictors of unhealthy eating occasions in children's daily lives)	230
Methods			
Training	3	Indicate if, and by what methods, training of participants for EMA protocol was used	230, Appendix AA
Technology	4	Describe what technology, if any, was used. Include the following information: device (e.g., mobile phone, portable computer), model (e.g., Nexus 4, iPod), operating system (e.g., Android, Windows), and EMA program name	230
Wave duration	5	State the number of waves for the study (e.g., 2 monitoring periods over the course of 1 year)	220
Monitoring period	6	State the number of days each wave of the study lasted, and how many weekdays versus weekend days	220
Prompting design	7	Indicate the prompting strategy used for the study (e.g., event-based, interval-based, or a combination of the two). If using interval-based strategy, indicate what type of schedule is used (e.g., fixed, random, or hybrid interval)	230
Prompt frequency	8	Intended frequency of prompts per day. Break down by weekdays and weekend days if applicable	230

Design features	9	Describe any design feature to address potential sources of bias (e.g., reactivity) or participant burden (e.g., EMA questions appearing in different orders)	287
Items	10	Report all the specific items that were used to measure the target variables	Appendix BB
Source of the items	11	Report the source of the items used in the EMA (e.g. pilot study with experts, pilot study with users, existing EMA questionnaire, existing non-EMA questionnaire, self-made)	230
Relevance items	12	Report if, and how, it was tested that all items are relevant for the construct of interest, for the target population of interest and for the context of use of interest.	230
Comprehensiveness items	13	Report if, and how it was tested that no key concepts are missing	287-288
Comprehensibility items	14	Report if, and how was tested that instructions, items and response options are understood by the population of interest as intended.	287
Results			
Attrition	15	Indicate participant attrition throughout the study; report attrition rates both by monitoring days and waves, if applicable	273
Prompt delivery	16	Report number of EMA prompts that were planned to be delivered. If possible, also report the number of EMA prompts that were actually received by participants and indicate reasons for why prompts were not sent out (e.g., technical issues or participant noncompliance reason such as phone was powered off)	287-288

	Latency	17	Report the amount of time from prompt signal to answering of prompt	
	Compliance rate	18	Report total answered EMA prompts across all subjects and the average number of EMA prompts answered per person. Report compliance rate both by monitoring days and waves, if applicable. Indicate reasons for noncompliance, if known	273
	Missing data	19	Report whether EMA compliance is related to demographic or time-varying variables	na
Discussion				
	Limitations	20	Discuss limitations of the study, taking into account sources of potential bias when using EMA methods (e.g., reactivity, use of technology)	287-288
	Conclusions	21	Provide a general interpretation of results and discuss the benefits of using EMA (e.g., improving understanding of daily behaviours)	288

Appendix DD - Utrecht Work Engagement Scale

The following 9 statements are about how you feel at work. Please read each statement carefully and decide if you ever feel this way about your job. If you have never had this feeling, cross the '0' (zero) in the space at the statement. If you have had this feeling, indicate how often you feel it by crossing the number (from 1 to 6) that best describes how frequently you feel that way.

Almost never	Rarely	Sometimes	Often	Very often	Always	
0	1	2	3	4	5	6
Never	A few times a year or less	Once a month or less	A few times a month	Once a week	A few times a week	Every day

1. _____ At my work, I feel bursting with energy (V11)
2. _____ At my job, I feel strong and vigorous (V12)
3. _____ I am enthusiastic about my job (DE2)
4. _____ My job inspires me (DE3)
5. _____ When I get up in the morning, I feel like going to work (V13)
6. _____ I feel happy when I am working intensely (AB3)
7. _____ I am proud on the work that I do (DE4)
8. _____ I am immersed in my work (AB4)
9. _____ I get carried away when I'm working (AB5)

Appendix EE - Consolidated criteria for reporting qualitative studies (b)

Developed from:

Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *International Journal for Quality in Health Care*. 2007. Volume 19, Number 6: pp. 349 – 357

No. Item	Guide questions/description	Reported on Page #
Domain 1: Research team and reflexivity		
<i>Personal Characteristics</i>		
1. Interviewer/facilitator	Which author/s conducted the interview or focus group?	225
2. Credentials	What were the researcher's credentials? E.g. PhD, MD	225
3. Occupation	What was their occupation at the time of the study?	225
4. Gender	Was the researcher male or female?	304
5. Experience and training	What experience or training did the researcher have?	225
<i>Relationship with participants</i>		
6. Relationship established	Was a relationship established prior to study commencement?	225
7. Participant knowledge of the interviewer	What did the participants know about the researcher? e.g. personal goals, reasons for doing the research	225
8. Interviewer characteristics	What characteristics were reported about the interviewer/facilitator? e.g. Bias, assumptions, reasons and interests in the research topic	226
Domain 2: study design		
<i>Theoretical framework</i>		
9. Methodological orientation and Theory	What methodological orientation was stated to underpin the study? e.g. grounded theory, discourse analysis, ethnography, phenomenology, content analysis	232
<i>Participant selection</i>		

10. Sampling	How were participants selected? e.g. purposive, convenience, consecutive, snowball	236
11. Method of approach	How were participants approached? e.g. face-to-face, telephone, mail, email	237
12. Sample size	How many participants were in the study?	219
13. Non-participation	How many people refused to participate or dropped out? Reasons?	236
<i>Setting</i>		
14. Setting of data collection	Where was the data collected? e.g. home, clinic, workplace	219
15. Presence of non-participants	Was anyone else present besides the participants and researchers?	232
16. Description of sample	What are the important characteristics of the sample? e.g. demographic data, date	235
<i>Data collection</i>		
17. Interview guide	Were questions, prompts, guides provided by the authors? Was it pilot tested?	225
18. Repeat interviews	Were repeat interviews carried out? If yes, how many?	
19. Audio/visual recording	Did the research use audio or visual recording to collect the data?	225
20. Field notes	Were field notes made during and/or after the interview or focus group?	225
21. Duration	What was the duration of the interviews or focus group?	225
22. Data saturation	Was data saturation discussed?	
23. Transcripts returned	Were transcripts returned to participants for comment and/or correction?	225
Domain 3: analysis and findings		
<i>Data analysis</i>		
24. Number of data coders	How many data coders coded the data?	232
25. Description of the coding tree	Did authors provide a description of the coding tree?	n/a
26. Derivation of themes	Were themes identified in advance or	232

	derived from the data?	
27. Software	What software, if applicable, was used to manage the data?	232
28. Participant checking	Did participants provide feedback on the findings?	292
<i>Reporting</i>		
29. Quotations presented	Were participant quotations presented to illustrate the themes/findings? Was each quotation identified? e.g. participant number	253-271
30. Data and findings consistent	Was there consistency between the data presented and the findings?	239
31. Clarity of major themes	Were major themes clearly presented in the findings?	253-271
32. Clarity of minor themes	Is there a description of diverse cases or discussion of minor themes?	253-271

Appendix FF –Algorithm for analysis of activPAL data

Sum	Sum(abs(dChannel1)) (X)	Sum(abs(dChannel2)) (Y)	Sum(abs(dChannel3)) (Z)	SVM
Sedentary	0.40	0.40	0.00	0.73
Fidgeting	221.65	201.90	235.30	386.40
Light	287.35	160.50	176.75	374.42
Moderate	1040.70	613.95	868.05	1488.87
Hard	1821.00	1149.85	1616.40	2693.87

Standard Dev	Sum(abs(dChannel1)) (X)	Sum(abs(dChannel2)) (Y)	Sum(abs(dChannel3)) (Z)	SVM
Sedentary	0.598243042	0.50262469	0	0.6185068
Fidgeting	147.7139038	170.0597109	165.4897357	271.783944
Light	46.51981908	41.1661162	50.38001785	75.7125709
Moderate	126.9227283	63.75733188	101.0458338	164.254312
Hard	207.779995	131.7934089	210.3849604	313.831201

Activity	Sum(abs(dChannel1))	Sum(abs(dChannel2))	Sum(abs(dChannel3))	SVM	SD
Light pedalling	287.35	160.50	176.75	374.41	75.0
Moderate pedalling	1040.70	613.95	868.05	1488.87	164.0
Hard pedalling	1821.00	1149.85	1616.40	2693.87	313.0
Fidgeting	221.65	201.90	235.30	386.40	271.0
Sedentary	0.40	0.40	0.00	0.73	