Testing the ‘teachable moment’ premise: does physical activity increase in the early survivorship phase?

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Abstract

Purpose Little is known about objectively measured physical activity during the early survivorship period. This study measured physical activity, fatigue, and quality of life (QOL) in breast cancer patients over the first year after completion of chemotherapy and compared results to a matched non-cancer group.

Methods Data was obtained from 24 breast cancer subjects (mean ± SD) 50.9±12.8 years at time points of 6 weeks, 6 months and 1 year after completion of adjuvant chemotherapy and from 20 matched women. The following variables were assessed, physical activity (RT3 accelerometer and International Physical Activity Questionnaire), quality-of-life (EORTC QLQ C-30) and fatigue (Brief Fatigue Inventory).

Results At 6 weeks after completion of chemotherapy, high levels of sedentary behaviour were found (6.8±1.9 h sedentary per day), which did not improve, and was no different to the comparison group (6.5±1.4 h). Less light activity was performed in the cancer cohort compared to the comparison group (p=0.003). Body mass index (BMI) increased significantly in the cancer cohort (p=0.015) and 1 year after chemotherapy finished only 13 % (n=3) had a BMI <25, while the comparable value was 45 % (n=9) in the non-cancer group. The QOL domain of cognitive function improved over the first 6 months (p=0.034) but physical functioning declined (p=0.008) over this time period. Fatigue did not change, and at the 1-year time point, 38 % of the cancer patients (n=11) reported high levels of fatigue.

Conclusion This study highlighted the unchanging sedentary behaviour and weight gain of breast cancer survivors during the first year after completion of chemotherapy, which may inform rehabilitation models in this population.

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Introduction

Sufficient levels of physical activity can confer multiple benefits in breast cancer survivors. Physical activity may alleviate some of the side effects of cancer treatment such as fatigue, pain, lymphedema, weight gain, and bone density loss [1, 2]. With survival rates up to 80 % in breast cancer patients [3], physical activity is increasingly important to attenuate the risk of developing longer term secondary diseases associated with inactivity such as diabetes and cardiovascular disease [4]. Increased physical activity levels have also been linked to lower levels of disease recurrence [5, 6]. High levels of sedentary behaviour, regardless of levels of moderate and vigorous physical activity, have more recently garnered attention in the cancer literature as an independent health risk due to associated physiological and metabolic sequelae such as adiposity, inflammatory processes, and impaired insulin resistance [7].

The ‘teachable moment’ premise coined by Demark-Wahnefried et al. [8] suggests that a cancer diagnosis may result in a motivation surge which initiates positive lifestyle changes such as increased physical activity levels. Some rehabilitation programmes in cancer survivors aim to capitalise on this ‘window of opportunity’ and the most opportune time for adaptation of positive lifestyle changes may be during the first year after completion of chemotherapy [9]. However, little is known about whether breast cancer patients spontaneously adopt, or revert to, healthy physical activity levels during that time.

Nearly all studies examining physical activity in cancer patients and survivors have used self-report measures. These convenient methods of measuring physical activity have established the direction of the relationship between physical activity and cancer risk, but are prone to inaccuracies [10]. Indeed, no consistent pattern of physical activity after cancer has emerged. A small number of studies showed a trend towards decreasing physical activity levels in the first year after diagnosis [11, 12] while several others have reported the opposite [13–17].

The next generation of research questions which follows from epidemiological findings such as the dose–response relationship between physical activity and beneficial outcomes and what interventions best increase physical activity require accurate measurement tools such as pedometers and accelerometers [18]. Furthermore, accurate measures of physical activity are essential to develop effective cancer rehabilitation programmes.

A small number of studies within the cancer literature incorporated accelerometers as measures of physical activity [19–22]. The majority of these studies incorporated accelerometers as an outcome to assess the effectiveness of exercise interventions [19–21]. Baseline measures within these studies indicate low physical activity levels. Lynch et al. [22] evaluated physical activity of long-term survivors (approximately 10 years after their initial diagnosis) by defining a selected group who could have already established activity behaviour patterns or developed comorbidities. Evaluating the physical activity behaviour of patients serially over the first year after completion of chemotherapy treatment would reflect important trends during this early survivorship phase may provide a basis for intervention programmes and also give an insight into the challenges of the 'teachable moment'.

We provide the first report of longitudinal, objectively measured physical activity levels of breast cancer survivors over the first year after completion of chemotherapy, with self-reported physical activity at the same time points. We also measured fatigue, quality of life (QOL) and body mass index (BMI). We recorded objective and subjective physical activity levels and BMI in a matched comparison group.

Materials and methods

Subjects and setting

This study was conducted in St. James's Hospital, Dublin, Ireland, a tertiary referral centre for breast cancer. Eligible patients were those who had completed >80 % of scheduled adjuvant chemotherapy for a first primary breast cancer. We excluded patients with evidence of metastatic disease or any comorbidity which significantly impaired functional mobility. Approval was obtained from the institutional ethics committee, and written informed consent was gained from each participant.

Study procedure

An RT3 accelerometer, an activity diary and three questionnaires were posted to each participant leading up to time points of 6 weeks, 6 months and 1 year after completion of chemotherapy.

As by definition, we could not measure pre-diagnosis levels of activity objectively; we recruited an age (±5 years) and educationally matched non-cancer comparison group of women through institutional e-mails. Objective and self-reported physical activity as well as body mass index was measured at a single time point in this group.

Study measures

Physical activity was assessed objectively using an RT3 accelerometer. The validity [23, 24] and reliability [25, 26] of this measure are well established. The RT3 accelerometer is a small waistband-mounted device which is sensitive to movement in three axes: vertical (x), anteroposterior (y) and mediolateral (z). This works by converting the voltage signal generated to a series of numbers called 'activity counts' which was set as accumulated vector magnitude ($[X^2+Y^2+Z^2]^{0.5}$) activity over a 1-min epoch or time sampling interval (mode 4). This device captures time spent in discrete domains of sedentary, light, moderate and vigorous domains of activity based on accumulated vector–magnitude cutoff points previously described [24]. The domains of light, moderate and vigorous activity were summed to provide a measure of total objectively measured physical activity.

Subjectively measured physical activity was assessed using the International Physical Activity Questionnaire (IPAQ) [27]. This questionnaire assesses physical activity across the following domains: leisure time, domestic and gardening activities and work-related and transport-related physical activity. The long form has been shown to have acceptable validity for assessing different domains of physical activity, physical activity intensities and total physical activity in healthy adults [28].

QOL was measured using the EORTC QLQ C30 V3 questionnaire [29]. This questionnaire includes multi-item scales and single-item scales. The multi-item components evaluate physical, role, cognitive, emotional and social domains as well as fatigue, pain, and nausea and vomiting. Single items include dyspnoea, appetite loss, sleep disturbance, constipation and diarrhoea. The scoring of the EORTC QLQ C30 was performed according to the EORTC scoring manual [30].

Fatigue was assessed using the Brief Fatigue Inventory (BFI). Psychometric properties of this scale were tested and established on almost 600 adults with cancer [31], and a recent review rated it highly in terms of 'quality' and 'user friendliness' [32] . The BFI consists of nine numerical scales, three items measure severity and six items measure interference with daily activities from 0 (none) to 10 (severe) with anchor points 'no fatigue' and 'fatigue as bad as you can imagine'.

Body mass and height were measured by oncology nursing staff using a Seca 764 electronic weighing and measuring station during scheduled appointments in the oncology day ward of St. James's Hospital. Weight was recorded at the time of cancer diagnosis and at the 1-year time point. As some of the study time points may not have corresponded closely with scheduled hospital appointments, the weight which corresponded closest with the study assessment time point was taken. In the case of missing data ($n=1$ at 1-year time point) or a time difference of greater than 12 weeks, self-reported weight ($n=3$ at 1-year time point) was used if available. Clinical variables such as cancer stage and chemotherapy regimen were collated by medical chart review and demographic details were obtained via participant interview.

Statistical analysis

Data were tested for normality using a Kolmogorov–Smirnov test. Normally distributed data were compared across time points using the general linear model procedure. Non-normally distributed data was compared using the Friedman's test. Data was examined to assess where significance existed. Associations between variables were measured using Pearson's product moment correlation coefficient. The Macros function of Microsoft Excel was used to assess compliance with the American College of Sports Medicine (ACSM) physical activity guidelines [33] using objectively measured physical activity. The Macros code identified individuals who met the following criteria: 150 min per week of moderate/vigorous physical activity, over 5 days of the week, at least 30 min per day and no less than 10 min in each bout. Data was analysed using SPSS 16.0.

Results

Thirty-seven individuals were approached for participation in this study. Twenty-seven participants consented to participate and were initially recruited to this study, leading to an accrual rate of 73 %. Three participants dropped out due to loss in interest ($n=1$), recurrent nausea and vomiting ($n=1$) and disease recurrence ($n=1$). Twenty-four participants completed all three assessments and their data is presented here. The overall retention rate over 1 year was therefore 88 %. Baseline demographic and disease-related information of participants is outlined in Table 1. Thirty-three percent ($n=8$) were in paid employment at the 6-week time point. This was 45.8 % ($n=11$) and 58 % ($n=14$) by the 6-month and 1-year time points, respectively. The mean age of the matched comparison group ($n=20$) was 50.8±12.8 years, with a range of 25–70 years and educational achievement was as follows: less than high school ($n=8$), high school graduates ($n=3$), associate degree ($n=5$), bachelor's degree ($n=2$) and advanced degree ($n=2$).

Table 1 Baseline demographic characteristics and disease-related information of participants

	Overall ($n=24$)
Age, mean (SD)	50.9 (12.8)
Range	25–70
Race/ethnicity, n (%)	
Caucasian	22 (91.7)
Asian	2 (8.3)
Marital status (married), n (%)	17 (70.8)
Gender, M/F	24/0
Occupation at diagnosis, n (%)	
Professional	5 (20.8)
Management/clerical	7 (29.2)
Manual/non-skilled	5 (20.8)
Not working/retired	7 (29.2)
Educational achievement, n (%)	
Less than high school	9 (37.5)
High school graduate	3 (12.5)
Associate degree	6 (25)
Bachelor's degree	3 (12.5)
Advanced degree	3 (12.5)
Cancer Stage, n (%)	
I	6 (25)
IIA	6 (25)
IIIA	5 (20.8)
IIIB	7 (29.2)
Surgery, n (%)	
Breast conserving surgery	13 (54.2)
Mastectomy	11 (45.8)
Chemotherapy regime, n (%)	
AC followed by paclitaxel	6 (25)
Docetaxol and cyclophosphamide	13 (54.2)
Other	5 (20.8)
Hormonal therapy	
Tamoxifen	8 (33.3)
Letrozole	5 (20.8)
Maintenance therapy	
Trastuzumab	7 (29.2)
Bevaczumab	5 (20.8)
Radiation therapy, n (%)	21(87.5)

AC cyclophosphamide and doxorubicin

BMI was 30.2±8.1 at diagnosis (range 18.5–50.3) and increased significantly by the 1-year time point (p=0.015). At the 1-year time point, BMI was 31.2±9.3 with a range of 19.7–56.8. By this time, only 13 % (n=3) were healthy weight, while the corresponding value was 45 % (n=9) in the comparison group. This was equivalent to a mean increase of 2.6±6.4 kg from the point of cancer diagnosis to 1 year after completion of chemotherapy. There was a significant difference between the BMI of the cancer cohort and matched comparison group (p=0.02). The BMI of the matched comparison group was 25.1±1.9 with a range of 20.2–39.9.

Objectively measured physical activity (Fig. 1 and Table 2) indicated a high level of sedentary behaviour; mean 6.8±1.9 h per day at the 6-week time point, 7.3±2.3 h per day at the 6-month time point and 7.6±2.3 h per day 1-year after chemotherapy completion. Although there was a trend shown of decreasing total physical activity (including domains of light, moderate and vigorous physical activity) over the time course of this study, this did not change significantly (p=0.550) and was no different to the comparison group (p=0.660). Time spent in moderate and vigorous activity was 62.7±62.8 min per day at the 6-week time point, 41.6±45.7 min per day at the 6-month time point and 42.8±42.2 min per day at the 12-month time point. In the comparison group, this was a mean of 37.7±37.7 min per day which was no different to the cancer cohort (p=0.360). The comparison group showed longer time in light activity compared to the cancer cohort (p=0.003), with differences shown between the comparison group and the cancer cohort at the 6-week and 12-month time points. A comparison was made to ACSM guidelines using objectively measured physical activity; only 4 % (n=1) met recommended levels at the 6-week time point, this was 8 % (n=2) at the 6-month time point, 4 % (n=1) at the 12 month time point and 4 % (n=1) for the comparison group.

Results of subjectively measured physical activity are shown in Table 2. There was no change in subjectively measured physical activity over the time course of the study (Table 2). Both the cancer cohort and matched comparison group consistently overestimated time in activity and underestimated time spent sitting. For example, 1 year after finishing chemotherapy, cancer survivors' self-reports indicated a total mean of 128.2 min per day using the sum of self-reported time spent in moderate and vigorous domains of activity and time spent walking (across leisure, transport, occupational and household), whereas the comparable value (minutes in moderate and vigorous domains of activity) for accelerometer data was 42.8 min per day (42.2). An alternative comparison is the number of subjects reaching physical activity guidelines by each measure. Using the sum of self-reported time spent in moderate and vigorous domains of

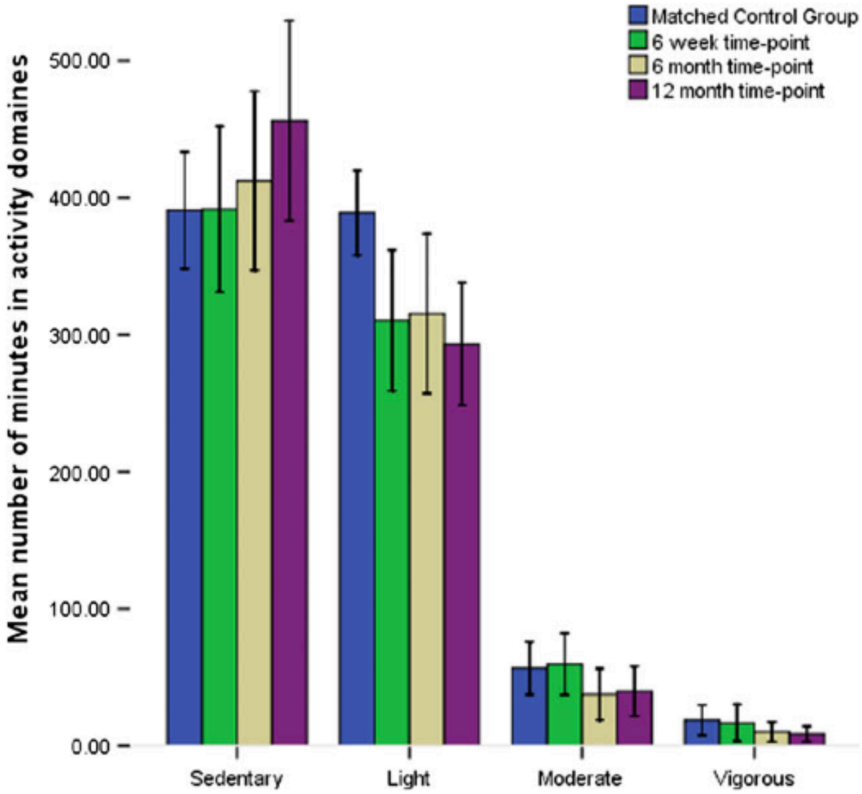

Fig. 1 Objective time (minutes per day) spent in domains of sedentary, light, moderate and vigorous activity in the cancer cohort at 6 weeks, 6 months and 12 months and in matched control group

Table 2 Mean (SD) IPAQ and RT3 results of participants at 6-week, 6-month and 12-month time points and matched control data; p value refers to comparison between all time points and comparison group

	6 weeks	6 months	12 months	Control group	p value
Self-report physical activity (IPAQ)					
Total walking (weekly MET-min)	1,164.9 (1,428.4)	1,492.7 (1,698.2)	1,990.2 (1,844.5)	2,023.4 (3,298.0)	0.997
Total moderate (weekly MET-min)	606.7 (848.7)	916.3 (1038.6)	1,118.7 (892.8)	1,098.6 (938.6)	0.246
Total vigorous (weekly MET-min)	2 (7.8)	61 (112.3)	112.0 (369.3)	27.3 (47.0)	0.334
Total sit weekday (h per day)	5.7 (2.3)	5.7 (3.3)	4.6 (2.7)	4.1 (2.4)	0.092
Total sit weekend (h per day)	6.1 (2.7)	5.6 (3.5)	4.9 (3.2)	4.0 (1.8)	0.066
Objective physical activity (RT3)					
Sedentary time (h per day)	6.8 (1.9)	7.3 (2.3)	7.6 (2.3)	6.5 (1.4)	0.132
Light activity (h per day)	5.1 (1.5)	5.4 (1.9)	5.0 (1.5)	6.5 (1.2)	0.003[a]
Mod/vig activity (h per day)	1.1 (1.1)	0.7 (0.8)	0.7 (0.7)	1.0 (1.0)	0.361

min minutes, *h* hours

[a] Post hoc analysis reveals difference between 6 weeks and control group and 12 months and control group

activity and time spent walking (across leisure, transport, occupational and household), 75 % ($n=18$) met physical activity guidelines of 150 min of activity per week. This was 92 % ($n=22$) at the 6-month time point and 100 % ($n=24$) at the 1-year time point. The corresponding value for the matched comparison group was 95 % ($n=19$).

Changes in QOL subsets are shown in Table 3. A negative change in the functioning scale indicates a dis-improvement, while a negative value in the symptom scales indicates an improvement. When compared over time, the only variables which changed were physical functioning which declined over the first 6 months of the study ($p=0.008$) and cognitive function which improved by the 6-month time point ($p=0.034$). Thirty-eight percent reported severe fatigue at the 6-week time point; this was compared to 48 % at the 6-month time point and 38.1 % at the 12-month time point.

Table 3 Combined mean (SD) EORTC-QLQ C30 scores at 6 weeks after cessation of chemotherapy, 6 months after cessation of chemotherapy and 12 months after completion of chemotherapy; mean scores subtracted from time points indicated

	6 weeks mean (SD)	6 months mean (SD)	1 year mean (SD)	Adjusted difference in mean change with 95 % confidence intervals		
				Δ 6 weeks–6 months mean (95 % CI)	Δ 6 weeks–1 year mean (95 % CI)	Δ 6 months–1 year mean (95 % CI)
Functioning scales						
Physical	85.8 (14.8)	76.4 (21.0)	79.5 (21.6)	−9.3 (−19.7→0.9)*	−6.3 (−16.8→4.2)	3.1 (−6.1→6.3)
Role	72.2 (28.1)	71.5 (28.0)	79.9 (28.2)	−0.7 (−16.6→15.2)	7.7 (−8.3→23.6)	8.4 (−7.6→24.2)
Cognitive	70.5 (28.0)	80.6 (26.3)	75.0 (31.1)	10.1 (−5.3→25.5)*	4.5 (−12.2→21.3)	−5.6 (−21.9→10.7)
Emotional	76.7 (24.9)	71.4 (26.9)	72.2 (30.7)	−5.3 (−20.1→9.3)	−4.5 (−20.3→11.3)	0.8 (−4.8→6.5)
Social	74.3 (25.1)	74.3 (28.2)	81.3 (25.7)	0 (−15.1→15.1)	7 (−7.4→21.3)	7 (−8.3→22.2)
Global QOL	69.1 (17.1)	69.8 (19.8)	70.5(23.7)	0.7 (−9.8→11.2)	1.4 (−10.3→13.1)	0.7 (−11.7→13.1)
Symptom scales						
Fatigue	33.8 (20.6)	30.6 (21.3)	25.9 (21.4)	−3.2 (−15.1→8.6)	−7.9 (−19.8→4.0)*	−4.7 (−16.7→7.5)
Nausea and vomiting	8.3 (16.3)	1.4 (4.7)	4.9 (10.4)	−6.9 (−0.2→-13.7)	−3.4 (−11.2→4.3)	3.5 (−1.1→8.1)
Pain	22.2 (24.4)	27.8 (28.1)	21.5 (28.9)	5.6 (−9.3→20.5)	−0.7 (−15.8→14.4)	−6.3 (−22.4→9.9)
Dyspnoea	16.7 (27.8)	18.1 (24.0)	22.2 (28.9)	1.4 (−13.3→16.1)	5.5 (−10.5→21.6)	4.1 (−11.4→19.2)
Sleep disturbance	37.5 (33.1)	34.7 (30.3)	23.6(26.9)	−2.8 (−20.7→15.2)	−13.9 (−31.0→3.2)*	−11.1 (−13.4→19.0)
Appetite loss	9.7 (18.3)	5.6 (21.2)	4.2 (11.3)	−4.1 (−15.4→7.1)	−5.5 (−14.2→3.1)	−1.4 (−11.0→8.2)
Constipation	7.0 (13.8)	12.5 (23.7)	8.3 (14.8)	5.5 (−5.4→16.5)	1.3 (−6.7→9.5)	−4.2 (−15.3→7.0)
Diarrhoea	11.1 (21.2)	5.6(12.7)	20.8(32.3)	−5.5 (−10.6→-0.5)	9.7 (−5.6→25.3)	15.2 (−8.3→19.5)
Financial impact	23.6 (30.3)	30.6 (39.2)	20.8 (32.3)	7.0 (−12.3→26.8)	−2.8 (−20.5→15.0)	−9.8 (−20.1→0.7)

*$p<0.05$

Discussion

The main findings of this study were high levels of objectively measured sedentary behaviour and the trajectory of increased weight gain throughout this early survivorship phase, as well as the overestimation of physical activity using self-report methods.

Our objectively measured physical activity data showed that approximately 50 % of waking hours were spent sedentary equivalent to around 7 h a day. Serial data and comparison with the matched non-cancer group demonstrated that levels of sedentary behaviour did not increase over the year after chemotherapy finished and were similar to the comparison group. Taken together, these findings imply that this level of inactivity likely reflects societal norms.

Previous studies which compared cancer survivors to non-cancer comparisons using self-report physical activity measures also found little difference in levels of sedentary behaviour between these two groups [34–37]. No available comparisons exist for objectively measured physical activity levels of breast cancer patients in the first year after completion of chemotherapy. A US-based cohort ($n=111$) of long-term breast cancer survivors [22], approximately 10 years after diagnosis, was reported to spend a mean of 9.3 ± 1.7 h sedentary per day (66 % of time spent sedentary) while the corresponding value for the non-cancer cohort was 8.2 ± 1.7 h [22], with sedentary time positively associated with adiposity ($p<0.05$). The higher levels of sedentary behaviour in the study by Lynch et al. compared to ours may be partly explained by age; the mean age of the cohort of 69.2 years was considerably older than the present study.

Physical activity levels in our cancer cohort remained the same during the time course of the study. Other studies have found a decline in physical activity after a cancer diagnosis [11, 38], while an increase in physical activity levels has also been reported [16]. We had expected that low activity levels would have increased at the 6-week time point after chemotherapy and would continue to increase as the year progressed. Of interest, the physical functioning element of the quality-of-life measure was highest at the 6-week time point and decreased significantly by 6 months. It is of course possible that we tested patients too early. Perhaps physical functioning and fatigue improve later than 1 year after chemotherapy (i.e., that the 'teachable moment' may be later than 1 year).

At both ends of the movement continuum, time in objectively measured moderate/vigorous physical activity and time spent sedentary, there were no differences between the comparison group and cancer cohort, and total objectively measured physical activity was no different between the groups. Teasing out individual physical activity domains, however, revealed that more time was spent in light activity in the comparison group compared to the cancer cohort, roughly equivalent to one extra hour per day. Light activity consists of many activities of daily living such as standing, slow walking and general moving around which may have important metabolic consequences, as 1 h per day of light activity (2.5 MET hours per day) could lead to a 0.75-kg weight gain per month for a 70-kg individual. This extra time in light activity did not displace sedentary time and was probably related to increased waking hours, as accelerometer wear time was approximately 1 h greater in the comparison group, likely reflecting increased levels of fatigue in the cancer cohort. It is not known whether light activity increases beyond the 1 year time point as fatigue may be expected to improve beyond this time frame. Whether this may be the case or not, decreasing sedentary time may be a more realistic and potentially useful initial target than the traditional focus on increasing moderate or vigorous activity in this cohort.

A striking finding of our study was the considerable difference between self-reported and objectively measured physical activity. This divergence confirms the tendency already documented in previous studies of cancer patients [19, 20, 39, 40] of overestimating physical activity. We found that using the self-report measure, more than 70 % of subjects met physical activity guidelines, but the corresponding value for objectively measured physical activity was approximately 5 %. This presents an interesting conundrum, as physical activity guidelines were developed based on studies that used self-report data. Therefore, if those studies also overestimated physical activity, it calls into question whether the same amount of objectively measured physical activity is necessary for health benefits; however, this remains unknown. In any case, the discrepancy between self-report and objective measures mandates caution in interpreting studies of physical activity in cancer and highlights the need to incorporate more robust tools such as accelerometers in future research.

BMI increased significantly in the cancer cohort and levels of overweight and obesity were markedly higher in the cancer cohort compared to the matched comparison group, with very few displaying a healthy BMI by the 1-year time point. A significant weight gain in a breast cancer cohort has previously been defined as a weight gain of >2.5 kg [41]. The mean change observed in this study was 2.6 kg from diagnosis to 1 year after cessation of chemotherapy. This increase in weight represents a worrying trend as increased weight gain after breast cancer is associated with an increased risk for recurrence and death [42].

Fatigue is clearly still a problem as by the 1-year time point after finishing chemotherapy; one third still complained of 'severe fatigue'. The washout period of chemotherapy regimens and latent treatment effects [43] are not fully known, and the metabolic consequences of treatment may result in increased fatigue. Cancer and its related treatments can induce debilitating and persistent fatigue [44]. In an effort to avoid fatigue, patients may downregulate energy expended in physical activity which may in turn induce further muscular and cardiorespiratory deconditioning [45], thereby resulting in a vicious self-perpetuating cycle of decreased physical activity and fatigue [46, 47]. It is possible that this mechanism was at work in some of our cancer cohort. Our cohort included five patients on maintenance bevacizumab as part of a clinical trial, which finished approximately 6/52 before the 1-year time point. We considered whether the inclusion of these patients could have adversely influenced our results, as bevacizumab, though usually well-tolerated, has been described as causing fatigue. We found that one participant who received bevacizumab reported high levels of fatigue at the 6-month and 1-year time point. However, four out of five of that group had fatigue scores below the mean for the group; therefore, we believe that bevacizumab did not systematically influence fatigue scores of the group as a whole.

Even though overall QOL levels did not change, we noted that the 'cognitive function' domain improved by the 6-month time point after cessation of chemotherapy. It is possible that this may be related to the often derided phenomenon of 'chemo-brain' or 'foggy thinking' following chemotherapy treatment.

Mirroring results from a recent study [48], this study did not find evidence of the 'teachable moment' as no behavioural change was observed in this cohort. Naturally, this leads to questions of how best to overcome this pattern of sedentary behaviour and low physical activity levels. It is likely to require a multifaceted approach beyond the health care professions, including population-based approaches alongside individual strategies, and not only increasing moderate and vigorous physical activity to mobilise weight loss and promote cardiovascular benefits but also to decrease sedentary time for discrete long-term health benefits. Bearing in mind the differences in physical activity profile between the cancer cohort and comparison group, an important first step may be to encourage the breaking up of sedentary time and to displace it by light activity by 'moving about more'. Perhaps, levels of light activity revert to comparison group levels later than the 1-year mark as fatigue improves. The challenge though is not for physical activity/levels of sedentary behaviour to revert to comparison group levels as these are low but to increase beyond societal norms. Teasing out the most optimal approach is imperative given the ever increasing group of breast cancer survivors at risk of the health consequences of sedentary behaviour and lack of physical activity. A larger long-term prospective study is necessary to further evaluate these relationships.

Our study has strengths and limitations. Its strengths include the use of objectively measured physical activity, a matched non-cancer comparison group and the longitudinal, prospective design of this study during the early survivorship period and excellent cohort maintenance (88 %). We had comprehensive data on all variables related to diagnosis and treatment verified from patients' medical records; in some studies, cancer stage and grade is self-reported which can be problematic. Participants self-selected into this study, and despite its small sample size, it included participants of differing educational attainment and a wide age range so may be generalised to adjuvantly treated breast cancer populations.

The main limitation of this study was the small sample size. A larger cohort might have elucidated further in one direction or another the apparent trend in our study towards decreased physical activity over time and allowed us to tease out differences between subgroups (e.g., according to treatment or educational attainment). Another potential issue is the difference in BMI between post-chemotherapy and comparison subjects, but the comparison subjects' lower BMI was not reflected in higher physical activity levels, so matching for BMI is unlikely to have altered our results.

Conclusion

This study provides the first data about the physical activity trajectory of breast cancer survivors during the early survivorship phase and may help to inform the design of rehabilitation models. Against a background of lower levels of light activity in the cancer cohort compared to the comparison group, an important first step may be to encourage the breakup of sedentary behaviour by 'moving about more'. Bearing in mind the pattern of increasing BMI, interventions also need to increase physical activity levels to mobilise weight loss, and a combined physical activity and dietary intervention may be most optimal in this regard. It would seem that finding the 'teachable moment' and motivating cancer patients to adopt sustained lifestyle changes are formidable challenges.

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