Health Information and Quality Authority
An tÚdarás Um Fhaisnéis agus Cáilíocht Sláinte

hpsc
Health Protection Surveillance Centre
Lárionad Faire um Chosaint Sláinte

# Analysis of factors associated with outbreaks of SARS-CoV-2 in nursing homes in Ireland: Waves 1 to 3

12 May 2022

# About the Health Information and Quality Authority

The Health Information and Quality Authority (HIQA) is an independent statutory authority established to promote safety and quality in the provision of health and social care services for the benefit of the health and welfare of the public.

HIQA's mandate to date extends across a wide range of public, private and voluntary sector services. Reporting to the Minister for Health and engaging the Minister for Children, Equality, Disability, Integration and Youth, HIQA has responsibility for the following:

- **Setting standards for health and social care services** — Developing person-centred standards and guidance, based on evidence and international best practice, for health and social care services in Ireland.
- **Regulating social care services** — The Chief Inspector within HIQA is responsible for registering and inspecting residential services for older people and people with a disability, and children's special care units.
- **Regulating health services —** Regulating medical exposure to ionising radiation.
- **Monitoring services** — Monitoring the safety and quality of health services and children's social services, and investigating as necessary serious concerns about the health and welfare of people who use these services.
- **Health technology assessment** — Evaluating the clinical and cost-effectiveness of health programmes, policies, medicines, medical equipment, diagnostic and surgical techniques, health promotion and protection activities, and providing advice to enable the best use of resources and the best outcomes for people who use our health service.
- **Health information** — Advising on the efficient and secure collection and sharing of health information, setting standards, evaluating information resources and publishing information on the delivery and performance of Ireland's health and social care services.
- **National Care Experience Programme** — Carrying out national service-user experience surveys across a range of health services, in conjunction with the Department of Health and the HSE.

# Version history

| Version number | Date | Details |
|---|---|---|
| **Version 1.0** | 26 May 2021 | Original analysis including data from first and second wave |
| **Version 2.0** | 11 March 2022 | Updated analysis to include third wave |

# About the Health Protection Surveillance Centre

The Health Protection Surveillance Centre (HPSC) is Ireland's specialist agency for the surveillance of communicable diseases.

HPSC is part of the Health Service Executive and works in partnership with health service providers and sister organisations in Ireland and around the world, to provide the best possible information for the control and prevention of infectious diseases. HPSC strives to protect and improve the health of the Irish population by providing timely information and independent advice, and by carrying out disease surveillance, epidemiological investigation and related research and training.

## *Functions of HPSC*

HPSC has six main areas of responsibility:

1. **Surveillance** of some of the major communicable diseases. By surveillance, we mean:
    - collecting data
    - collating it
    - analysing it and
    - communicating information to those who need to know
2. **Operational support** - providing expert advice to, and responding to requests for support from, departments of public health or hospitals;
3. **Training** for professionals working in communicable disease control;
4. **Research** - identifying and developing best practice in communicable diseases;
5. **Policy advice** - providing advice to government departments and appropriate agencies in relation to the development of standards, guidelines and practices, and promoting the adoption of best practice by different agencies;
6. **Public information** - providing information on infectious diseases to the public and the media.

## Table of Contents

## Acknowledgements

HIQA and the HPSC would like to thank all of the individuals and organisations who provided their time, advice and information in support of this work.

Particular thanks are due to the HIQA COVID-19 Expert Advisory Group (EAG) who provided advice and information (membership outlined on www.hiqa.ie)

## List of abbreviations used in this report

| | |
|---|---|
| **CI** | Confidence interval |
| **COVID-19** | Coronavirus disease 2019 |
| **ED** | electoral division |
| **HIQA** | Health Information and Quality Authority |
| **HSE** | Health Service Executive |
| **HPSC** | Health Protection Surveillance Centre |
| **IR** | incidence ratio |
| **LTCF** | long-term care facility |
| **NPHET** | National Public Health Emergency Team |
| **OR** | odds ratio |
| **SARS-CoV-2** | Severe Acute Respiratory Syndrome Coronavirus 2 |
| **SD** | standard deviation |
| **WHO** | World Health Organization |

# Analysis of factors associated with outbreaks of SARS-CoV-2 in nursing homes in Ireland

## Key points

- Residents of long-term care facilities, such as nursing homes, have been disproportionately affected by COVID-19. They have been impacted through incidence, morbidity, mortality, and public health measures such as visit restrictions.
- Given the vulnerability of nursing home residents to the effects of COVID-19, a particular emphasis has been placed on safeguarding this population in Ireland, including the establishment of the COVID-19 Nursing Homes Expert Panel. This panel recommended that HIQA and the HPSC undertake a detailed epidemiological analysis of factors associated with the occurrence of outbreaks of SARS-CoV-2 in these settings.
- HIQA and the HPSC completed an analysis in February 2021, including data up to 21 November 2020 (the first and second waves of the epidemic in Ireland). This report presents the results of an updated analysis, including the third wave of the epidemic (defined as 22 November 2020 to 11 May 2021). As per the original analysis, the primary outcome of interest was the occurrence of an outbreak (yes or no), while the secondary outcome was the extent of an outbreak, that is, the number of residents infected. The impact of morbidity and mortality was outside the scope of the analysis.
- This analysis drew on a number of data sources contributing information on community-level and facility-level variables. These included descriptive information on 595 nursing homes in Ireland that were registered with HIQA for at least part of the study period and details of community incidence and outbreak events in nursing homes (sourced from the HPSC). Data were up to 11 May 2021, covering the first, second, and the majority of the third wave of the epidemic in Ireland (note that the stop point reflects the cyber-attack on the HSE information systems on 12 May 2021).
- The results of this updated analysis largely reflect the findings of the original report in that:
    - The probability of the occurrence of an outbreak of SARS-CoV-2 in a nursing home on any given day was significantly associated with

community incidence of COVID-19, the size of a nursing home, and being in close proximity to other nursing homes.

- The extent of an outbreak increased with the number of beds in a home. Where more than one outbreak occurred in a home, the extent tended to decrease with subsequent outbreaks.
- The type of nursing home (that is, publicly or privately operated) was not significantly associated with either the probability of an outbreak occurring or the extent of an outbreak.
- The overall analysis remained limited by a lack of reliable and consistent data across nursing homes for a number of potentially influential facility-level and resident-level factors.
- The results of the analysis should overall be considered to be exploratory in nature due to the lack of availability of relevant data for establishing causal relationships and due to the model being designed to assess factors that may have been associated with the outbreaks as opposed to examining individual causal relationships.

- A number of differences are noted within the updated analysis, they are:
  - There were more outbreaks in the third wave than in the first two waves combined. However, there were fewer nursing homes that had more than one outbreak.
  - Vaccination was significant with the rollout of the second dose in particular associated with a reducing probability of an outbreak occurring within a nursing home and a decreasing extent of outbreak when they did occur.
  - The probability of an outbreak was noted to reduce with having had experienced previous outbreaks and with an increasing population density in the locality.
  - The changing geography of the pandemic was more pronounced: relative to nursing homes in Dublin city, those in rural areas and cities other than Dublin were associated with a lower probability of an outbreak. Nursing homes in cities other than Dublin were associated with an increased probability of experiencing an outbreak in waves two and three relative to wave one.

  - A reducing extent of outbreak was associated with an increasing local incidence and a reducing deprivation level of the locality.
  - Some of the associations that emerged within this analysis, such as deprivation and population density, may reflect adjustment within the models for heterogeneity within area types.

- There was substantial uncertainty in the magnitude of the observed associations. Potentially important resident-level and facility-level factors are not routinely collected and may be important in explaining the observed incidence of outbreaks among residents. While these data may be challenging to collect, such information would greatly facilitate future analyses of this nature and may have ongoing value when considering other viral outbreaks.
- Overall, while the third wave provided substantially more information for analysis, each wave of the epidemic in Ireland has been associated with distinct nuances which influence the overall findings of this analysis, including changing levels of community incidence, the emergence of variants, the geographical and demographic distribution of cases, the stringency and public compliance and adherence to public health measures and the vaccination rollout. Therefore, the overall applicability of these findings to current and future time periods is limited.

# 1. Background

Individuals in long-term care facilities (LTCFs) or congregated care facilities, such as nursing homes, have been disproportionately affected in terms of COVID-19 incidence, morbidity and mortality.[1-3] In Ireland, residents of such facilities have represented a substantial number of COVID-19 cases and associated deaths.

Given the vulnerability of nursing home residents to COVID-19, in May 2020 the National Public Health Emergency Team (NPHET) recommended the establishment of the COVID-19 Nursing Homes Expert Panel to examine the complex issues surrounding the management of COVID-19 in this cohort.[4] The panel completed an extensive programme of work including data collection, an epidemiological analysis, stakeholder engagement, and a systematic review of research evidence. The outcomes of this work were outlined to the Minister for Health and published on 19 August 2020, with associated recommendations from the panel.[4] Recommendation 6.7 within this report states that:

> HPSC, HSE and HIQA should produce a detailed epidemiological analysis comparing both risk and protection factors associated with having an outbreak or not at all in HIQA regulated facilities.[4]

Accordingly, HIQA and the HPSC completed an analysis in February 2021, including data up to 21 November 2020 (that is, the first and second waves of the epidemic in Ireland), with the following key findings outlined:

- The probability of an outbreak occurring in a nursing home increased with rising community incidence around the home, the number of beds within the home and other nursing homes being in close proximity.
- In terms of the extent of an outbreak, smaller outbreaks were observed to be associated with having previously experienced an outbreak of SARS-CoV-2. The proportion of residents in a nursing home affected by an outbreak decreased with an increasing number of beds.
- No association was observed between the probability of an outbreak occurring, or the extent of an outbreak once it occurs, and whether a home was publicly or privately operated.
- There was a notable difference between the first and second waves, with both a reduced likelihood of an outbreak occurring, and smaller outbreaks, within the second wave (2 August to 21 November) compared with the first (1 March to 1 August). Overall, the patterns of association observed in the first wave were less pronounced in the second wave.

- The analysis was limited by a lack of reliable and consistent data across nursing homes for a number of potentially influential facility-level and resident-level factors. Causal risk factors could not be established due to the lack of availability of relevant data for establishing causal relationships, and therefore the results of the analysis should be considered to be exploratory in nature.

Following a further request form the COVID-19 Nursing Homes Expert Panel to include subsequent data for the third wave of the epidemic in Ireland, the aim of this report is to update the analysis from February 2021 to capture data from 22 November 2020 to 11 May 2021 (to note, the stop point reflects the cyber-attack on the HSE information systems on 12 May 2021).

# 2. Methods

This report represents a collaborative analysis between HIQA and the HPSC. A protocol outlining the associated processes was adhered to throughout the conduct of this analysis and is available on www.hiqa.ie.

## Setting

For the purposes of this report, a nursing home is defined as any designated centre for older people in Ireland registered with HIQA. There were 595 nursing homes registered with HIQA across the Republic of Ireland for at least part of the period included in the analysis.

## Outcomes of interest

Two outcomes of interest were considered within this analysis:

- For a nursing home that is not currently experiencing an outbreak: occurrence of an outbreak or no occurrence of an outbreak on any given day (binary measure)
    - Defined as per the HPSC definition of two or more cases of laboratory confirmed COVID-19 regardless of symptomatic presentation, or two or more cases of illness with symptoms consistent with COVID-19 infection with at least one person confirmed as a case of COVID-19.[(2)] Of note, this is an updated definition since August 2020, prior to which suspected outbreaks of COVID-19 were also notifiable.
    - For the main analysis, the focus was on confirmed outbreaks involving two or more confirmed cases among residents within nursing homes. A secondary analysis addressed all confirmed and suspected outbreaks, including those limited to staff members.
- Extent of an outbreak, inferred from the number of residents infected within a given outbreak as a proportion of all residents.

## Data sources and input variables

While this analysis aimed to identify and quantify risk factors associated with outbreaks, the extent to which this was possible was determined by the available data. Based on an exploration of international studies examining outbreaks of COVID-19 in nursing homes, a number of potential risk factors for outbreaks at the resident, facility, and community level were identified. Data from within the Irish setting, which either directly or indirectly quantified those risk factors were sourced.

The approach was that of an exploratory data analysis to identify potentially relevant and plausible factors using the available data. While this approach does not allow a causal relationship or the magnitude of the effect to be definitively estimated, it does support the broad identification of factors and characteristics associated with outbreaks of SARS-CoV-2 in nursing homes.

Data were obtained and assessed to determine completeness and suitability for inclusion within this analysis from a number of sources as outlined below:

- HIQA: Data relating to the type (that is, publicly or privately operated), bed capacity and location of the 595 registered nursing homes in Ireland included in the analysis.
- HPSC:
    - Data relating to outbreaks within nursing homes in Ireland, including the:
        - date the outbreak was identified
        - first and last date of notification of associated cases
        - number of outbreak cases among residents and healthcare workers
        - whether the outbreak was confirmed or suspected
        - duration of the outbreak.
    - An outbreak was considered to have started on the earliest reported date (i.e., symptom onset of first case, notification or outbreak identification) and finished 28 days after the last reported date (of symptom onset of last case, notification or outbreak identification).
    - Daily incidence of COVID-19 in Ireland, including locality by electoral division. Due to the potential impact of delayed processing when demand for testing exceeded available capacity, where possible, date of onset was used to limit the impact of delayed notification.
- HSE[1]:
    - Dates on which vaccination was provided to residents at each nursing home. The data distinguished between first and second dose.
- Central Statistics Office: Small area population data.
- Additional data sources: Ordnance Survey Ireland mapping data, OpenStreetMap routing data to calculate drive times,[5] Trinity deprivation index,[6] small area urban-rural classification.[7]

[1] Data source: Health Service Executive-Integrated Information Services COVAX datalake

Reliable data in a format that facilitated analysis was unavailable for a number of potentially important explanatory variables which have been described within the international literature to date.[8] These included occupancy levels, resident demographics, staffing levels, skill mix, staff to resident ratios, resident transfer rates to and from acute hospitals, and movement between nursing homes.

There were insufficient data available to enable the inclusion of a covariate regarding compliance with infection prevention and control regulations. Through its regulation function, HIQA collects data on nursing home compliance with these regulations. However, these data pertain to compliance at the time of inspection and may not generally represent compliance. Therefore, these data would not provide the coverage required for this analysis. Information relating to the physical structure of facilities was available in the form of individual floor plans for each registered nursing home. However, extraction of details such as counts of accommodation type (single, twin, multi-occupancy) would require detailed evaluation and collation for use in this form of analysis, which, given the number of nursing homes included, was not deemed feasible. Furthermore, a knowledge of the layout of a nursing home would be of limited value in the absence of associated occupancy data.

Variables relating to the implementation of restrictive measures were not included in the analysis as they typically represent a response to incidence overall and not just in nursing homes. Additionally, the level of restrictive measures within a nursing home, for example, limits on visitation, was not necessarily uniform across homes. Based on individual risk assessments, some homes continued restrictions when no longer mandated.

## Data preparation

Due to the changing nature of the epidemic in terms of the demography of notified cases and the public health response, three distinct waves of COVID-19 were included within the analysis: 1 March 2020 to 1 August 2020, 2 August 2020 to 21 November 2020, and 22 November 2020 to 11 May 2021. The third wave is defined as having ended on 26 June 2021. However, due to the 12 May 2021 cyber-attack on the HSE information systems, there are limitations to the data available from that point to the end of the third wave.

Local community incidence in the vicinity of each nursing home was included in the analysis. Catchments around each home were estimated using aggregates of electoral divisions based on those nearest the home by travel time. Catchments were defined electoral divisions within 20 minutes' drive time and within 20 kilometres; however, each catchment included a minimum of five and maximum of 10 electoral divisions. This aimed to characterise incidence in the area surrounding a home. With larger catchments, heterogeneity in incidence would be reduced. The incidence

estimates excluded cases in nursing home outbreaks and, in the main analysis, also excluded healthcare workers linked to nursing home outbreaks. Incidence was calculated for each day from 1 March 2020 to 11 May 2021, expressed as cases per 100,000 population.

A variable of neighbouring homes was also used in the analysis. This was calculated as the number of neighbouring nursing homes both within 15 minutes' drive time and within five kilometres of the nursing home in question. A high density of homes in an area may point towards a higher level of movement of people between homes, such as visitors, or use of the same companies for services such as cleaning.

Explanatory variables included in the analysis:

- Number of beds – the number of registered beds in the home. It should be noted that occupancy levels can vary substantially and no daily occupancy data were available. A higher number of beds indicates a home with more residents and, as a consequence, more staff.
- Local incidence – the 14-day incidence of notified COVID-19 cases per 100,000 in the catchment area of the nursing home.
- Nursing home type – publicly (HSE) or privately operated. In the analysis of the first two waves, private homes were subdivided based on whether they were the only home owned by the operator or one of several owned by the same operator. In light of challenges in validating the accuracy of that coding, this sub-categorisation was refined to 'public' or 'private' for the current analysis.
- Area type – five categories (city [Dublin], city [other], town, village, and rural) that describe the urban-rural status of the nursing home location.
- Prior outbreak – whether or not the home had previously experienced a SARS-CoV-2 outbreak among residents.
- Vaccination– whether or not vaccination had been provided to residents of a home. Vaccination was typically carried out so that the majority of residents were vaccinated in a single visit. Vaccination was coded as a home-specific factor variable with three levels: no vaccination; first dose rolled out; and second dose rolled out. The vaccination dates were not available for five homes, and in these cases the dates were estimated from the average of the roll-out dates for their neighbouring homes.
- Neighbours – the number of nursing homes within 5km and within 15 minutes of the home.
- Deprivation – the deprivation score of the electoral division that the nursing home is located in, included as a measure of socio-economic disadvantage in

the area where a home is situated. It should be noted that the deprivation level of the area in which a home is located may not be an accurate reflection of the socio-economic status of residents as the catchment area for a home could be quite large, particularly in a rural area.

The previous version of this analysis included the wave and number of days since the start of the wave as covariates. As all vaccination occurred in the third wave, inclusion of variables for both wave and vaccination could impact on the regression coefficients and associated standard errors, and so only the wave variable was retained for this analysis. Models were run with and without wave as a covariate to determine the impact on coefficients. The number of days since the start of a wave was dropped on the basis that its inclusion as a linear predictor is of limited use. The coefficient for days since the start of the wave is most likely influenced by the timing of the wave's peak and therefore, the observed effect may be an artefact of the break-points between waves.

## Data analysis

The analysis aimed to explore potential risk factors and nursing home characteristics associated with outbreaks of SARS-CoV-2 infection, and the extent of these outbreaks. The methodology replicated the approach used in the analysis of the first and second waves. As before, the main analysis included only outbreaks that involved two or more residents. A secondary analysis was undertaken of all suspected and confirmed outbreaks in nursing homes, including those which were exclusively in healthcare workers.

The probability of an outbreak was again estimated using repeated measures logistic regression. In order to calculate the probability of an (incident) outbreak on any given day, the outbreak status (the dependent variable) for each home was defined for each individual day of the analysis in the form of a binary variable ('outbreak' versus 'no outbreak'). Days on which outbreaks were ongoing were excluded from the analysis to avoid double counting of the probability of an outbreak. Homes were only included for the period over which they were registered with HIQA. As before, a number of interaction terms were included in the model to allow the relationship between the dependent variable and the relevant explanatory variable to vary by subgroup. The goodness-of-fit was assessed using Akaike's Information Criterion (AIC), the Hosmer-Lemeshow test, and the area under the curve (AUC). The McFadden's pseudo-$R^2$ is also reported as a crude measure of the variance explained by the model, accepting that it may be misleading for a logistic regression. Preference was given to retaining all plausible explanatory variables.

The analysis of associations with the extent of an outbreak was performed using a negative binomial model, due to evidence of over-dispersion in the outcome data. As

the model estimates the number of cases in a home, the outputs are presented as incidence ratios.

# 3. Results

In total, there were 592 documented suspected or confirmed outbreaks involving residents and or staff across 389 nursing homes between February 2020 and May 2021. Given the purpose of this report, only the main analysis of confirmed outbreaks involving residents is presented (375 outbreaks across 293 homes). The secondary analysis, including all outbreaks (suspected, confirmed, or exclusively in healthcare workers) is provided in Appendix 1.

## Context of analysis

The context for this analysis is the burden of the COVID-19 epidemic in Ireland to date on nursing home residents and staff. Figure 1 provides the demography of cases diagnosed nationally with COVID-19 across the first three waves of the epidemic. As illustrated, there was a change in the age profile of individuals infected, with a greater proportion of younger individuals diagnosed in the second and third waves. However, when viewed as an average incidence per 100,000, it is apparent that there was a continued substantial burden of disease in the elderly in the second and third waves. While accounting for 2% of the population, those aged 85 years and older represented 9% of cases in the first wave but only 2% in the second and third waves. However, those aged over 85 years accounted for between 12% and 14% of cases hospitalised across the three waves and between 40% and 44% of deaths.

When interpreting the following plots, consideration should be given to the changing public health measures and testing strategies as the epidemic progressed. The first wave lasted 154 days, during which more than 600,000 RT-PCR tests to detect SARS-CoV-2 were carried out in the publicly-funded system. During the second wave, 1.25 million tests were carried out over 112 days, while in the third wave approximately 3.5 million tests were undertaken over 171 days. The average test positivity rate was 4.1% in the first wave, 3.5% in the second wave and 5.3% in the third wave. There was substantial variability in positivity rates within each wave. Capacity for testing increased gradually during the first wave. The limited capacity at the onset of the pandemic meant that, for a period, testing was largely limited to individuals with two or more symptoms of COVID-19. By the start of the second wave, with increased testing capacity and low incidence of COVID-19, there was increased testing of asymptomatic individuals (close contacts) and use of serial testing as a precautionary measure in settings where infection is more likely to occur. In the third wave, demand for testing peaked during December 2020 and January 2021 leading to reduced testing requirements for close contacts and asymptomatic individuals. As such, direct comparison of COVID-19 incidence across the waves may be misleading.

## Figure 1. Population pyramids of notified COVID-19 cases in the first three waves

Wave 1

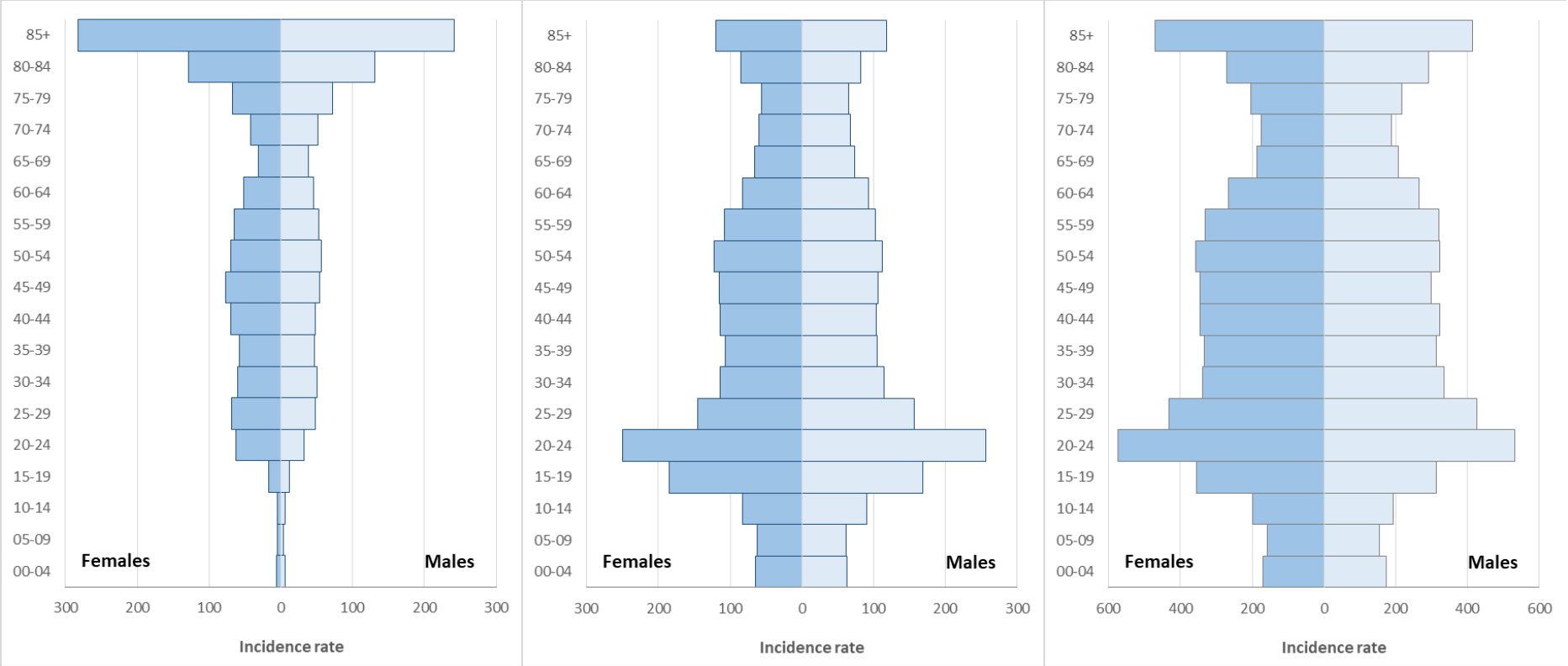
1 March 2020 to 1 August 2020

Wave 2

2 August 2020 to 21 November 2020

Wave 3

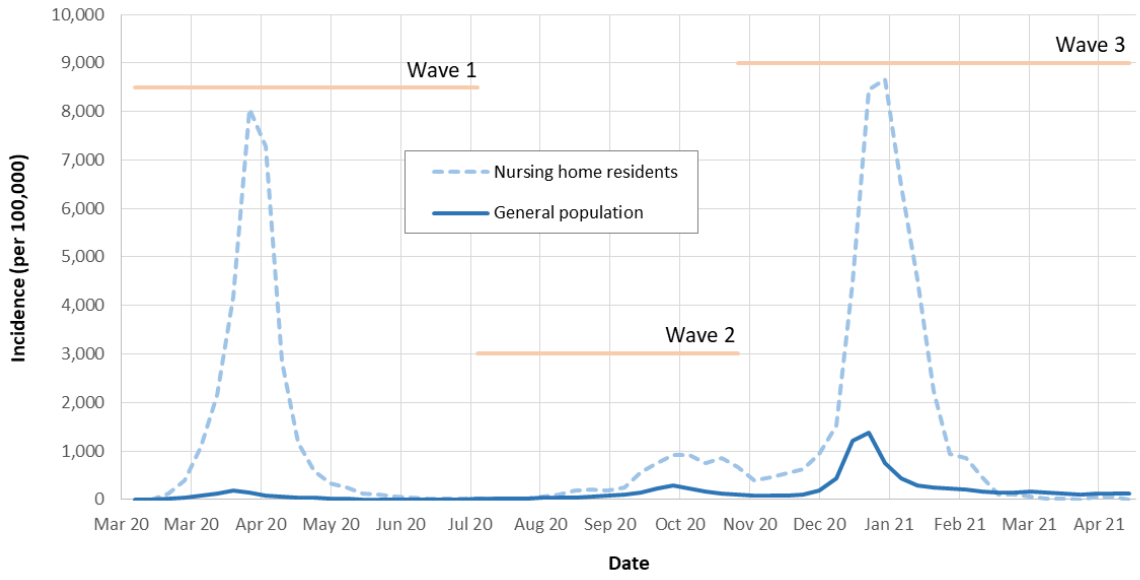
22 November 2020 to 11 May 2021




Note: incidence rate calculated as average 14 day incidence per 100,000 population across each wave.

Furthermore, there were notable differences across the waves in terms of the pattern of incidence over time. As shown in Figure 2, the incidence per 100,000 in nursing home residents was substantially higher than for the general population at the peak of each wave. However, for nursing home residents, the peak incidence in the third wave was similar to that experienced in the first wave, whereas for the general population, incidence was much higher in the third wave. In the first and third waves, peak incidence in nursing homes was one week after peak incidence in the general population, while in the second wave, the peaks coincided.

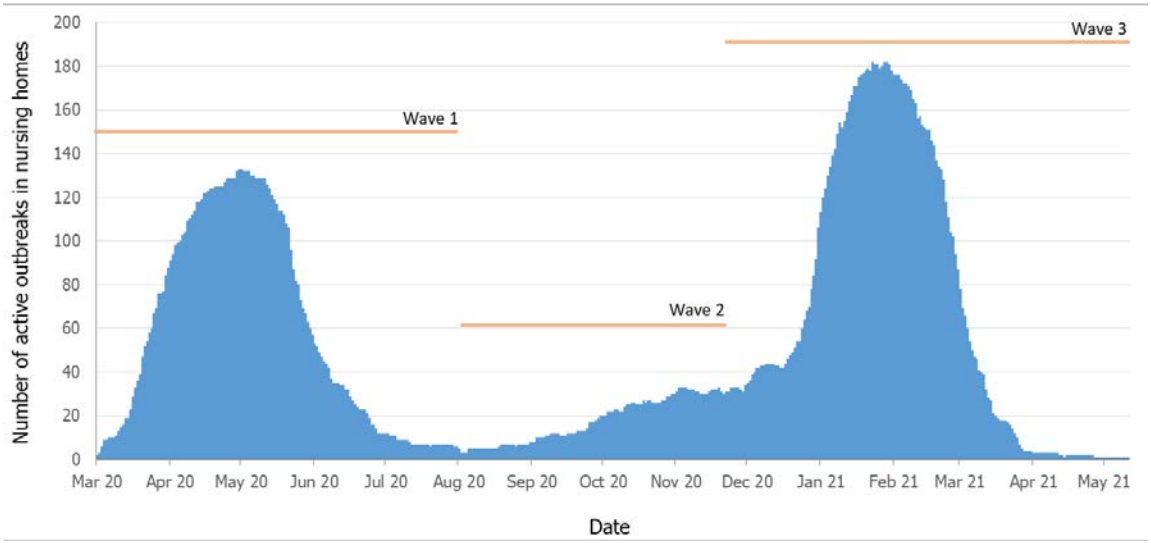
**Figure 2. Incidence of COVID-19 over time**




Note: it was assumed that the population in nursing homes is approximately 30,000 and that the total population is 5,011,500.

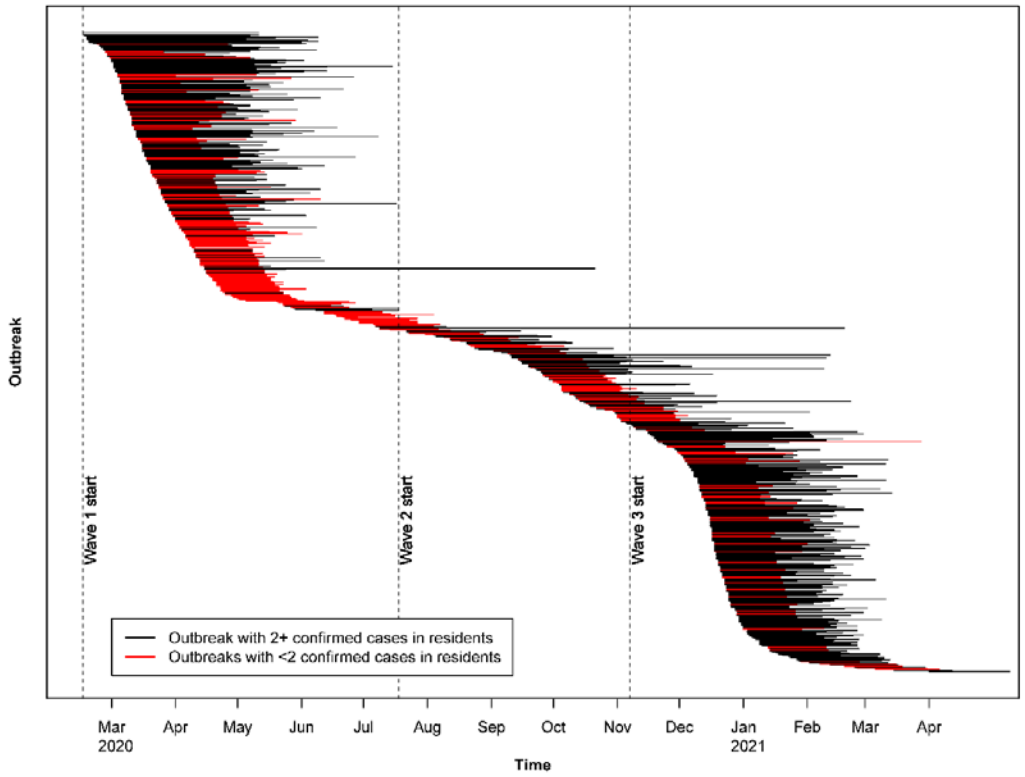
Figure 3 and Figure 4 illustrate time-related factors of outbreaks of SARS-CoV-2 in nursing homes. The number of simultaneous outbreaks across homes was much greater in the first and third waves of the epidemic than in the second (Figure 3). Additionally, there has been a downward trend in the duration of outbreaks that include residents, from an average of 67 days in the first wave to 59 days in the second wave and 53 days in the third wave.

## Figure 3. Number of concurrent outbreaks in nursing homes over time (for all outbreaks involving two or more residents)




Footnote: An outbreak is defined as the period from the first case to 28 days after the last case in the outbreak. The graph shows the number of homes that had an active outbreak on any given day.

## Figure 4. Duration of outbreaks in nursing homes over time

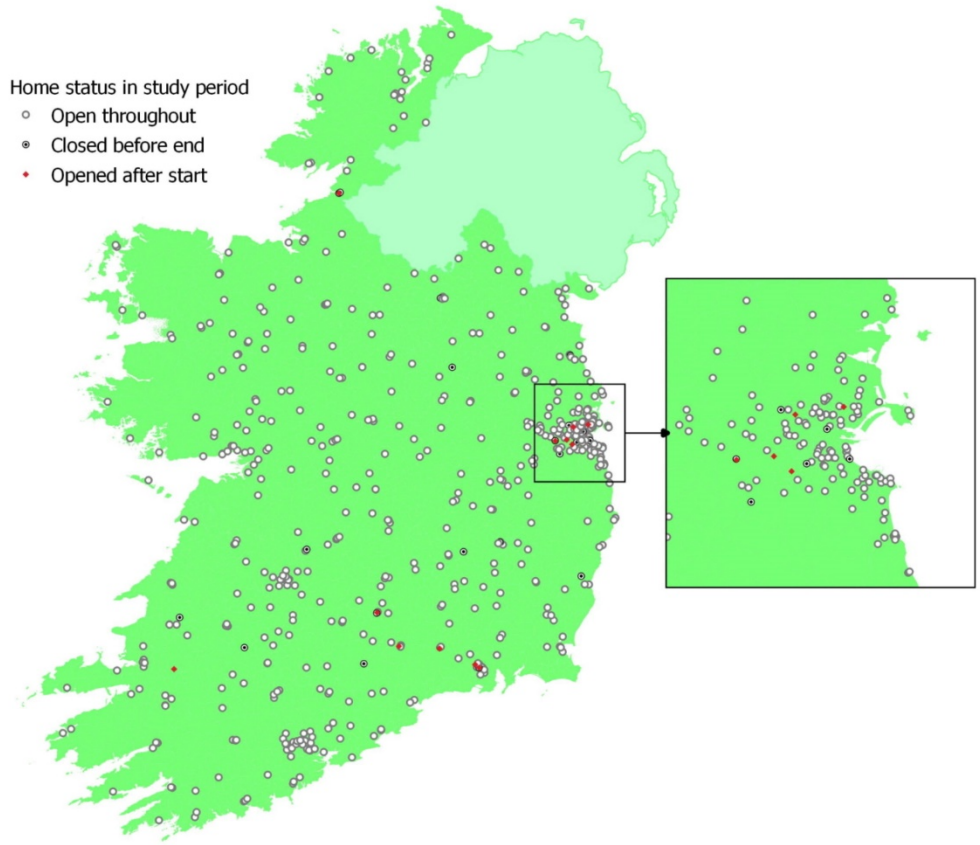



Footnote: The duration of an outbreak is defined as the date of the first case to 28 days after the date of the last case included in the outbreak. Duration is based on cases in both residents and healthcare workers included in the outbreak.

## Descriptive characteristics of included nursing homes

Figure 5 illustrates the geographical locations of nursing homes across Ireland. As expected, there is dispersion across the country with higher density in more populated areas, with Dublin city having a notably high density overall. The descriptive characteristics of the nursing homes included in this analysis are outlined in Table 1. As shown, there were data relating to 595 registered nursing homes over the study period of which 128 (22%) were publicly operated, and 467 (78%) were privately operated. More nursing homes are located in towns (n = 231, 39%) than other area types, and in areas of noted deprivation (n = 223 in the highest deprivation quintile, 37%).

**Figure 5. Locations of all HIQA-registered nursing homes in Ireland**




The number of open homes ranged from 574 to 584 in the first wave, 574 to 577 in the second wave, and 571 to 575 in the third wave. During the study period, 559 homes were open throughout, 24 closed and 12 opened.

In total, 375 confirmed outbreaks involving residents occurred in 293 nursing homes across Ireland between February 2020 and May 2021. The number of homes experiencing at least one outbreak was 136 in the first wave of the epidemic, 46 in the second wave and 184 in the third wave, accounting for at least 23%, 8% and 32% of open nursing homes in each wave, respectively. Seventy-one nursing homes were noted to have two or more outbreaks in the epidemic up to May 2021. A total

of 275 homes that were registered through the entire study period had no outbreaks at any point. A further 27 homes that were only registered for part of the study period had no outbreaks.

The observed probability of an outbreak starting varied over time, with a peak of 0.015 (or one in 67 homes) on day 20 of the first wave, 0.005 (or one in 187 homes) on day 55 of the second wave, and 0.027 (or one in 37 homes) on day 40 of the third wave (Figure 6). The first and third waves are characterised by a curve that largely follows the curve of community incidence of COVID-19. In contrast, the second wave is relatively flat in profile.

Figure 7 illustrates the percentage of nursing homes, by county, affected by an outbreak in waves one, two, and three of the epidemic.

**Figure 6. Probability of an outbreak occurring by days since the start of the wave (for all outbreaks including two or more residents)**

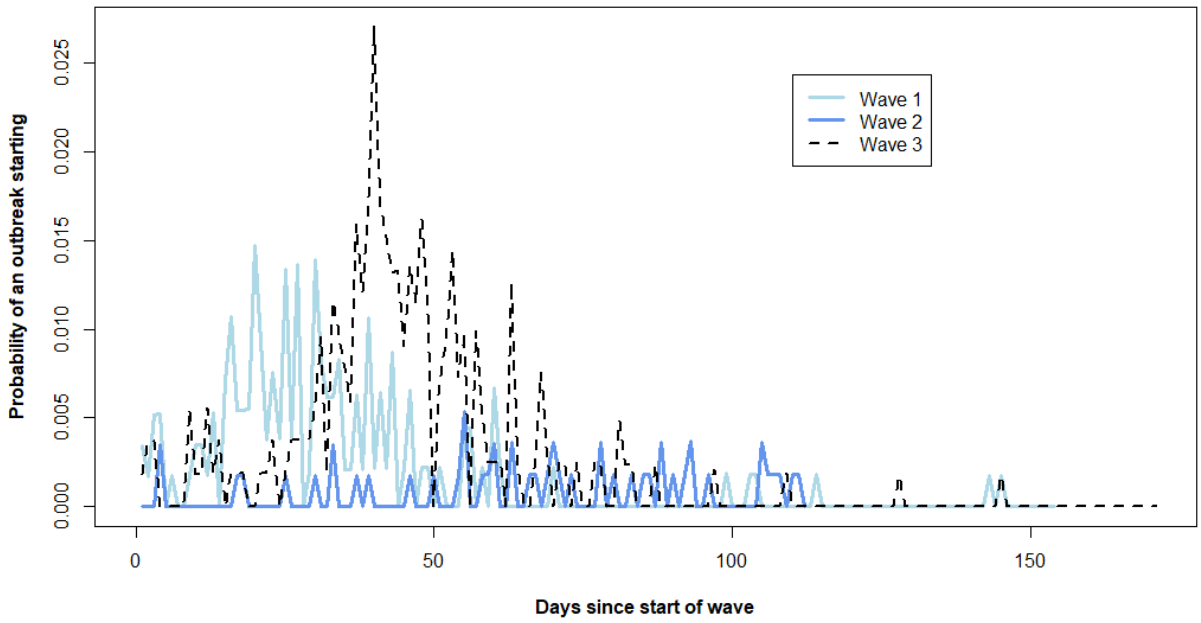
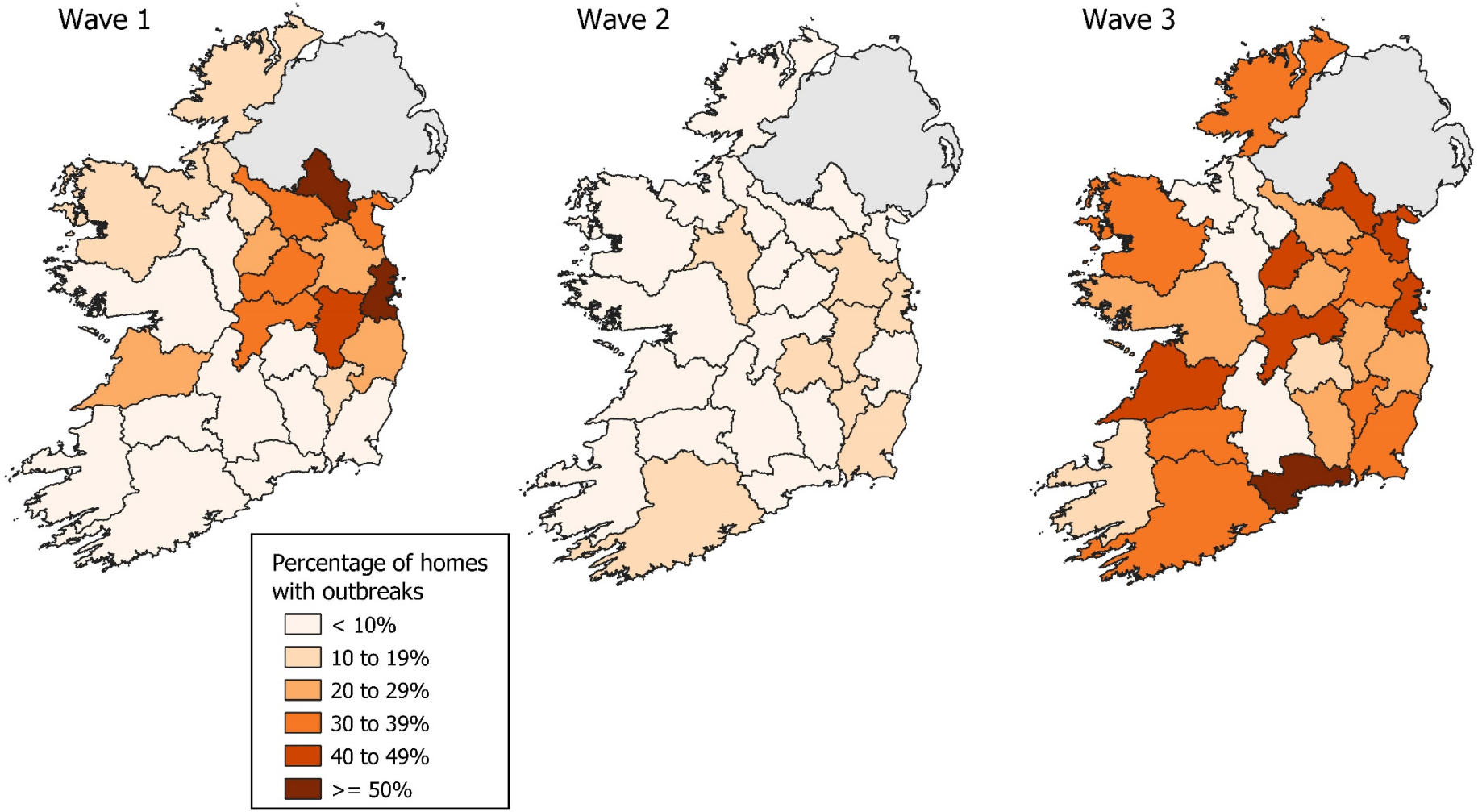


**Figure 7. Percentage nursing homes affected by confirmed outbreaks involving two or more residents, by county**



## Table 1. Descriptive characteristics of HIQA registered nursing homes included in analysis (n =595)

| Characteristic | All nursing homes | Affected by outbreak | | | | | |
|---|---|---|---|---|---|---|---|
| | | Wave 1 | | Wave 2 | | Wave 3 | |
| | | Yes (outbreak) | No (no outbreak) | Yes (outbreak) | No (no outbreak) | Yes (outbreak) | No (no outbreak) |
| Homes (n) | 595 | 136 | 456 | 46 | 532 | 184 | 393 |
| Beds, mean (sd) | 54.8 (30.8) | 74.8 (38.0) | 48.8 (25.3) | 70.9 (38.1) | 54.0 (29.6) | 68.1 (34.8) | 49.4 (26.8) |
| Homes within 5km/15 minutes, mean (sd) | 2.8 (4.3) | 5.1 (5.7) | 2.1 (3.5) | 4.0 (5.0) | 2.6 (4.2) | 3.6 (5.0) | 2.3 (3.8) |
| Home type, n (%) | | | | | | | |
| Public | 128 (22%) | 21 (15%) | 106 (23%) | 11 (24%) | 105 (20%) | 34 (18%) | 82 (21%) |
| Private | 467 (78%) | 115 (85%) | 350 (77%) | 35 (76%) | 427 (80%) | 150 (82%) | 311 (79%) |
| Outbreak count, n (%) | | | | | | | |
| 1 | 222 (76%) | 131 (96%) | | 44 (96%) | | 183 (99%) | |
| 2 | 62 (21%) | 5 (4%) | | 2 (4%) | | 1 (1%) | |
| 3 | 8 (3%) | 0 (0%) | | 0 (0%) | | 0 (0%) | |
| 4 | 0 (0%) | 0 (0%) | | 0 (0%) | | 0 (0%) | |
| 5 | 1 (0%) | 0 (0%) | | 0 (0%) | | 0 (0%) | |
| Proportion residents in outbreak, mean (sd) | 0.32 (0.25) | 0.34 (0.23) | | 0.27 (0.23) | | 0.35 (0.26) | |
| Duration of outbreak (days), mean (sd) | 57.8 (24.1) | 66.0 (28.1) | | 58.9 (30.1) | | 53.4 (15.4) | |
| Local 14-day incidence per 100,000,* mean (sd) | | | | | | | |
| Average | 34.9 (29.5) | 115.5 (51.0) | 93.5 (54.5) | 311.2 (91.7) | 281.3 (109.5) | 311.6 (105.3) | 272.6 (107.5) |
| Max | 194.6 (196.3) | 358.8 (238.3) | 346.8 (259.7) | 1550.5 (630.1) | 1416.7 (738.1) | 1550.9 (669.2) | 1375.8 (752.5) |

**Table 1 continued.**

| Characteristic | All nursing homes | Affected by outbreak | | | | | |
|---|---|---|---|---|---|---|---|
| | | Wave 1 | | Wave 2 | | Wave 3 | |
| | | Yes (outbreak) | No (no outbreak) | Yes (outbreak) | No (no outbreak) | Yes (outbreak) | No (no outbreak) |
| Area type, n (%) | | | | | | | |
| City (Dublin) | 98 (16%) | 50 (37%) | 46 (10%) | 8 (17%) | 86 (16%) | 39 (21%) | 54 (14%) |
| City (other) | 47 (8%) | 6 (4%) | 41 (9%) | 7 (15%) | 39 (7%) | 24 (13%) | 22 (6%) |
| Town | 231 (39%) | 48 (35%) | 182 (40%) | 23 (50%) | 200 (38%) | 68 (37%) | 155 (39%) |
| Village | 85 (14%) | 14 (10%) | 71 (16%) | 4 (9%) | 77 (14%) | 24 (13%) | 57 (15%) |
| Rural | 134 (23%) | 18 (13%) | 116 (25%) | 4 (9%) | 130 (24%) | 29 (16%) | 105 (27%) |
| Deprivation quintile ¥, n (%) | | | | | | | |
| 1 (least deprived) | 108 (18%) | 29 (21%) | 79 (17%) | 10 (22%) | 96 (18%) | 34 (18%) | 72 (18%) |
| 2 | 78 (13%) | 23 (17%) | 54 (12%) | 6 (13%) | 70 (13%) | 24 (13%) | 52 (13%) |
| 3 | 71 (12%) | 15 (11%) | 56 (12%) | 6 (13%) | 62 (12%) | 22 (12%) | 45 (11%) |
| 4 | 115 (19%) | 31 (23%) | 83 (18%) | 8 (17%) | 104 (20%) | 43 (23%) | 70 (18%) |
| 5 (most deprived) | 223 (37%) | 38 (28%) | 184 (40%) | 16 (35%) | 200 (38%) | 61 (33%) | 154 (39%) |

*Incidence based on local catchment area for electoral divisions within 20 minutes/20 km of nursing home (minimum 5 and maximum 10 electoral divisions).

¥ Deprivation reported here as a categorical variable (quintiles). In the regression analyses, deprivation was included in the form of a continuous score.

## Factors associated with the occurrence of an outbreak

For the dependent outcome of occurrence or no occurrence of an outbreak on a given day, a logistic regression analysis was conducted. As highlighted in the methods section, the model sought to infer the relative association between each available explanatory variable and the probability of an outbreak beginning in a home on a given day, restricted to homes that were not already experiencing an outbreak at that time. For this exploratory analysis, a univariable assessment was first performed for each potential explanatory variable of interest. Following this, a single adjusted model was constructed, which included all variables assessed in the univariable analyses and a number of *a priori* interaction terms. Results of the univariable and multivariable analyses are presented individually for each explanatory variable in Table 2 (supplementary model outputs are provided in Appendix 2). The adjusted model demonstrated a reasonable fit to the data overall (Hosmer-Lemeshow: $\chi^2$ = 7.14, df = 8, $p$=0.52; Area Under Curve (AUC) = 0.83; McFaddens pseudo $R^2$ = 0.11).

Several factors were observed to be associated with increased probability of an outbreak following inclusion within the multivariable model. These were:

- local community incidence around the home (log-transformed, aOR = 1.14 per 10 cases per 100,000 population, 95% CI: 1.09 to 1.21, p < 0.001)
- number of nursing homes in close proximity (aOR = 1.08, 95% CI: 1.04 to 1.13, p < 0.001)
- number of beds within the home (aOR = 1.17 per 10 beds, 95% CI: 1.14 to 1.20, p = 0.001). Relative to the first wave, the impact of bed numbers was less pronounced in the third wave.
-

The following factors were associated with a reduced probability of an outbreak:

- vaccination provided to nursing home residents (first dose aOR = 0.31, 95% CI: 0.20 to 0.47, p < 0.001; second dose aOR = 0.02, 95% CI: 0.01 to 0.05, p < 0.001)
- having experienced a previous outbreak (aOR = 0.52, 95% CI: 0.39 to 0.68, p < 0.001)
- increasing population density around the home (aOR = 0.98, 95% CI: 0.96 to 1.00, p = 0.035).

After accounting for the covariates, area type and wave were important predictors. Relative to Dublin city, rural areas and other cities had a lower risk of outbreaks. However, relative to Dublin, other cities had a substantially increased risk in the

second and third waves. Towns also had an elevated risk in the second and third waves. The impact of local incidence was also increased in the third wave.

**Table 2. Unadjusted and adjusted odds ratios of an outbreak of COVID-19 occurring in a nursing home**

| | Unadjusted | | | Adjusted^ | | |
|---|---|---|---|---|---|---|
| **Variable** | **OR** | **95% CI** | ***p*-value** | **OR** | **95% CI** | ***p*-value** |
| Number of beds¥ | 1.16 | 1.13 to 1.19 | <0.001 | 1.17 | 1.14 to 1.20 | <0.001 |
| Nursing home type | | | | | | |
| Public (reference) | 1.00 | - | - | 1.00 | - | - |
| Private single | 1.21 | 0.93 to 1.59 | 0.172 | 0.92 | 0.70 to 1.24 | 0.578 |
| Area | | | | | | |
| Dublin city (reference) | 1.00 | - | - | 1.00 | - | - |
| City | 0.72 | 0.49 to 1.04 | 0.084 | 0.36 | 0.13 to 0.84 | 0.029 |
| Town | 0.55 | 0.42 to 0.71 | <0.001 | 0.60 | 0.34 to 1.08 | 0.083 |
| Village | 0.45 | 0.31 to 0.64 | <0.001 | 0.69 | 0.32 to 1.45 | 0.333 |
| Rural | 0.32 | 0.23 to 0.45 | <0.001 | 0.46 | 0.22 to 0.94 | 0.035 |
| Wave | | | | | | |
| First (reference) | 1.00 | - | - | 1.00 | - | - |
| Second | 0.44 | 0.31 to 0.60 | <0.001 | 0.15 | 0.07 to 0.32 | <0.001 |
| Third | 1.22 | 0.98 to 1.52 | 0.082 | 0.48 | 0.26 to 0.86 | 0.015 |
| Local incidence§ | 1.18 | 1.14 to 1.24 | <0.001 | 1.14 | 1.09 to 1.21 | <0.001 |
| Deprivation | 0.95 | 0.90 to 1.01 | 0.095 | 0.95 | 0.90 to 1.01 | 0.124 |
| Neighbouring nursing homes | 1.07 | 1.05 to 1.09 | <0.001 | 1.08 | 1.04 to 1.13 | <0.001 |
| Population density | 1.02 | 1.01 to 1.02 | <0.001 | 0.98 | 0.96 to 1.00 | 0.035 |
| Previous outbreak | 0.86 | 0.67 to 1.09 | 0.222 | 0.52 | 0.39 to 0.68 | <0.001 |
| Vaccination | | | | | | |
| None (reference) | 1.00 | - | - | 1.00 | - | - |
| First dose | 1.11 | 0.72 to 1.64 | 0.602 | 0.31 | 0.20 to 0.47 | <0.001 |
| Second dose | 0.04 | 0.01 to 0.10 | <0.001 | 0.02 | 0.01 to 0.05 | <0.001 |
| *Interaction terms* | | | | | | |
| Local incidence x Wave one | | | | 1.00 | - | - |
| Local incidence x Wave two | | | | 1.04 | 0.90 to 1.23 | 0.635 |
| Local incidence x Wave three | | | | 1.36 | 1.19 to 1.55 | <0.001 |
| City x Wave two | | | | 6.91 | 1.89 to 26.65 | 0.004 |
| Town x Wave two | | | | 2.95 | 1.27 to 7.31 | 0.015 |
| Village x Wave two | | | | 1.64 | 0.40 to 5.90 | 0.461 |
| Rural x Wave two | | | | 1.31 | 0.32 to 4.61 | 0.685 |
| City x Wave three | | | | 7.21 | 2.82 to 21.14 | <0.001 |
| Town x Wave three | | | | 1.81 | 1.04 to 3.19 | 0.038 |
| Village x Wave three | | | | 1.83 | 0.85 to 4.05 | 0.127 |
| Rural x Wave three | | | | 1.85 | 0.90 to 3.87 | 0.098 |

^All variables outlined in table were included in the adjusted analysis.

¥Centred and rescaled to be per 10 beds.

§Rescaled to be in increments of 10 cases per 100,000 and log transformed.

Separate subgroup analyses were undertaken for data from each of the waves. The separate analyses were consistent with the findings of the overarching analysis in terms of the magnitude and direction of effect of the covariates. However, it should be noted that no covariate was found to have a statistically significant association in the subgroup analysis of the second wave suggesting a lower level of predictability of the second wave, as compared with the first or third waves. The analysis of the second wave being influenced by the relatively small number of outbreaks that occurred.

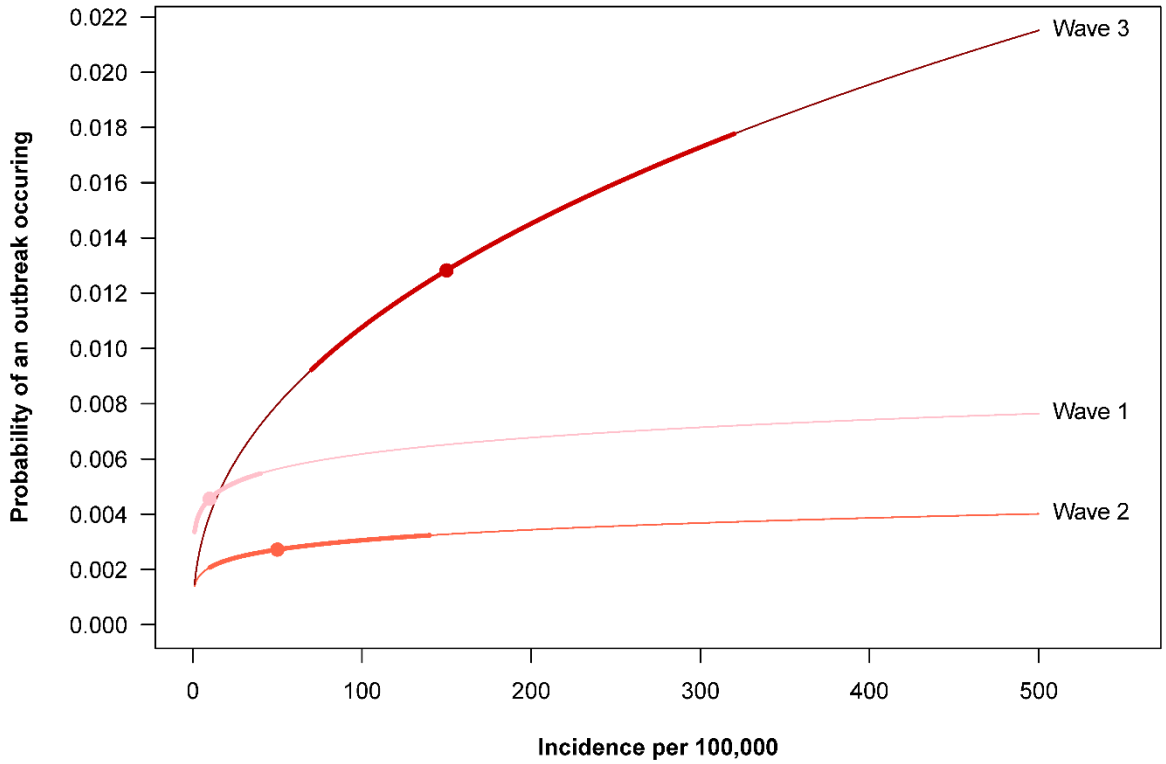
## Contextualisation of findings – probability of an outbreak occurring

Below is a set of hypothetical examples to contextualise the relative importance of the different factors identified which were associated with an increase in the probability of an outbreak occurring in a nursing home.

### *Incidence*

For a private nursing home with 60 beds and no prior outbreaks, located in a town, the probability of an outbreak increased with incidence (Figure 8). The probability of an outbreak during the first wave increased from 0.004 (1 in 240 homes) at an incidence of 5 cases per 100,000 to 0.008 (1 in 131 homes) at an incidence of 500 cases per 100,000. In the third wave, the association was different, with the probability increasing from 0.003 (1 in 341) homes at an incidence of 5 cases per 100,000 to 0.022 (1 in 46) homes at an incidence of 500 cases per 100,000. In all three waves, it should be noted that there was uncertainty in the association between local incidence and the probability of an outbreak occurring.

**Figure 8. Probability of an outbreak by local incidence and wave**

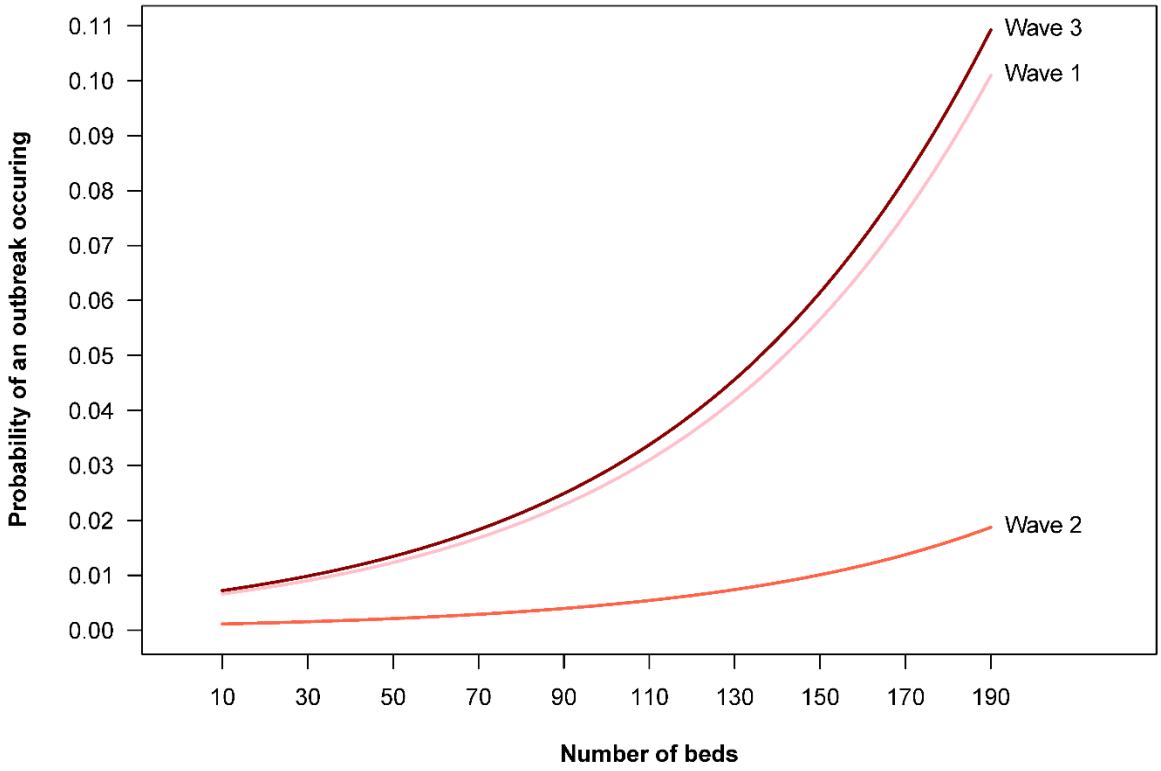



Footnote: example based on private nursing home with 60 beds and no prior outbreaks, located in a town. Thicker line segments indicate the interquartile range for observed local incidence in each wave. Points indicate median local incidence in each wave.

### *Number of beds*

The probability of an outbreak increased with the number of beds. In the following example, a HSE-run nursing home in Dublin is modelled based on a local incidence of 150 cases per 100,000. The average number of beds for a HSE-run nursing home in Dublin is 73, for which the probability of an outbreak is 0.018 in the first wave (or 1 in 57 homes), 0.003 in the second wave (1 in 330 homes) and 0.019 in the third wave (1 in 52 homes). Under the same conditions, a nursing home with only 30 beds has approximately a 49% lower risk of an outbreak occurring. There were very wide confidence bounds associated with the estimates, highlighting the large degree of uncertainty around the effect of beds on the probability of an outbreak.

**Figure 9. Probability of an outbreak by number of beds and wave**




Footnote: example based on a public nursing home in Dublin at the peak of the first wave with a local incidence of 200 cases per 100,000 population.

## *Vaccination*

Vaccination was found to be associated with a protective effect, lowering the probability of an outbreak. The vaccination programme was rolled out during the third wave, starting at the end of December 2020. For a private nursing home in a city area with 51 beds and no prior outbreaks, in the third wave with a local incidence of 285 per 100,000 the probability of an outbreak decreased from 0.034 (1 in 29 homes) with no vaccination, to 0.011 (1 in 92 homes) after the roll-out of the first dose, to 0.001 (1 in 1,380 homes) after the second dose.

## Secondary analysis- probability of an outbreak occurring (all documented outbreaks)

A secondary analysis was completed of all suspected and confirmed outbreaks across residents and or staff. Given the lack of available data on staffing levels to enable an appropriate assessment of extent, this analysis was limited to factors associated with an outbreak occurring or not in a nursing home on any given day. As shown in Appendix Table A1.2, the results were largely similar to the main analysis with the exception of some differences in factors relating to geography.

## Factors associated with the extent of an outbreak

For the dependent outcome of the extent of an outbreak once it occurs, as inferred from the number of residents infected, a negative binomial regression was conducted. The model was run with beds as a covariate (AIC = 2,945.4) and as an offset (AIC = 2,936.1). As the difference in the AIC was modest, the model with beds as a covariate was selected to enable quantifying the impact of bed numbers on the extent of outbreaks. Unlike the analysis of probability of an outbreak, log-transformation of local incidence did not improve the model fit within this analysis so the untransformed local incidence was used.

The resulting unadjusted and adjusted incidence ratios (IRs) for each input variable are provided in Table 3. It should be noted that the predictive ability of the model was limited, with predicted extent falling into a narrower range than the observed values. However, the purpose of the model was exploratory and to identify associations rather than for forecasting.

The number of beds in a home again has an effect with the extent of an outbreak increasing with increasing number of beds (IR = 1.08 per 10 beds, 95% CI: 1.04 to 1.11, p<0.001). The low magnitude of effect means that while the absolute size of an outbreak increases with number of beds, the relative size decreases in terms of the proportion of residents infected. For example, a doubling of beds leads to a less than doubling in the extent of the outbreak. Unlike the analysis based only on the first two waves, the association between local incidence and the extent of an outbreak is now statistically significant (IR = 0.97 per 10 cases per 100,000, 95% CI: 0.96 to 0.98, p = 0.001). The direction of effect is that an increase in local incidence is associated with a lower extent of outbreak. The occurrence of a previous outbreak within a nursing home was noted to lessen the extent of subsequent outbreaks overall (IR = 0.52, 95% CI: 0.42 to 0.66, p<0.001). Vaccination was associated with less extensive outbreaks, although the effect was only statistically significant for the second dose (IR = 0.26, 95% CI: 0.12 to 0.63, p = 0.001). Higher deprivation in the area surrounding a nursing home was associated with a lower extent of an outbreak (IR = 0.96, 95% CI: 0.92 to 1.00, p = 0.041).

The second wave was associated with a statistically significant reduction in the extent of an outbreak relative to the first wave (IR = 0.64, 95% CI: 0.44 to 0.93, p = 0.014). After accounting for local incidence, there was no difference between the third wave and the first wave.

**Table 3. Unadjusted and adjusted incidence ratios for the proportion of residents infected in an outbreak**

| Variable | Unadjusted | | | Adjusted^ | | |
|---|---|---|---|---|---|---|
| | IR | 95% CI | *p*-value | IR | 95% CI | *p*-value |
| Number of beds¥ | 1.05 | 1.02 to 1.07 | <0.001 | 1.08 | 1.04 to 1.11 | <0.001 |
| Local incidence§ | 1.00 | 1.00 to 1.00 | 0.349 | 0.97 | 0.96 to 0.99 | 0.001 |
| Nursing home type | | | | | | |
| Public (reference) | 1.00 | - | - | 1.00 | - | - |
| Private | 1.24 | 0.99 to 1.54 | 0.051 | 1.10 | 0.89 to 1.36 | 0.377 |
| Area | | | | | | |
| Dublin city (reference) | 1.00 | - | - | 1.00 | - | - |
| City | 1.06 | 0.78 to 1.45 | 0.727 | 0.98 | 0.69 to 1.41 | 0.928 |
| Town | 1.00 | 0.81 to 1.23 | 0.994 | 1.01 | 0.71 to 1.44 | 0.943 |
| Village | 0.94 | 0.70 to 1.26 | 0.673 | 0.90 | 0.60 to 1.36 | 0.632 |
| Rural | 1.21 | 0.93 to 1.60 | 0.165 | 1.13 | 0.75 to 1.69 | 0.583 |
| Wave | | | | | | |
| First (reference) | 1.00 | - | - | 1.00 | - | - |
| Second | 0.67 | 0.51 to 0.88 | 0.003 | 0.64 | 0.44 to 0.93 | 0.014 |
| Third | 0.86 | 0.72 to 1.03 | 0.108 | 1.11 | 0.88 to 1.41 | 0.370 |
| Previous outbreak | 0.58 | 0.48 to 0.71 | <0.001 | 0.52 | 0.42 to 0.66 | <0.001 |
| Vaccination | | | | | | |
| None (reference) | 1.00 | - | - | 1.00 | - | - |
| First dose | 0.65 | 0.47 to 0.92 | 0.010 | 0.73 | 0.53 to 1.03 | 0.062 |
| Second dose | 0.29 | 0.13 to 0.75 | 0.005 | 0.26 | 0.12 to 0.63 | 0.001 |
| Deprivation | 0.95 | 0.91 to 0.99 | 0.014 | 0.96 | 0.92 to 1.00 | 0.041 |
| Neighbouring nursing homes | 0.99 | 0.98 to 1.01 | 0.344 | 0.99 | 0.96 to 1.02 | 0.462 |
| Population density | 1.00 | 0.99 to 1.00 | 0.567 | 1.00 | 0.99 to 1.02 | 0.660 |
| *Interaction terms* | | | | | | |
| Number of beds x Wave one | | | | 1.00 | - | - |
| Number of beds x Wave two | | | | 0.96 | 0.90 to 1.03 | 0.213 |
| Number of beds x Wave three | | | | 0.98 | 0.93 to 1.03 | 0.361 |
| Local incidence x Wave one | | | | 1.00 | - | - |
| Local incidence x Wave two | | | | 1.04 | 1.02 to 1.07 | <0.001 |
| Local incidence x Wave three | | | | 1.03 | 1.01 to 1.04 | 0.001 |

^All variables outlined in table were included in the adjusted analysis.

¥Centred and rescaled to be per 10 beds.

§Rescaled to be in increments of 10 cases per 100,000.

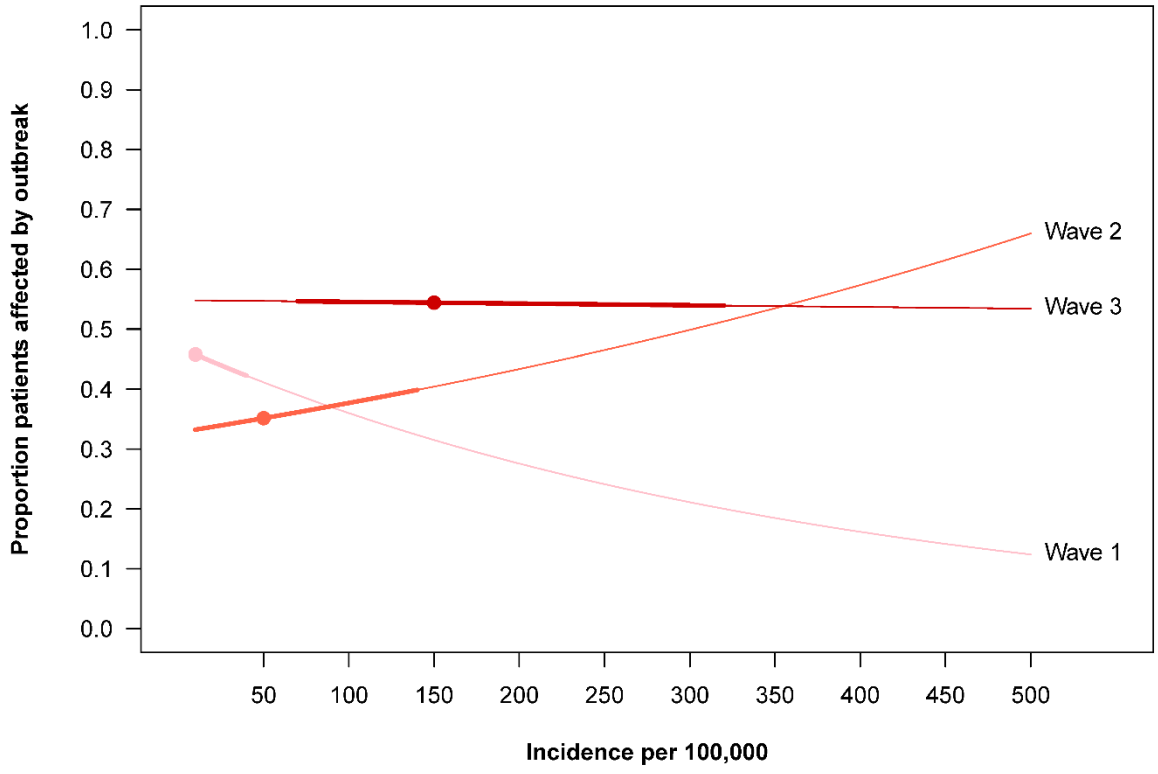
## Contextualisation of findings – extent of an outbreak

Below is a set of hypothetical examples to contextualise the relative importance of the different factors identified which were observed to impact the extent of an outbreak in a nursing home once it occurred.

### *Incidence*

Based on a public nursing home with 32 beds in a village area and no prior outbreaks, the relationship between extent of an outbreak and local incidence differs by wave (Figure 10). In the first wave, the extent of an outbreak decreased with local incidence, but it is important to note that the range of incidence experienced in the first wave was limited compared to subsequent waves. In the second wave, extent increased with local incidence while in the third wave there was almost no change in extent by local incidence.

**Figure 10. Proportion of residents infected by an outbreak by local incidence and wave**



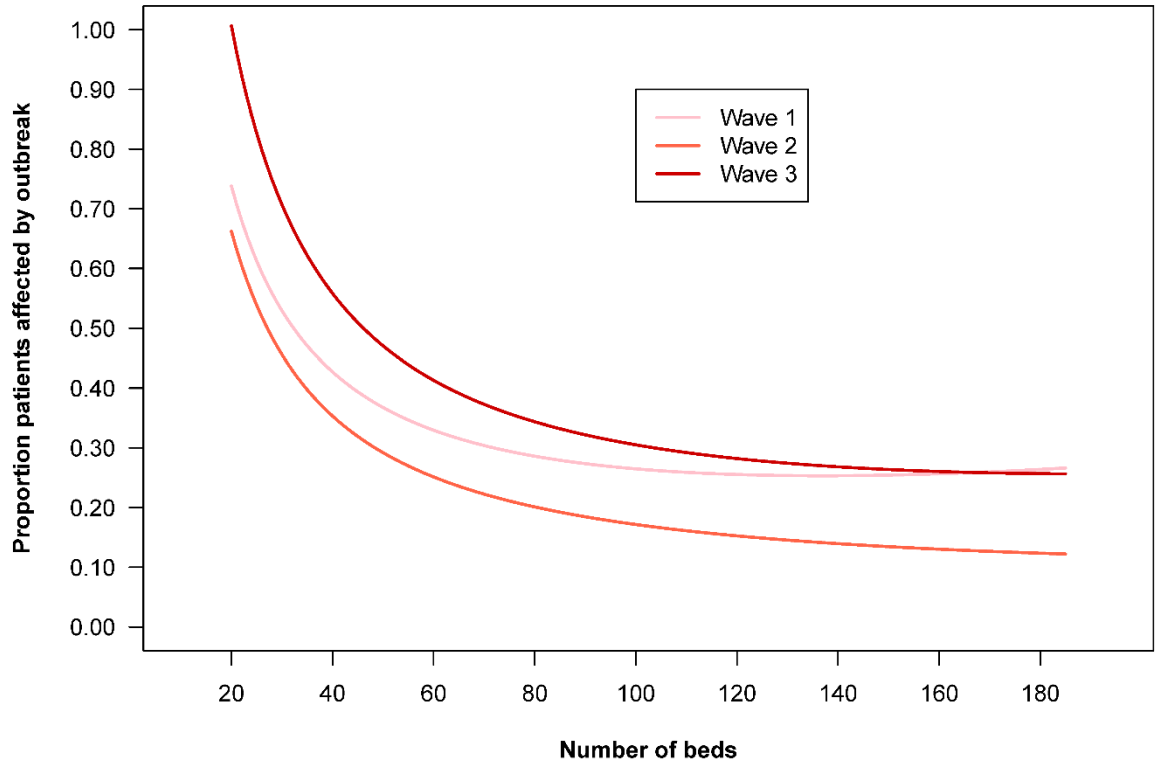

Footnote: example based on a public nursing home in a village area with 32 beds. Thicker line segments indicate the interquartile range for observed local incidence in each wave. Points indicate median local incidence in each wave.

### *Number of beds*

As is expected, the absolute number of residents infected in an outbreak increases with the number of beds. However, the proportion infected decreases with increasing numbers of beds. This is because the rate of increase in cases is less than the rate of increase in beds. In the following example (Figure 11), a privately-operated nursing home in Dublin is modelled with a local incidence of 50 cases per 100,000. Such a home typically has 71 beds, in which we would have expected an outbreak to include 21 patients (or 30% of residents if the home is at full occupancy) in the first wave, 16 residents (23%) in the second wave and 26 (37%) in the third wave.

The important caveat is the assumption of 100% occupancy, or at least that occupancy does not vary systematically by size of home. If occupancy is typically lower in larger homes, then the assumption does not hold and it might explain the finding of the extent of an outbreak (proportion of residents infected) decreasing with increasing home size.

**Figure 11. Proportion of residents infected by an outbreak by size of home**




Footnote: example based on a privately operated nursing home in Dublin with a local incidence of 50 cases per 100,000 population.

### *Vaccination*

The model outputs indicate that the extent of an outbreak decreased with increasing numbers of vaccine doses provided. Based on a 52 bed private nursing home in a rural area, assuming a local incidence of 150 cases per 100,000 in the third wave, the extent of an outbreak decreased with increasing vaccination. With no vaccination, the extent of an outbreak would be 56% in home with no prior outbreaks, and 29% in a home with a prior outbreak. After the roll-out of the first dose, the extent of an outbreak is reduced to 41% in a home with no prior outbreak and 21% in a home with a prior outbreak. Finally, with the roll-out of the second dose, the extent of an outbreak is further reduced to 15% in a home with no prior outbreak and 8% in a home with a prior outbreak.

### *Deprivation*

The association of a reduced extent of outbreak with increased deprivation is unexpected, given that lower socio-economic status is often associated with poorer health outcomes. This association between deprivation and poor health has been demonstrated at both an individual and an area level. In the context of nursing home residents, it would be anticipated that any effect of area deprivation would be very limited given that they may have little interaction with the local community. It should be noted, however, that the magnitude of effect is small. For a private home in Dublin city, the interquartile range of deprivation scores runs from –1.46 to 0.59 (which spans from the least deprived 20% of areas to the most deprived 20% of areas). For a typical home with 91 beds, the expected extent decreases from 29% to 27%. It is possible that the deprivation variable allows the model to moderate for an effect that is not fully captured by area type. It should be borne in mind that there is substantial heterogeneity within area type.

### *Extent of subsequent outbreaks*

Based on the model output, having had a prior outbreak among residents is associated with a reduced extent of subsequent outbreaks. Amongst other factors, this could plausibly be influenced by protective immunity among residents previously infected, or through improved infection prevention and control standards following an initial outbreak. It could also reflect reduced occupancy after the previous outbreak which would not be adjusted for by using the number of beds as a measure of home size.

Of the 71 homes that experienced a second outbreak among residents, only 21 had less than 10% of the residents affected by the first outbreak whereas 35 had less than 10% affected in their second outbreak. Five of the second outbreaks occurred in the first wave, twelve in the second wave and 54 in the third wave. There was much more variability in the proportion of residents affected during the second outbreak in the third wave compared to the first or second wave (Figure 12). There

were a number of homes that had extensive second outbreaks following relatively well-contained first outbreaks.

There general trend showed that subsequent outbreaks tended to be smaller (Figure 13). The average first outbreak included 26% of beds while the second included 19% on average, and the third 9% on average.

Where the second outbreak occurred in the second or third wave, there was a negative correlation such that the larger first outbreak was associated with the smaller second outbreak. This association may suggest that immunity (amongst residents and or staff) may be playing a role in limiting the extent of subsequent outbreaks. However, it could also point to reduced occupancy after a first outbreak. It was also not apparent that the gap between outbreaks or the size of the home had any impact on the extent of a second outbreak relative to the first. However, in the absence of data on occupancy and mortality, it was not possible to conduct a detailed analysis.

**Figure 12. Comparison of extent of first and second outbreak in homes that had two or more outbreaks**

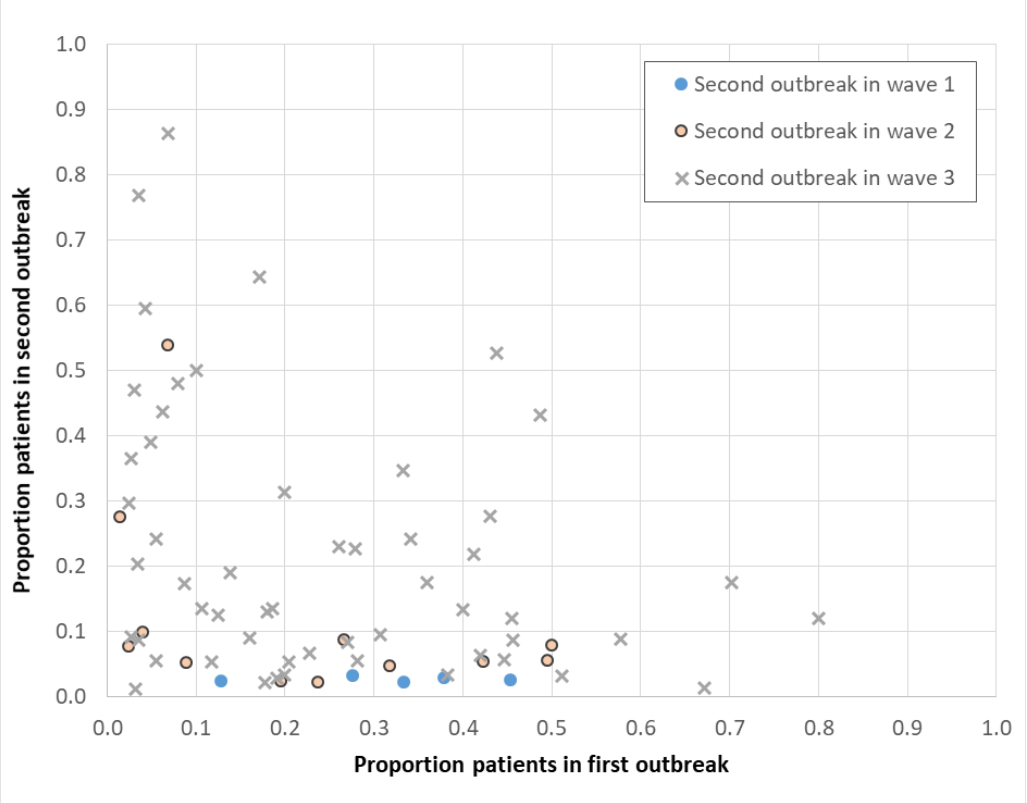
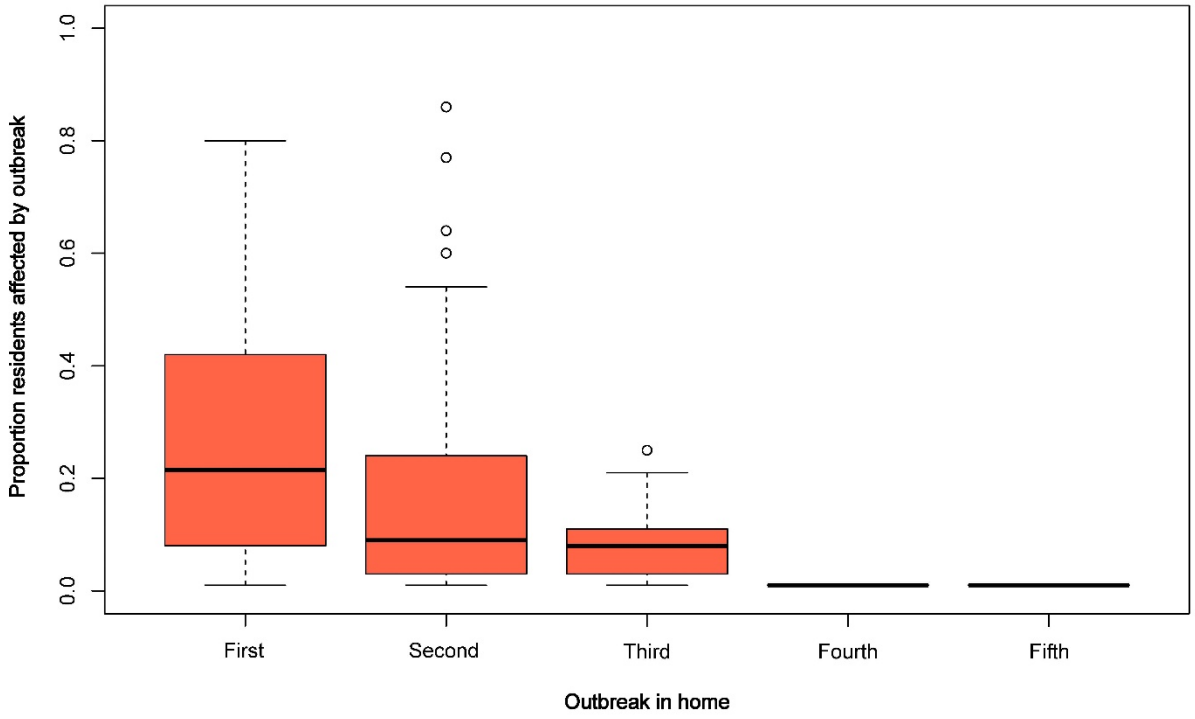


**Figure 13. Extent of repeated outbreaks in homes**



# 4. Discussion

This updated analysis sought to determine the role of a number of factors in relation to the probability that a confirmed outbreak of SARS-CoV-2 involving residents within a nursing home will occur on any given day and the extent of such an outbreak. This updated analysis builds on a previous report published by HIQA to include data from the third wave of the epidemic in Ireland (from 22 November 2021 to 11 May 2021). The results of this updated analysis largely reflect the findings of the original report in that:

- The probability of an outbreak of SARS-CoV-2 in a nursing home on any given day was significantly associated with community incidence of COVID-19, the size of a nursing home, and being in close proximity to other nursing homes.
- The extent of an outbreak once it occurred, increased with the number of beds in a home and decreased with subsequent outbreaks in a nursing home.
- The type of nursing home (that is, publicly or privately operated) was not associated with either the probability of an outbreak occurring or the extent of an outbreak.
- The overall analysis remained limited by a lack of reliable and consistent data across nursing homes for a number of potentially influential facility-level and resident-level factors. The results of the analysis should overall be considered to be exploratory in nature, due to the lack of availability of relevant data for establishing causal relationships.

A number of differences are noted within the updated analysis which will be discussed further below, they are:

- The probability of an outbreak was noted to reduce with having had experienced previous outbreaks and with an increasing population density of the area in which a home was located.
- Outbreaks had a greater extent with lower local incidence of COVID-19 and where the home was located in a less deprived area.
- The addition of vaccination is clearly associated with increasing national vaccination in the third wave and was associated with a reducing probability of an outbreak occurring within a nursing home and a decreasing extent of an outbreak when they did occur.

- There were more outbreaks in the third wave than in the first two waves combined, although that was in the context of a much higher community prevalence of COVID-19. In the third wave, fewer nursing homes had more than one outbreak.
- The changing geography of the pandemic was more pronounced with nursing homes in city and rural areas associated with a lower probability of an outbreak occurring relative to those in Dublin city. While nursing homes in city areas other than Dublin were associated with an increased probability of experiencing an outbreak in waves two and three relative to wave one.
- The third wave provided substantially more information for this analysis than was available for the previous analysis. This is particularly relevant considering the relatively low number of outbreaks seen in the second wave. However, it is apparent that each wave is associated with its own challenges and distinctions, limiting the overall applicability of our findings to future periods. The public health measures in place, the local and national incidence, public behaviour and compliance with public health measures all change over time such that the context for future waves is likely to be different from those included in this analysis.

The findings of this analysis indicate that while a rising community incidence was associated with an increased probability of the occurrence of an outbreak, a reducing extent of outbreak was associated with an increasing incidence. This finding may possibly be attributed to the infrastructure and staffing levels of a home, the infection prevention and control procedures in place, the emphasis of public health initiatives, and or the clinical guidance specifically directed to protect these facilities.[2, 4] However, it must be considered that these findings may further reflect important data which were not available for this analysis, such as mortality rates or changes in occupancy levels and demography during the time elapsed.

The finding of having experienced a previous outbreak within a nursing home being associated with a reduction in the probability and extent of subsequent outbreaks may reflect that learning occurred following the initial waves and outbreaks experience, with improvement and refinement of measures to contain outbreaks as the epidemic has progressed. Similarly, while a greater number of overall outbreaks were observed in the third wave than in the first two waves combined, fewer nursing homes had more than one outbreak than in the first two waves. When a home experiences an outbreak, that outbreak lasts from the date of notification of the first case to 28 days after the notification of the last case. The average duration of an outbreak was 57.8 days, during which time a home cannot experience a new

outbreak. In other words, having an outbreak reduces the time available to have another outbreak. However, the trend for decreasing extent is also likely influenced by protective immunity due to either prior infection and or vaccination (which was rolled out during the third wave). Another consideration is that an outbreak is intended to reflect related cases. However, there is the potential for multiple virus introductions to occur in longer outbreaks, but the continued existence of new cases within the 28-day window did not allow for that to be detected. In other words, a long and extensive outbreak may in fact, reflect multiple outbreaks.

While perhaps unsurprising and not definitive given the nature of the analysis undertaken, vaccination within the third wave influenced the overall outcomes observed with a reducing probability of an outbreak occurring, alongside a decreasing extent of outbreaks, as the vaccination roll-out progressed. This finding illustrates the benefits of the vaccination programme and the sequenced undertaking in terms of priority groupings for vaccination in Ireland. However, the current uncertainty regarding the degree and duration of the protective immunity in such populations and the impact of variants requires careful consideration when interpreting these results and the application to current and potential future waves of the epidemic. The main aim of the Irish vaccination programme was to reduce severe disease, hospitalisation and death related to COVID-19. While a large number of outbreaks occurred in the third wave, their impact in terms of hospitalisation and mortality will have been partially mitigated through vaccination. As such, an analysis of the morbidity and mortality associated with outbreaks in nursing homes could further establish the impact of the vaccination programme.

For a number of the findings outlined within the analyses, such as the influence of population density and deprivation level within the surrounding area, it is plausible that the output reflects a moderating effect of the model. Area type was included within the model to distinguish between urban and rural geographies. Areas were classified into five categories and there was heterogeneity within them in terms of the characteristics of the catchments around individual homes. So, for example, while average population density increases with more urban area types, some homes in cities have a lower population density in their catchment than some homes based in a village. As such, the variables for deprivation, neighbouring homes and population density provide additional adjustment over and above what is achieved by area type alone. Alternatively, these statistically significant associations of area-level factors may reflect proxies for nursing home level factors that were not included due to a lack of data. The residents of a nursing home may come from a large catchment area, and hence conditions in the locality of the nursing home would be expected to have a limited impact on outbreaks. It is also unclear that

characteristics such as staffing levels or the dependency level of residents may be correlated with deprivation or number of neighbouring homes.

Each wave of the epidemic in Ireland has been associated with distinct nuances which influence the overall findings of this analysis including changing levels of community incidence, the geographical and demographic distribution of cases, the stringency of public health measures, the vaccination roll out, and public compliance and adherence to public health measures. Therefore, while the results of this analysis may provide some important learnings from the epidemic to date, the overall applicability of some of the findings to future time periods may be considered limited.

*Limitations*

As within the previous report, there are a number of important limitations to consider when interpreting the overall results of this analysis including:

- The lack of potentially important data relating to resident-level and facility-level factors which have been highlighted in similar analyses as being of significance, such as the physical structure of the homes (for example, ratio of single to multi-occupancy rooms), the demography and dependency level of residents within a nursing home, staffing levels and skill-mix, the ratio of staff to residents, and the movement between nursing homes, and resident transfers.[8, 9] Data related to some variables were available to a degree but were typically captured as point-in-time measures in a sample of nursing homes. As such, the data are unlikely to be representative of the conditions and variation in those conditions experienced throughout the epidemic. Again, it is acknowledged that some of these data are challenging to collect, given the likelihood of variation over time and the burden placed on homes to gather and provide the data. However, the centralised collection of such information would greatly facilitate future analyses of this nature and may have ongoing value when considering other viral outbreaks.

- Similarly, a number of explanatory variables included within the analyses may serve as proxies or have important interactions with such absent data and may impact on the overall findings of this report.

- Data on vaccination were included in this analysis. There were challenges validating the data and, in the absence of occupancy data within a nursing home, it was not possible to present it as percentage coverage. It is understood that in excess of 90% coverage was achieved in most homes. It was important to include vaccination at the individual home level as there was variability in when vaccination occurred. The other potential limitation is that

there is a lag between vaccination and achieving the associated level of protection. It is typically assumed that it takes two weeks to obtain protection from the first dose and one week for the second dose. These lags may differ for the elderly and the acquisition of protection does not happen instantaneously after the lag. To avoid over-complicating the model, vaccination was coded as a binary indicator of whether or not the first or second dose had been provided from the day of vaccination.

- As noted, data included within this analysis were up to 11 May 2021. This means that a complete analysis of the third wave has not been provided (considered as ending on 27 June 2021). However, due to the 12 May 2021 cyber-attack on the HSE information systems, there are limitations to the data available from that point to the end of the third wave. Given the substantially decreased risk of outbreaks after the roll-out of vaccination, it is unlikely that the inclusion of data to the end of the third wave would substantively change the findings of the analysis.
- The data on outbreaks have been collected prospectively as part of the HPSC's CIDR system. The data were designed for the surveillance of outbreaks and not for analysis of risk factors associated with the occurrence of those outbreaks.
- The local incidence in the vicinity of nursing homes was calculated using data on cases geocoded to electoral divisions. The accuracy of geocoding is dependent on the quality of the address information provided and whether people consistently provide their home or work address. It was assumed that local incidence was a good proxy for the risk of staff or visitors entering a nursing home while infected with SARS-CoV-2. The definition of local catchment was set to include surrounding small areas, including between five and 10 electoral divisions, giving an average catchment of 24,601 people. It is possible that staff and visitors may live outside the defined catchment and hence the local incidence may not be representative of the incidence where staff and visitors live.
- The model was not explicitly spatial in nature, as the relative positions of homes were not included in the model.
- Overall, causal risk factors could not be established due to the lack of availability of relevant data for establishing causal relationships. The analysis results should be considered descriptive in nature, and as such, this report and the related findings are limited to high-level, exploratory analysis.

## Conclusions

This updated analysis aimed to determine:

- the relative importance of a number of factors to the probability that an outbreak of SARS-CoV-2 involving residents within a nursing home will occur on any given day
- where an outbreak occurs
- what factors influence the extent of an outbreak overall across the three waves of the epidemic in Ireland (up to 11 May 2021).

The findings of this updated analysis largely reflect the original findings that the probability of experiencing an outbreak in a nursing home increased with rising community incidence in the locality of the home, the size of the home in terms of number of beds, and if there was a high density of other nursing homes in the area. The extent of an outbreak was associated with an increased number of beds in a home, and a lower proportion of residents infected in subsequent outbreaks. No association was observed between nursing home type (that is publicly or privately operated) and either outcome within this analysis.

Some additional associations emerged from this analysis, such as deprivation and population density, that may reflect moderating effects within the models for factors relating to geographic differences not captured due to heterogeneity within area types. There were a greater number of overall outbreaks in the third wave than in the first two waves combined, likely due to the much higher levels of community incidence of COVID-19; however, fewer nursing homes had more than one outbreak than in the first two waves.

A vaccination programme was rolled out in nursing homes in January 2021 with the aim of reducing the risk of severe disease, hospitalisation and death related to COVID-19. The addition of vaccination was very significant, with vaccination in the third wave associated with a substantially reduced probability of an outbreak occurring within a nursing home.

There was substantial uncertainty in the magnitude of some of the associations and a number of potentially informative measures, such as staffing levels or occupancy, were unavailable for this analysis. Improved data collection could facilitate an analysis that better captures the characteristics of individual homes and would potentially provide a better insight into the factors associated with SARS-CoV-2 outbreaks in homes.

Each wave of the epidemic in Ireland has been associated with distinct nuances which influence the overall findings of this analysis, including changing levels of community incidence, the geographical and demographic distribution of cases, the

stringency of public health measures, the emergence of new variants, the vaccination roll out, and public compliance and adherence to public health measures. Therefore, while the third wave provided substantially more information for analysis, the overall applicability of some of the findings to current and future periods may be limited.

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# Appendices

## Appendix 1 Analysis including all documented outbreaks (suspected, confirmed, and those limited to healthcare workers only)

### Table A1.1. Descriptive characteristics of HIQA registered nursing homes included in analysis

| Characteristic | All nursing homes | Affected by outbreak | | | | | |
|---|---|---|---|---|---|---|---|
| | | Wave 1 | | Wave 2 | | Wave 3 | |
| | | Yes (outbreak) | No (no outbreak) | Yes (outbreak) | No (no outbreak) | Yes (outbreak) | No (no outbreak) |
| Homes (n) | 595 | 253 | 339 | 83 | 495 | 225 | 352 |
| Beds, mean (sd) | 54.8 (30.8) | 69.0 (35.1) | 44.2 (21.6) | 69.3 (36.8) | 53.0 (28.9) | 65.5 (33.4) | 48.9 (27.1) |
| Homes within 5km/15 minutes, mean (sd) | 2.8 (4.3) | 4.0 (5.2) | 1.8 (3.2) | 3.8 (4.7) | 2.6 (4.2) | 3.3 (4.8) | 2.3 (3.9) |
| Home type, n (%) | | | | | | | |
| Public | 128 (22%) | 47 (19%) | 80 (24%) | 20 (24%) | 96 (19%) | 41 (18%) | 75 (21%) |
| Private | 467 (78%) | 206 (81%) | 259 (76%) | 63 (76%) | 399 (81%) | 184 (82%) | 277 (79%) |
| Outbreak count, n (%) | | | | | | | |
| 1 | 223 (58%) | 233 (92%) | | 79 (95%) | | 221 (98%) | |
| 2 | 131 (34%) | 18 (7%) | | 4 (5%) | | 4 (2%) | |
| 3 | 31 (8%) | 2 (1%) | | 0 (0%) | | 0 (0%) | |
| 4 | 2 (1%) | 0 (0%) | | 0 (0%) | | 0 (0%) | |
| 5 | 1 (0%) | 0 (0%) | | 0 (0%) | | 0 (0%) | |
| Proportion residents in outbreak, mean (sd) | 0.22 (0.25) | 0.18 (0.23) | | 0.15 (0.22) | | 0.29 (0.27) | |
| Duration of outbreak (days), mean (sd) | 49.5 (23.5) | 50.5 (26.9) | | 45.9 (26.7) | | 49.8 (17.1) | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Local 14-day incidence per 100,000,* mean (sd) | | | | | | | |
| Average | 34.9 (29.5) | 107.1 (54.4) | 92.2 (53.8) | 320.7 (92.2) | 277.5 (109.8) | 302.0 (104.5) | 274.2 (109.3) |
| Max | 194.6 (196.3) | 355.9 (260.1) | 344.8 (250.6) | 1554.1 (619.4) | 1406.1 (746.1) | 1506.4 (656.0) | 1383.8 (772.2) |
| Area type, n (%) | | | | | | | |
| City (Dublin) | 98 (16%) | 71 (28%) | 25 (7%) | 15 (18%) | 79 (16%) | 46 (20%) | 47 (13%) |
| City (other) | 47 (8%) | 12 (5%) | 35 (10%) | 10 (12%) | 36 (7%) | 26 (12%) | 20 (6%) |
| Town | 231 (39%) | 99 (39%) | 131 (39%) | 42 (51%) | 181 (37%) | 83 (37%) | 140 (40%) |
| Village | 85 (14%) | 23 (9%) | 62 (18%) | 7 (8%) | 74 (15%) | 32 (14%) | 49 (14%) |
| Rural | 134 (23%) | 48 (19%) | 86 (25%) | 9 (11%) | 125 (25%) | 38 (17%) | 96 (27%) |
| Deprivation quintile ¥, n (%) | | | | | | | |
| 1 (least deprived) | 108 (18%) | 58 (23%) | 50 (15%) | 15 (18%) | 91 (18%) | 42 (19%) | 64 (18%) |
| 2 | 78 (13%) | 35 (14%) | 42 (12%) | 14 (17%) | 62 (13%) | 30 (13%) | 46 (13%) |
| 3 | 71 (12%) | 28 (11%) | 43 (13%) | 15 (18%) | 53 (11%) | 25 (11%) | 42 (12%) |
| 4 | 115 (19%) | 52 (21%) | 62 (18%) | 10 (12%) | 102 (21%) | 51 (23%) | 62 (18%) |
| 5 (most deprived) | 223 (37%) | 80 (32%) | 142 (42%) | 29 (35%) | 187 (38%) | 77 (34%) | 138 (39%) |

*Incidence based on local catchment area for electoral divisions within 20 minutes/20 km of nursing home (minimum 5 and maximum 10 electoral divisions).

¥ Deprivation reported here as a categorical variable (quintiles). In the regression analyses, deprivation was included in the form of a continuous score.

## Table A1.2. Factors associated with the occurrence of an outbreak (all possible outbreaks)

| Variable | Unadjusted | | | Adjusted^ | | |
|---|---|---|---|---|---|---|
| | OR | 95% CI | *p*-value | OR | 95% CI | *p*-value |
| Number of beds¥ | 1.14 | 1.12 to 1.17 | <0.001 | 1.15 | 1.13 to 1.18 | <0.001 |
| Nursing home type | | | | | | |
| Public (reference) | 1.00 | - | - | 1.00 | - | - |
| Private | 1.12 | 0.92 to 1.39 | 0.270 | 0.85 | 0.68 to 1.07 | 0.150 |
| Area | | | | | | |
| Dublin city (reference) | 1.00 | - | - | 1.00 | - | - |
| City | 0.63 | 0.45 to 0.86 | 0.005 | 0.36 | 0.18 to 0.68 | 0.003 |
| Town | 0.60 | 0.49 to 0.74 | <0.001 | 0.71 | 0.46 to 1.12 | 0.135 |
| Village | 0.44 | 0.32 to 0.58 | <0.001 | 0.56 | 0.31 to 1.00 | 0.053 |
| Rural | 0.42 | 0.33 to 0.54 | <0.001 | 0.73 | 0.44 to 1.22 | 0.233 |
| Wave | | | | | | |
| First (reference) | 1.00 | - | - | 1.00 | - | - |
| Second | 0.39 | 0.30 to 0.49 | <0.001 | 0.16 | 0.09 to 0.27 | <0.001 |
| Third | 0.74 | 0.62 to 0.88 | 0.001 | 0.36 | 0.22 to 0.60 | <0.001 |
| Local incidence§ | 1.14 | 1.11 to 1.18 | <0.001 | 1.20 | 1.16 to 1.25 | <0.001 |
| Deprivation | 0.95 | 0.91 to 1.00 | 0.036 | 0.95 | 0.91 to 1.00 | 0.052 |
| Neighbouring nursing homes | 1.06 | 1.04 to 1.07 | <0.001 | 1.05 | 1.01 to 1.09 | 0.007 |
| Population density | 1.02 | 1.01 to 1.02 | <0.001 | 0.99 | 0.97 to 1.00 | 0.088 |
| Previous outbreak | 0.82 | 0.67 to 0.99 | 0.043 | 0.60 | 0.48 to 0.75 | <0.001 |
| Vaccination | | | | | | |
| None (reference) | 1.00 | - | - | 1.00 | - | - |
| First dose | 0.78 | 0.52 to 1.12 | 0.211 | 0.29 | 0.19 to 0.42 | <0.001 |
| Second dose | 0.06 | 0.03 to 0.10 | <0.001 | 0.03 | 0.02 to 0.06 | <0.001 |
| *Interaction terms* | | | | | | |
| Local incidence x Wave one | | | | 1.00 | - | - |
| Local incidence x Wave two | | | | 1.02 | 0.91 to 1.17 | 0.709 |
| Local incidence x Wave three | | | | 1.25 | 1.11 to 1.40 | <0.001 |
| City x Wave two | | | | 4.37 | 1.61 to 11.80 | 0.003 |
| Town x Wave two | | | | 1.99 | 1.08 to 3.79 | 0.032 |
| Village x Wave two | | | | 1.52 | 0.53 to 3.97 | 0.410 |
| Rural x Wave two | | | | 0.78 | 0.31 to 1.85 | 0.587 |
| City x Wave three | | | | 5.62 | 2.64 to 12.56 | <0.001 |
| Town x Wave three | | | | 1.33 | 0.83 to 2.12 | 0.234 |
| Village x Wave three | | | | 2.06 | 1.08 to 3.95 | 0.028 |
| Rural x Wave three | | | | 1.04 | 0.60 to 1.81 | 0.894 |

^All variables outlined in table were included in the adjusted analysis.

¥ Centred and rescaled to be per 10 beds.

§ Rescaled to be in increments of 10 cases per 100,000 and log transformed.

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