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

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Health Protection Surveillance Centre
Lárionad Faire um Chosaint Sláinte

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

Finalised: 18 February 2021
Published: 26 May 2021

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.

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.

Contents

Foreword

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is a highly infectious virus which has caused over 100 million cases of COVID-19 since its emergence in 2019, with a considerable level of associated mortality. In the context of the ongoing COVID-19 pandemic, SARS-CoV-2 constitutes a significant public health concern due to its high basic reproduction rate, the absence of innate immunity in the human population, the limited evidence of effective treatment approaches, and the constrained supply of vaccines in the early stages of population-level immunisation programmes.

Nursing home residents are particularly vulnerable to the effects of COVID-19, and there has been a large and sustained effort to protect this population in Ireland. This has included the establishment of the COVID-19 Nursing Homes Expert Panel by the National Public Health Emergency Team (NPHET) in May 2020, to examine the complex issues surrounding the management of COVID-19 in this cohort. The Expert Panel report recommended that HIQA and the HPSC undertake a detailed epidemiological analysis comparing both risk and protective factors associated with outbreaks of SARS-CoV-2 in HIQA-regulated nursing homes.

Accordingly, this report outlines the collaborative analysis undertaken by HIQA and the HPSC on factors associated with the likelihood of the occurrence of an outbreak of SARS-CoV-2 in nursing homes in Ireland, and the extent of the outbreak should such an event occur.

HIQA and the HPSC would like to thank their respective teams, the members of the HIQA COVID-19 Expert Advisory Group and all who contributed to the preparation of this report.

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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

- Throughout the COVID-19 pandemic, residents of long-term care facilities, such as nursing homes, have been disproportionately affected in terms of incidence, morbidity and mortality.
- 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 comparing factors (risk or protective) associated with outbreaks of SARS-CoV-2 or not in these settings.
- This report presents the results of an analysis of the relative importance of a number of factors to the likelihood of an outbreak of SARS-CoV-2 involving residents occurring on any given day in a nursing home in Ireland. 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.
- This analysis drew on a number of data sources contributing information on community-level and facility-level variables. These included descriptive information on the 572 HIQA-registered nursing homes in Ireland at the time the analysis was undertaken (sourced from HIQA, November 2020), and details of community incidence and outbreak events in nursing homes (sourced from the HPSC). Data were up to 21 November 2020, covering the first and second waves of the epidemic in Ireland.
- The analysis indicates that 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. No association was observed between the probability of an outbreak and whether a home was publicly or privately operated.
- In terms of the extent of the 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 extent of an outbreak and whether a home was publicly or privately operated.

- There was a notable difference between the first and second wave, 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.
- This 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.
- Consideration should be given to the collection of data on potential risk factors for which limited evidence was available for this analysis. Any such data collection should be compliant with national data collection standards and be carefully considered in terms of the resources to collect and maintain the data compared with its usefulness to improve care and inform decision-making. If additional data are to be collected, relevant stakeholders should be consulted to ensure the feasibility of collection and relevance of the data.
- Overall, the results of this analysis indicate that as local community incidence rises, so too does the likelihood of an outbreak occurring in a nursing home. The probability of an outbreak is higher in larger nursing homes (in terms of number of beds), and in nursing homes which are situated in close proximity to other nursing homes. The size of the nursing home, in terms of number of beds, and previously having experienced an outbreak of SARS-CoV-2, appear to influence the overall extent of an outbreak. The probability and extent of outbreaks were observed to reduce in the second wave of the epidemic compared with the first. The applicability of these results to current or potential future waves is unclear given the emergence of new variants of concern and the rollout of a comprehensive vaccination programme.

1. Background

The transmissibility and impact of the SARS-CoV-2 virus is reflected in the continued growth of COVID-19 cases and associated mortality worldwide, with many countries that had previously suppressed the virus to low levels experiencing considerable resurgence of infections.[1] Throughout the COVID-19 pandemic, individuals in long-term care facilities (LTCFs) or congregated care facilities, such as nursing homes, have been disproportionately affected in terms of incidence, morbidity and mortality.[2-4]

In Ireland, residents of such facilities have represented a substantial number of COVID-19 cases and associated deaths. A detailed epidemiological analysis of nursing homes, examining data up to 27 June 2020, indicated that 14.5% of residents aged over 65 had been infected compared with 0.4% of the general population of similar age, with nursing home clusters constituting 56% (n = 971) of all reported deaths at that point.[5] This frequency appears relatively reflective of reported European and global trends during the COVID-19 pandemic with LTCF residents accounting for 46% of all COVID-19 deaths on average across 21 countries assessed in one report.[6] Residents of nursing homes are particularly vulnerable to contracting the SARS-CoV-2 virus given the congregated settings in which they live and the high contact nature of these environments.[5] This population typically comprise older, frailer individuals with comorbidities and immunosenescence (that is, a gradual deterioration of the immune system with age) who are more likely to experience a greater burden of disease and associated mortality.[2-5] Additionally, the symptoms of COVID-19 may mimic symptoms of other conditions, impeding early detection of a SARS-CoV-2 infection.[5]

As such, a particular concern in nursing homes is the prevention of outbreaks of SARS-CoV-2 infections among residents and staff. An outbreak is defined by the Health Protection Surveillance Centre (HPSC) as:

- 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.[3]

Of note, this is an updated definition since August 2020, prior to which suspected outbreaks of COVID-19 were also notifiable.

Data from the HPSC on outbreaks highlight that nursing homes have experienced outbreaks throughout the COVID-19 epidemic in Ireland.[7] To prevent such outbreaks from occurring, the HPSC outlines three elements of risk management for such facilities:[3]

- preventing the virus entering the facility
- reducing the spread of the virus if present
- mitigating harm of the virus.

The foremost objective is the preclusion of SARS-CoV-2 entering the facility through measures such as active monitoring and testing of staff and residents, guidance on resident transfers, reduction of visitation and minimisation of staff moving between facilities.[3] Should preclusion attempts be unsuccessful, concerted efforts are placed on the remaining two elements of reducing spread of infection and mitigating harm for residents and staff through strict infection prevention control, outbreak management, surveillance and early identification of cases.[3] While noting the importance of outbreak prevention in such facilities, the World Health Organization (WHO) further emphasises the need for balanced and proportioned responses to ensure the physical, emotional and cognitive needs of residents are not excessively impacted.[8]

Nursing homes in Ireland are designated centres for older persons, and hence regulated by the Health Information and Quality Authority (HIQA).[9] Regulations specify the minimum standard required of the provider and were developed to build resilience in the system and provide assurance of the safeguarding of residents through the provision of safe and quality care. However, these facilities can be diverse in terms of ownership, management, facilities, and resident characteristics.[9]

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.[5] 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 the 19 August 2020, with associated recommendations from the panel.[5] 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.[5]

Accordingly, the aim of this report is to fulfil the outlined recommendation of the COVID-19 Nursing Homes Expert Panel through an analysis of factors associated with outbreaks of SARS-CoV-2 infections, and the extent of those outbreaks, within nursing homes in Ireland. Exploration of factors associated with morbidity and or mortality in nursing home residents was outside the scope of this analysis.

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. At the time when data were obtained for this analysis (November 2020), there were 572 nursing homes registered with HIQA across the Republic of Ireland.

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.[3] 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 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.

Data sources and input variables

While the aim of this analysis was 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 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 572 registered nursing homes in Ireland.
- HPSC (Computerised Infectious Disease Reporting (CIDR) database): Data relating to outbreaks within nursing homes in Ireland, including the date the outbreak was identified, first and last date of notification of included cases, number of cases for residents and healthcare workers, whether the outbreak was confirmed or suspected, and duration of the outbreak. An outbreak was considered to have started on the earliest reported date (of symptom onset, notification or outbreak identification) and finished 28 days after the last reported date (of symptom onset, notification or outbreak identification). Daily incidence of COVID-19 in Ireland, including locality by electoral division. One noted limitation is that a number of test samples taken during March and April 2020 were sent to Germany for processing. The delayed processing meant that the cases had delayed notification dates. Where possible, date of onset was used to limit the impact of delayed notification.
- Department of Health (DoH): Start and end date of public health measures relating to domestic travel by county.
- Central Statistics Office (CSO): Small area population data.
- Additional data sources: Ordnance Survey Ireland mapping data, OpenStreetMap routing data,[10] Trinity deprivation index,[11] small area urban-rural classification.[12]

Reliable data in a format which facilitated analysis was unavailable for a number of potentially important explanatory variables which have been described within the international literature to date.[13] 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 from 2020 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 infection prevention and control regulations. Historical data were available as well as

a review of a sample of nursing homes completed during May 2020. The historical compliance data represent point in time measurements that may not fairly represent conditions throughout the COVID-19 epidemic. The May 2020 review was performed on a sample of nursing homes, excluding those with active COVID-19 outbreaks, and hence 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 and time constraints, 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; additionally, the level of restrictive measures within a nursing home, for example visitation, is not necessarily uniform across homes.

Data preparation

Due to the changing nature of the epidemic in terms of the demography of notified cases and the public health response, two distinct waves of COVID-19 in 2020 were included within the analysis: 1 March to 1 August, and 2 August to 21 November. Additionally, given significant differences in epidemiological characteristics compared with the rest of Ireland, Dublin city was treated as a separate locality when considering area type.

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 to include electoral divisions within 20 minutes and 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. Incidence was calculated for each day from 1 March to 21 November 2020, 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 and 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 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 per 100,000 in the catchment of the nursing home.
- Nursing home type – publicly (HSE) or privately operated, with the latter subdivided depending on whether it was the only home owned by the operator ('single') or one of several owned by the same operator ('multi').
- 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.
- Neighbours – the number of nursing homes within 5km and 15 minutes of the home.
- Deprivation – the deprivation score of the electoral division that the nursing home is located in, as a measure of socio-economic disadvantage.
- Wave – which of the two waves of the COVID-19 epidemic is represented by the data.
- Day – number of days since start of the wave.

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. For the purposes of this report, two sets of analysis were completed. Given the expert panel recommendation from which this report stemmed, the occurrence and extent of confirmed outbreaks which included residents were assessed as the main analysis. A secondary analysis was completed and included all suspected and confirmed outbreaks in nursing homes, including those which were exclusively in healthcare workers.

The probability of an outbreak was estimated using a 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, as opposed to the first day of an outbreak, were excluded from the analysis to avoid double counting of the probability of an outbreak, as it is not possible to have overlapping outbreaks

within a facility. Following the inclusion of the explanatory variables in the logistic regression model, the analysis estimates the probability of an outbreak commencing on a certain day, given the conditions at the time (for example, local incidence, whether the home had experienced an outbreak previously) and the fixed characteristics of the home (for example, number of beds, type of home).

A series of interaction terms were further included in the model to allow the relationship between the dependent variable and the relevant explanatory variable to vary by subgroup. In this analysis, subgroups were defined by nursing home type (publicly or privately operated) and by wave (first or second). This is particularly important as the association between outbreaks and nursing home size, for example, was considered likely to differ in the first and second waves.

The model output was the predicted probability of an outbreak occurring given the explanatory variables included in the model. The coefficients associated with each explanatory variable were converted to odds ratios for the tables presented in the main report. 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. In count data models, the total number of beds can be included as an offset which allows the outputs to be expressed as a rate, or as an explanatory variable (as per the analysis of probability of outbreaks). Here, the number of beds was included as a covariate to enable an assessment of whether nursing home size is important in the extent of outbreaks. As a sensitivity analysis, the model was estimated with number of beds as an offset and as an explanatory variable, with models compared using AIC. As the model estimates the number of cases in a home, the outputs are presented as incidence ratios.

3. Results

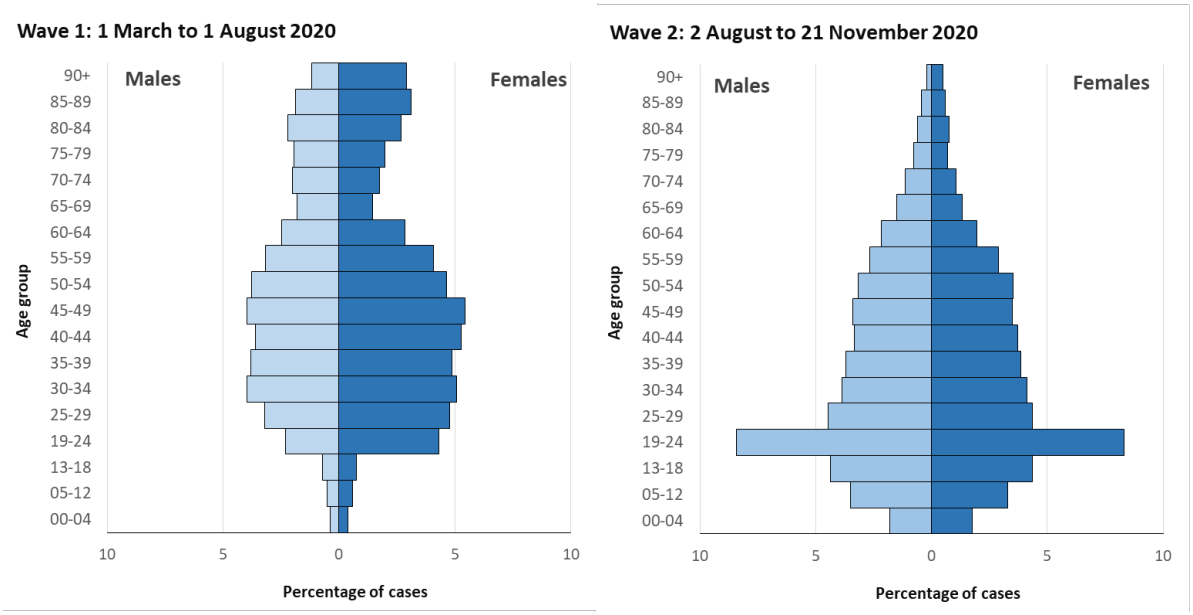
In total, there were 359 documented suspected or confirmed outbreaks involving residents and or staff across 292 nursing homes between February and November 2020. Given the purpose of this report, only the main analysis of confirmed outbreaks involving residents is presented (179 outbreaks across 161 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 and second 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 wave.

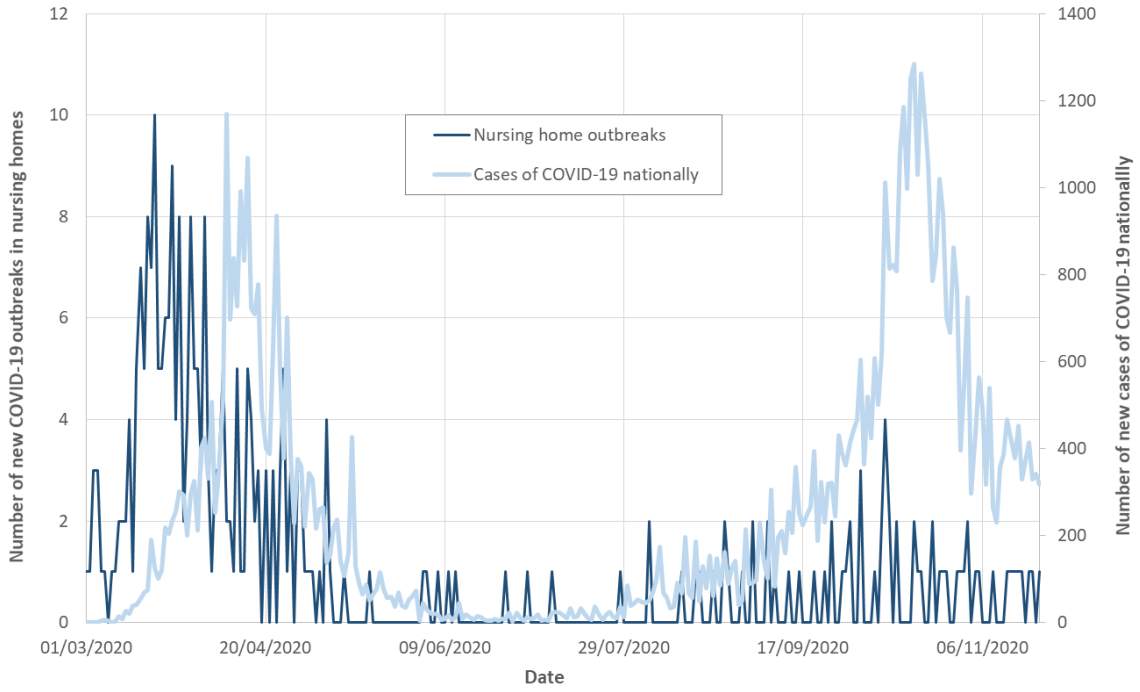
When interpreting the following plots, consideration should be given to the changing public health measures and testing strategies in place as the epidemic progressed. The first wave lasted 137 days, during which 636,000 RT-PCR tests to detect SARS-CoV-2 were carried out. During the second wave, 1,264,000 tests were carried out over 112 days. The test positivity rate was 4.1% in the first wave and 3.5% in the second wave. Capacity for testing increased gradually during the first wave. The limited capacity at the outset 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. As such, direct comparison of COVID-19 incidence across the waves may be misleading.

Figure 1. Population pyramids of notified COVID-19 cases in waves one and two



Furthermore, there were notable differences between the first and second waves in terms of incidence, with the first wave presenting a sharp high peak while the second wave exhibited a more gradual increase to a higher peak overall. As shown in Figure 2, while the peak of outbreaks in nursing homes preceded the community incidence peak in the first wave, it displayed a similar trend to the community incidence seen in the second wave. Of note, increased infection prevention and control training in nursing homes, including a focus on active outbreak management and early detection of cases through serial testing of staff and residents, likely played a role in this trend.

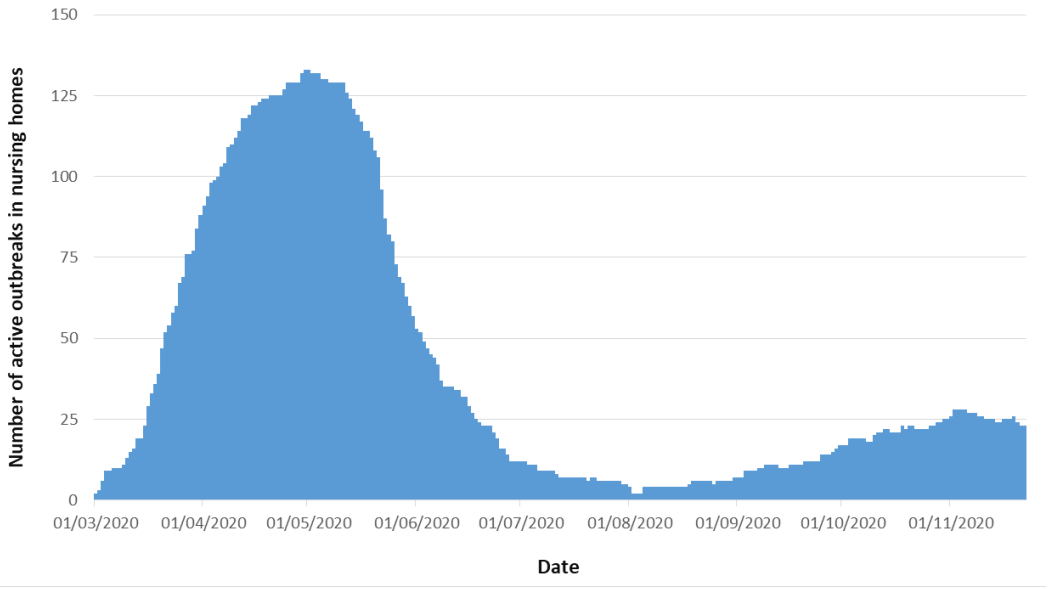
Figure 2. Incidence of COVID-19 and incidence of nursing home outbreaks over time



Footnote: for the group of samples taken during March and April 2020 with delayed testing, the date of sample collection was used rather than date of test result.

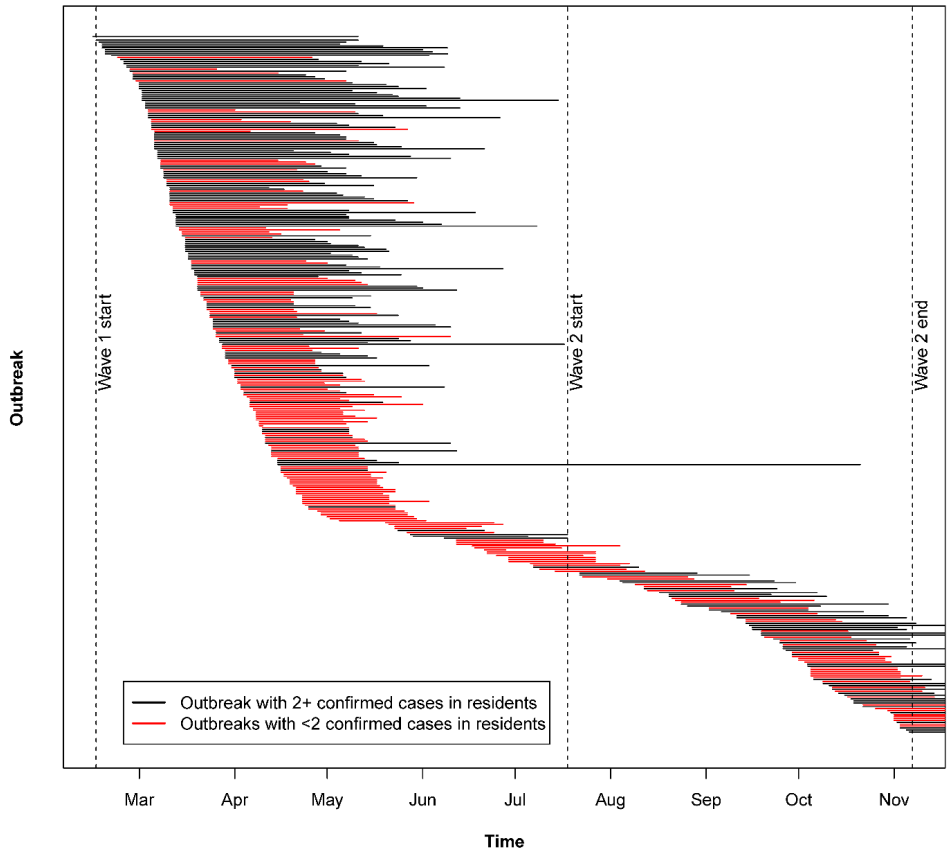
Figure 3 and Figure 4 illustrate time-related factors of outbreaks of SARS-CoV-2 in nursing homes. As shown, the concurrency of outbreaks across homes was much greater in the first wave of the epidemic than in the second. Additionally, the duration of outbreaks has shown a downward trend with outbreaks in the second wave typically shorter and less extensive than those in the first.

Figure 3. Number of concurrent outbreaks in nursing homes over time



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

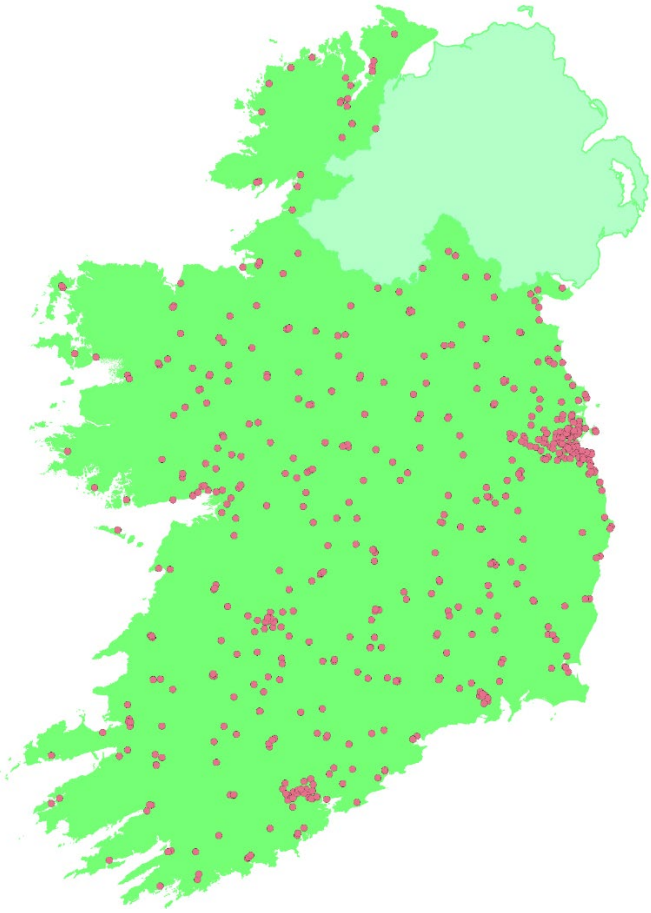


Footnote: The duration of an outbreak is defined as the date of the first case to 28 days after the date of the last case. Duration is based on cases in both residents and healthcare workers included in the outbreak.

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 572 registered nursing homes of which 113 (20%) were publicly operated, 360 (63%) were privately operated by companies who managed one nursing home only, and 99 (17%) were privately operated by companies who managed more than one nursing home. More nursing homes were located in towns (n = 220, 38%) than other area types, and in areas of noted deprivation (n = 211 in the highest deprivation quintile, 37%).

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



In total, 179 confirmed outbreaks involving residents occurred in 161 nursing homes across Ireland between February and November 2020. Of these, 127 experienced at least one outbreak in the first wave of the epidemic, and 38 experienced at least one outbreak in the second wave. Sixteen nursing homes were noted to have two or more outbreaks in the epidemic up to November 2020.

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, and 0.004 (or one in 273

homes) on day 93 of the second wave (Figure 6). The first wave is characterized 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 wave one and wave two 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)

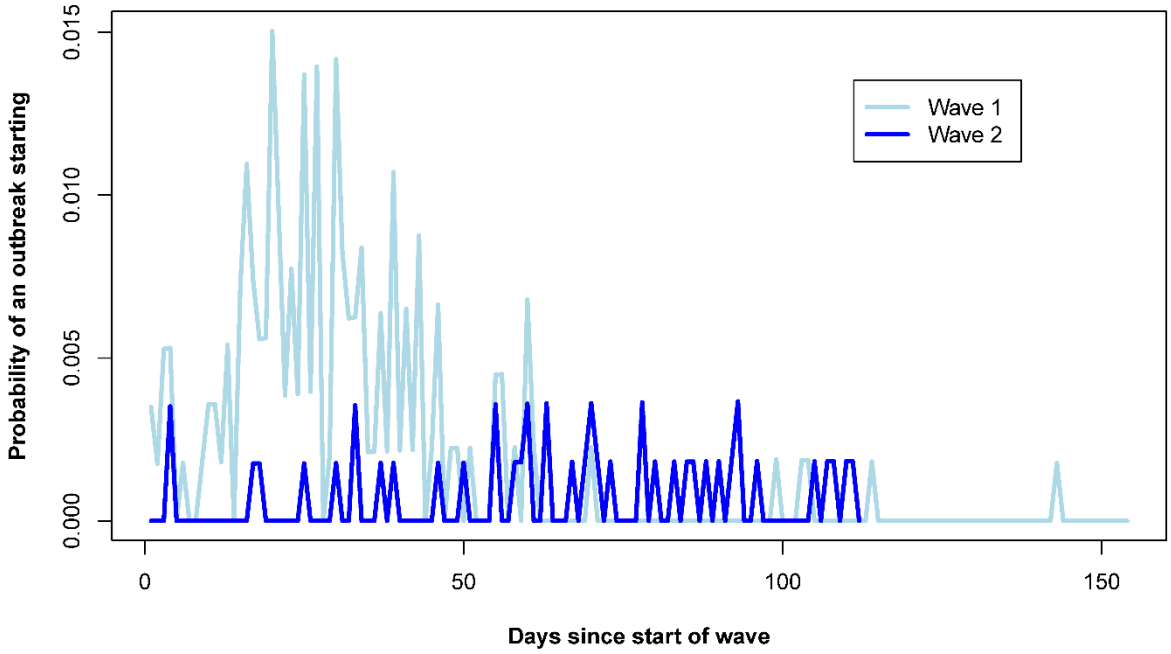


Table 1. Descriptive characteristics of HIQA registered nursing homes included in analysis (n =572)

Characteristic	All nursing homes	Affected by confirmed outbreak involving residents			
		Wave 1		Wave 2	
		Yes (outbreak)	No (no outbreak)	Yes (outbreak)	No (no outbreak)
Homes (n)	572	132	440	40	532
Beds, mean (SD)	56.0 (30.8)	76.0 (37.4)	50.0 (25.6)	72.7 (39.9)	54.7 (29.6)
Homes within 5km/15 minutes, mean (SD)	2.9 (4.6)	5.6 (6.1)	2.1 (3.7)	4.1 (5.0)	2.8 (4.5)
Home type, n (%)					
Public	113 (20%)	20 (15%)	93 (21%)	9 (23%)	104 (20%)
Private (single^)	360 (63%)	83 (63%)	277 (63%)	20 (50%)	340 (64%)
Private (multi)	99 (17%)	29 (22%)	70 (16%)	11 (28%)	88 (17%)
Outbreak count, n (%)					
1	145 (90%)	127 (96%)		38 (95%)	
2	15 (9%)	5 (4%)		2 (5%)	
3	0 (0%)	0 (0%)		0 (0%)	
4	1 (1%)	0 (0%)		0 (0%)	
Proportion of residents in outbreak, mean (SD)	0.31 (0.23)	0.33 (0.22)		0.25 (0.22)	
Duration of outbreak (days), mean (SD)	61.2 (23.5)	64.9 (24.7)		49.2 (13.4)	
Local 14-day incidence per 100,000,* mean (SD)					
Average	58.9 (27.1)	41.7 (24.0)	24.0 (24.3)	113.1 (49.5)	94.6 (48.2)
Max	387.1 (269.3)	222.7 (186.9)	142.9 (186.4)	391.7 (251.7)	352.0 (240.4)

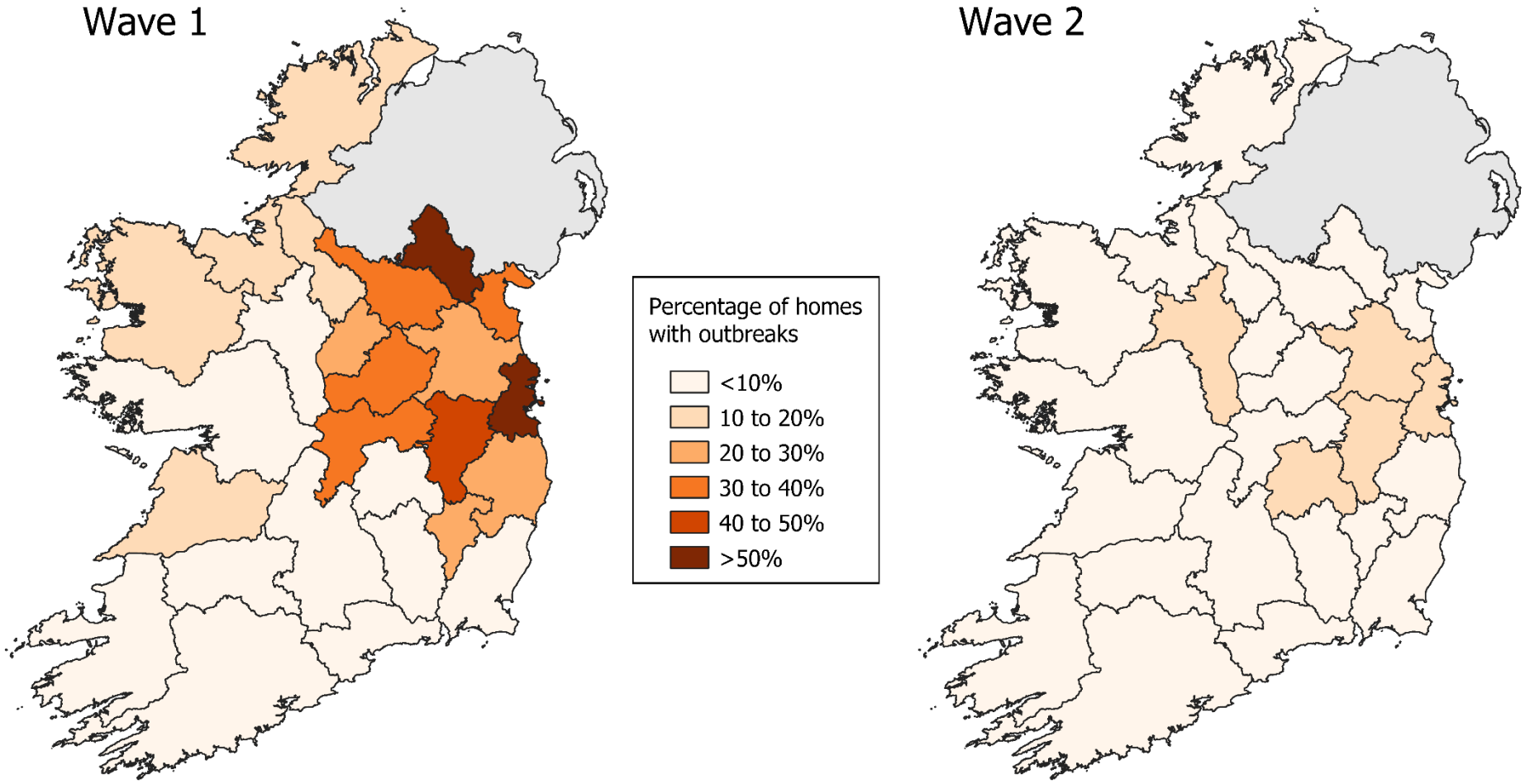
Characteristic	All nursing homes	Affected by confirmed outbreak involving residents			
		Wave 1		Wave 2	
		Yes (outbreak)	No (no outbreak)	Yes (outbreak)	No (no outbreak)
Area type, n(%)					
City (Dublin)	92 (16%)	49 (37%)	43 (10%)	7 (18%)	85 (16%)
City (other)	46 (8%)	6 (5%)	40 (9%)	5 (13%)	41 (8%)
Town	220 (38%)	46 (35%)	174 (40%)	20 (50%)	200 (38%)
Village	81 (14%)	13 (10%)	68 (15%)	4 (10%)	77 (14%)
Rural	133 (23%)	18 (14%)	115 (26%)	4 (10%)	129 (24%)
Deprivation quintile,[¥] n (%)					
1 (least deprived)	105 (18%)	28 (21%)	77 (18%)	8 (20%)	97 (18%)
2	77 (13%)	23 (17%)	54 (12%)	5 (13%)	72 (14%)
3	67 (12%)	16 (12%)	51 (12%)	6 (15%)	61 (11%)
4	112 (20%)	30 (23%)	82 (19%)	8 (20%)	104 (20%)
5 (most deprived)	211 (37%)	35 (27%)	176 (40%)	13 (33%)	198 (37%)

^'Single' refers to a privately operated home where the provider does not run any other homes, 'multi' refers to one of several privately operated homes run by the same provider.

*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.

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



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, 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, as well as 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: χ^2 = 9.7138, df = 8, p=0.29; Area Under Curve (AUC) = 0.85; McFaddens pseudo R^2 = 0.12).

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

- number of beds within the home (aOR = 1.14 per 10 beds, 95% CI: 1.02 to 1.25, p = 0.012)
- local community incidence around the home (aOR = 1.03 per 10 cases per 100,000, 95% CI: 1.02 to 1.04, p < 0.001)
- another nursing home being in close proximity (aOR = 1.05, 95% CI 1.00 to 1.10, p = 0.038).

The second wave of the epidemic was associated with a notable reduction in the probability of an outbreak occurring compared with the first wave (aOR = 0.05, 95% CI: 0.02 to 0.11, p<0.001). The passing of time within a wave (days since beginning of the wave) was associated with a slight reduction in the daily probability of an outbreak overall (aOR = 0.97, 95% CI 0.96 to 0.98, p<0.001); however, the interaction between this element and the second wave highlights that this observation was only true for the first wave, whereas a small increase in probability was observed as time passed during the second wave (aOR = 1.05, 95% CI 1.03 to 1.05, p<0.001).

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

Variable	Unadjusted			Adjusted^		
	OR	95% CI	*p*-value	OR	95% CI	*p*-value
Days since beginning of wave	0.98	0.98 to 0.98	<0.001	0.97	0.96 to 0.98	<0.001
Number of beds[¥]	1.19	1.15 to 1.23	<0.001	1.14	1.02 to 1.25	0.012
Nursing home type						
Public (reference)	1.00	-	-	1.00	-	-
Private single	1.13	0.77 to 1.71	0.550	0.91	0.59 to 1.42	0.657
Private multi	1.54	0.97 to 2.48	0.069	1.16	0.69 to 1.94	0.571
Area						
Dublin city (reference)	1.00	-	-	1.00	-	-
City	0.32	0.16 to 0.59	0.001	0.66	0.30 to 1.39	0.290
Town	0.44	0.31 to 0.62	<0.001	0.89	0.50 to 1.61	0.689
Village	0.32	0.18 to 0.52	<0.001	0.86	0.40 to 1.84	0.691
Rural	0.22	0.13 to 0.35	<0.001	0.57	0.27 to 1.22	0.144
Local incidence[§]	1.01	1.01 to 1.02	0.060	1.03	1.02 to 1.04	<0.001
Deprivation	0.95	0.87to 1.02	0.181	0.95	0.87 to 1.03	0.219
Neighbouring nursing homes	1.09	1.06 to 1.11	<0.001	1.05	1.00 to 1.10	0.038
Previous outbreak	2.71	0.45 to 8.49	0.162	2.19	0.35 to 7.59	0.296
Wave two (reference: wave one)	0.39	0.27 to 0.54	<0.001	0.05	0.02 to 0.11	<0.001
Interaction terms						
Number of beds x Type (Private-single)				1.07	0.96 to 1.19	0.220
Number of beds x Type (Private-multi)				0.96	0.84 to 1.09	0.485
Days since beginning of wave x Wave two				1.05	1.03 to 1.05	<0.001
Number of beds x Wave two				0.95	0.87 to 1.03	0.217
Local incidence x Wave two				0.98	0.95 to 1.00	0.062

^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.

Separate subgroup analyses were undertaken for data from each of the first and second 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. This suggests a lower level of predictability of the second wave, as compared with the first, the analysis of the second wave being influenced by the relatively small number of outbreaks that occurred.

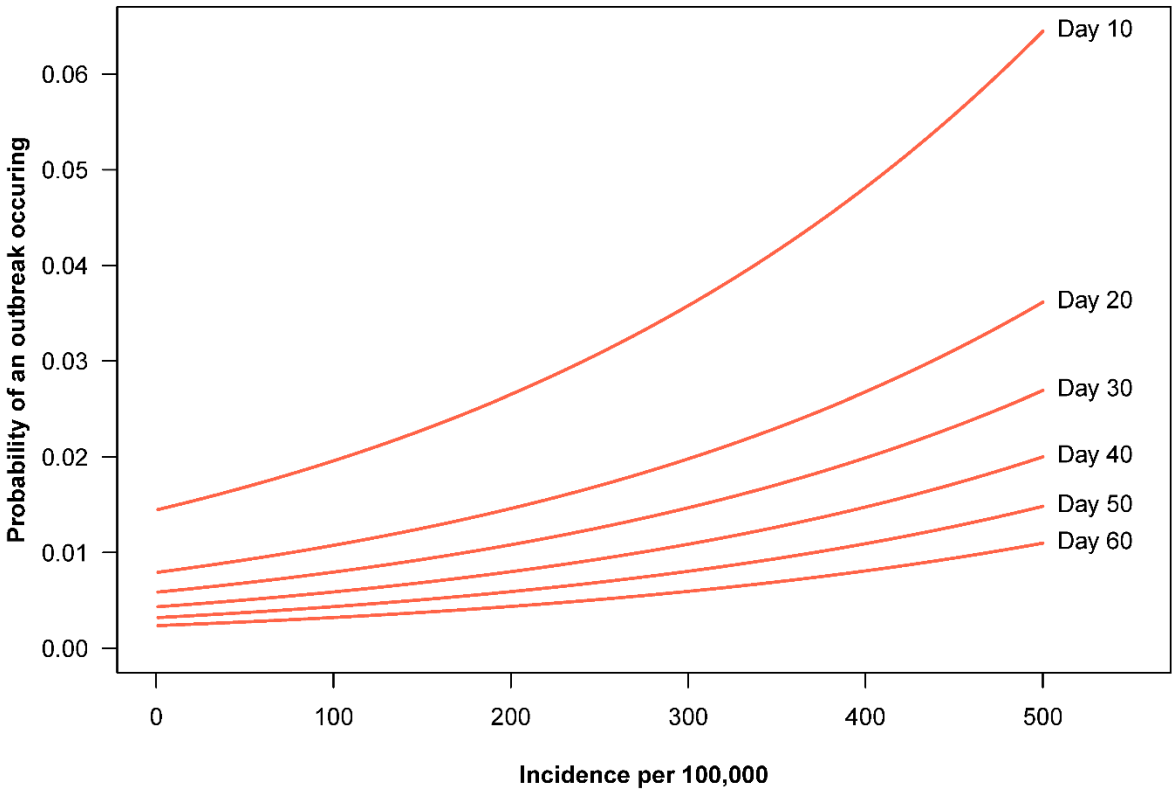
Contextualisation of findings – probability of an outbreak occurring

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

Incidence and timing

For a private nursing home with 60 beds and no prior outbreaks, located in a town, the probability of an outbreak in the first wave was dependent on both the local incidence and the timing within the wave. The probability of an outbreak increases with incidence, but decreases over time (Figure 8). The probability of an outbreak is highest early in the wave and increases exponentially with local incidence. The probability of an outbreak on day 10 with an incidence rate of 5 per 100,000 is the same as with 21 per 100,000 on day 20, 30 per 100,000 on day 30 and 40 per 100,000 on day 40.

Figure 8. Probability of an outbreak by local incidence and days since start of wave



Footnote: example based on private nursing home with 60 beds and no prior outbreaks, located in a town.

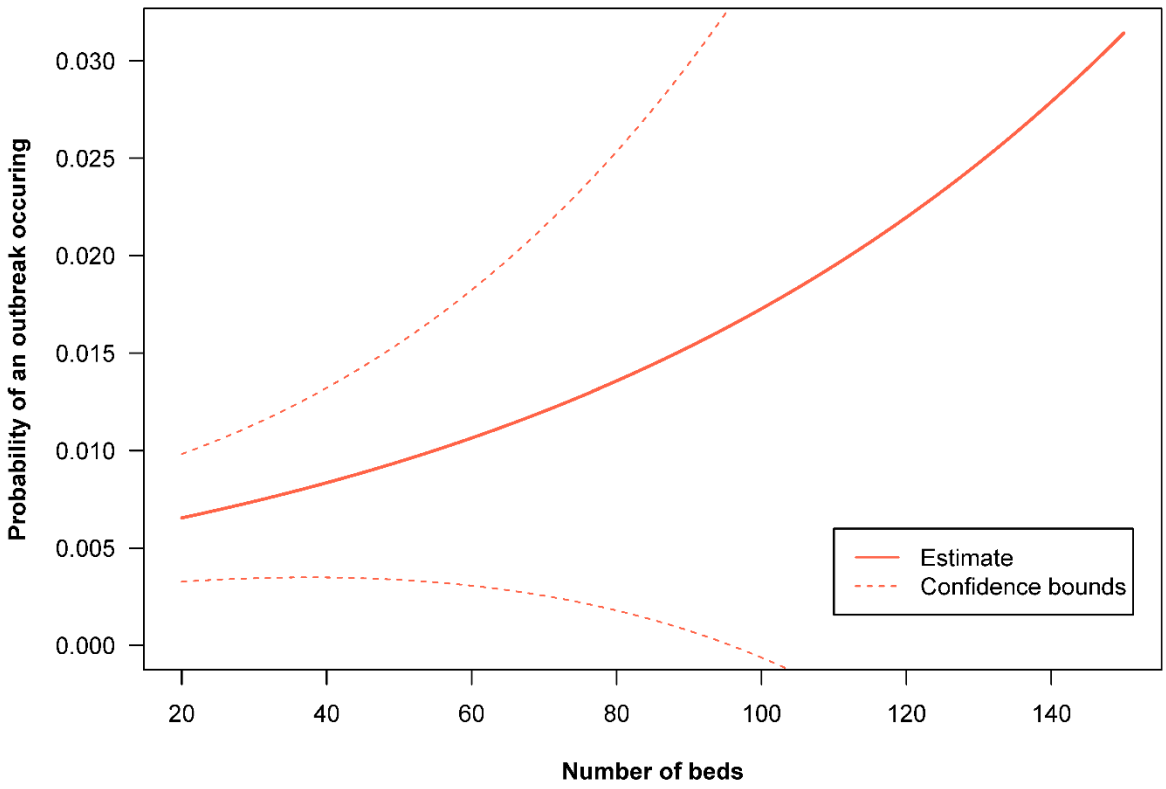
Contrary to the first wave, the probability of an outbreak increased over time in the second wave. The magnitude of the effect is small such that under identical conditions (for example, incidence, beds, type of nursing home), after 60 days the relative risk of an outbreak is approximately 0.17 in the first wave and 1.55 in the

second wave. If the probability of an outbreak was 0.05 on day 20, then on day 80 the probability would be 0.008 in the first wave and 0.077 in the second wave. This was influenced by the fact that the second wave followed a different profile to the first wave. At the end of the second wave, the incidence of COVID-19 had not returned to the low levels observed at the start of the 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 at the peak of the first wave (day 50, 200 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 at the peak is 0.016 (see Figure 9). That is to say, for every 63 nursing homes of that size there is one with an outbreak per day. Under the same conditions, a nursing home with only 30 beds would have a probability of 0.007 (or one in 135 homes) while a nursing home with 150 beds would have a probability of 0.031 (equivalent to one in 32 homes). The very wide confidence bounds highlight 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

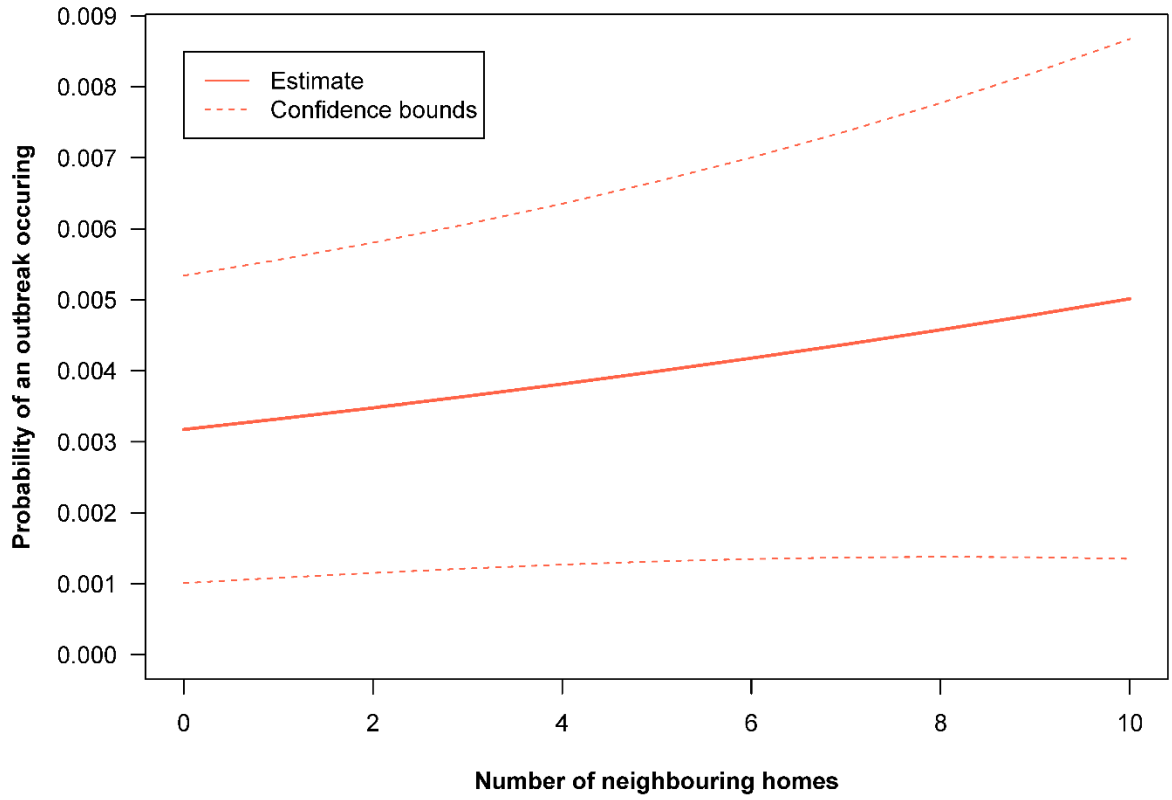


Footnote: example based on a public nursing home in Dublin at the peak of the first wave with a local incidence of 200 cases per 100,000 population.

Number of neighbouring nursing homes

The probability of an outbreak increased with increasing numbers of nursing homes within 5km and a 15 minute drive. A higher density of nursing homes typically occurs in more urban areas. In the following example, the number of neighbouring nursing homes is varied for a private nursing home in a city area (outside Dublin). The local incidence is assumed to be 88 per 100,000, the peak observed in such homes on day 50 of the first wave. The probability of an outbreak increases with the number of neighbouring nursing homes, such that a home with 10 neighbours is 1.5 times as likely to have an outbreak as one with no neighbours (Figure 9). However, the absolute difference in risk (0.0016) is relatively minor. As such, the impact of number of neighbouring homes on risk is limited.

Figure 10. Probability of an outbreak by number of neighbouring nursing homes



Footnote: example based on a private nursing home in a city outside Dublin at the peak of the first wave with a local incidence of 88 cases per 100,000 population.

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 1.2, the results were relatively similar to the main analysis. The main differences were a reduced probability of occurrence for nursing homes located in cities (relative to Dublin city) and the lack of significance of neighboring nursing homes in the adjusted model.

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 = 1,427.1) and as an offset (AIC = 1,427.9). Given that there was no meaningful difference in the AIC, the model with beds as a covariate was selected to quantify the impact of beds on the extent of outbreaks.

The resulting unadjusted and adjusted incidence ratios (IRs) for each input variable are provided in Table 3 (supplementary model outputs are provided in Appendix 2).

The number of beds in a home again has an effect with an increasing extent of an outbreak seen with increasing number of beds (IR = 1.08 per 10 beds, 95% CI 1.05 to 1.12, $p<0.001$). 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 previous analysis, local incidence was not deemed a significant predictor for the extent of an outbreak. The occurrence of a previous outbreak within a nursing home was noted to lessen the extent of subsequent outbreaks overall (IR = 0.49, 95% CI 0.28 to 0.84, $p=0.009$). Similar to the previous analysis, a difference was noted between the two waves with smaller outbreaks observed in the second wave (IR = 0.09, 95% CI 0.01 to 1.03, $p=0.036$). An increasing number of days since the beginning of a wave was again associated with having smaller outbreaks (IR = 0.98, 95% CI 0.97 to 0.99, $p<0.001$); however, the interaction between this variable and the wave indicates that again this was only seen within the first wave, while the second wave was associated with marginally larger outbreaks as the wave progressed (IR = 1.03, 95% CI 1.01 to 1.04, $p<0.001$).

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[¥]	1.07	1.03 to 1.10	<0.001	1.08	1.05 to 1.12	<0.001
Local incidence[§]	0.99	0.98 to 1.00	0.105	0.99	0.97 to 1.01	0.373
Nursing home type						
Public (reference)	1.00	-	-	1.00	-	-
Private single	1.11	0.78 to 1.54	0.564	0.95	0.71 to 1.26	0.713
Private multi	1.07	0.72 to 1.59	0.069	1.31	0.93 to 1.85	0.128
Area						
Dublin city (reference)	1.00	-	-	1.00	-	-
City	0.60	0.36 to 1.07	0.066	0.64	0.38 to 1.11	0.108
Town	0.99	0.74 to 1.32	0.958	1.06	0.73 to 1.54	0.757
Village	0.87	0.57 to 1.36	0.515	1.11	0.68 to 1.84	0.674
Rural	1.35	0.91 to 2.04	0.149	1.52	0.91 to 2.53	0.111
Previous outbreak	0.39	0.26 to 0.60	<0.001	0.49	0.28 to 0.84	0.009
Days since beginning of wave	1.00	1.00 to 1.00	<0.001	0.98	0.97 to 0.99	<0.001
Wave two (reference: wave one)	0.62	0.47 to 0.83	0.001	0.09	0.01 to 1.03	0.036
Deprivation	0.94	0.89 to 1.00	0.058	0.99	0.93 to 1.05	0.630
Neighbouring nursing homes	0.99	0.97 to 1.01	0.466	0.99	0.96 to 1.02	0.422
Interaction terms						
Number of beds x Wave 2				1.00	0.93 to 1.08	0.945
Local incidence x Wave two				1.02	0.99 to 1.04	0.272
Days since beginning of wave x Wave two				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.

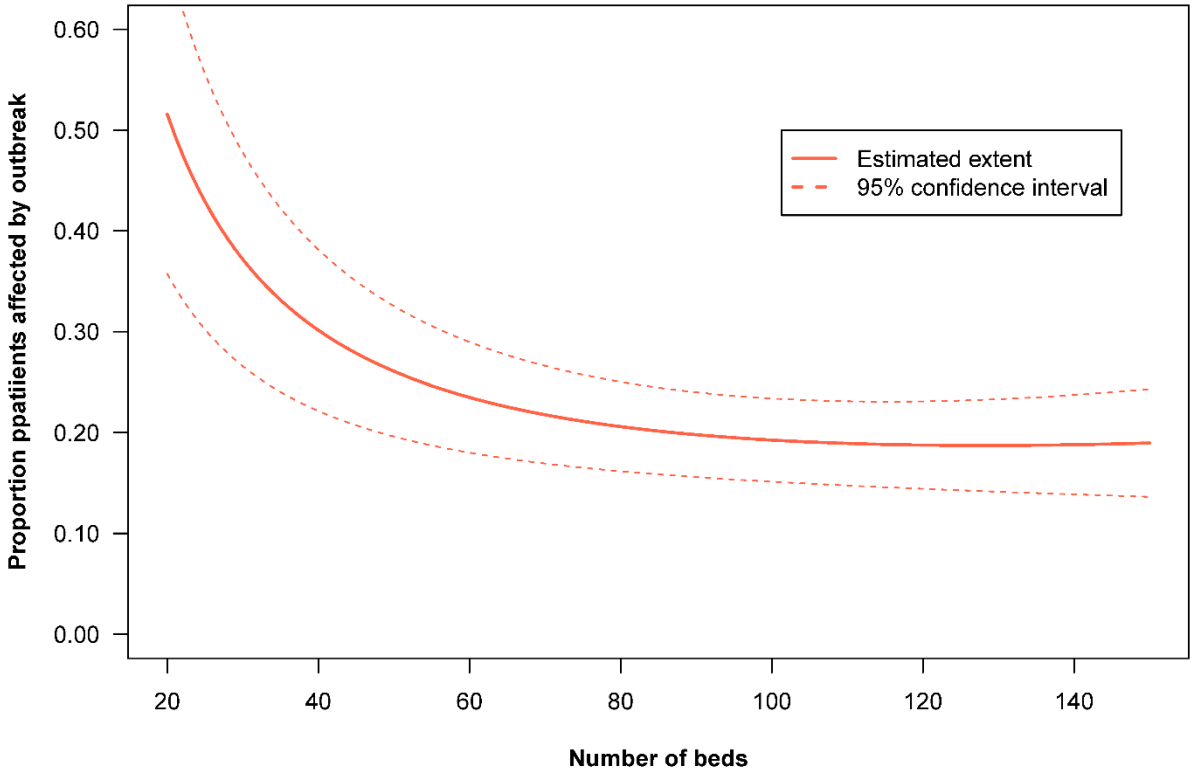
Number of beds

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 of beds. In the following example (Figure 11), a privately-operated nursing home in Dublin is modelled with typical local incidence at the time

of an outbreak during the first wave (day 32, 51 cases per 100,000). Such a home typically has 93 beds, in which we expect an outbreak to include 18 patients (or 19% of residents if the home is at full occupancy). If the home had 56 beds (the average across all homes), then the outbreak would be expected to include 14 cases (25% of residents if the home is at full occupancy).

The important caveat to this understanding 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



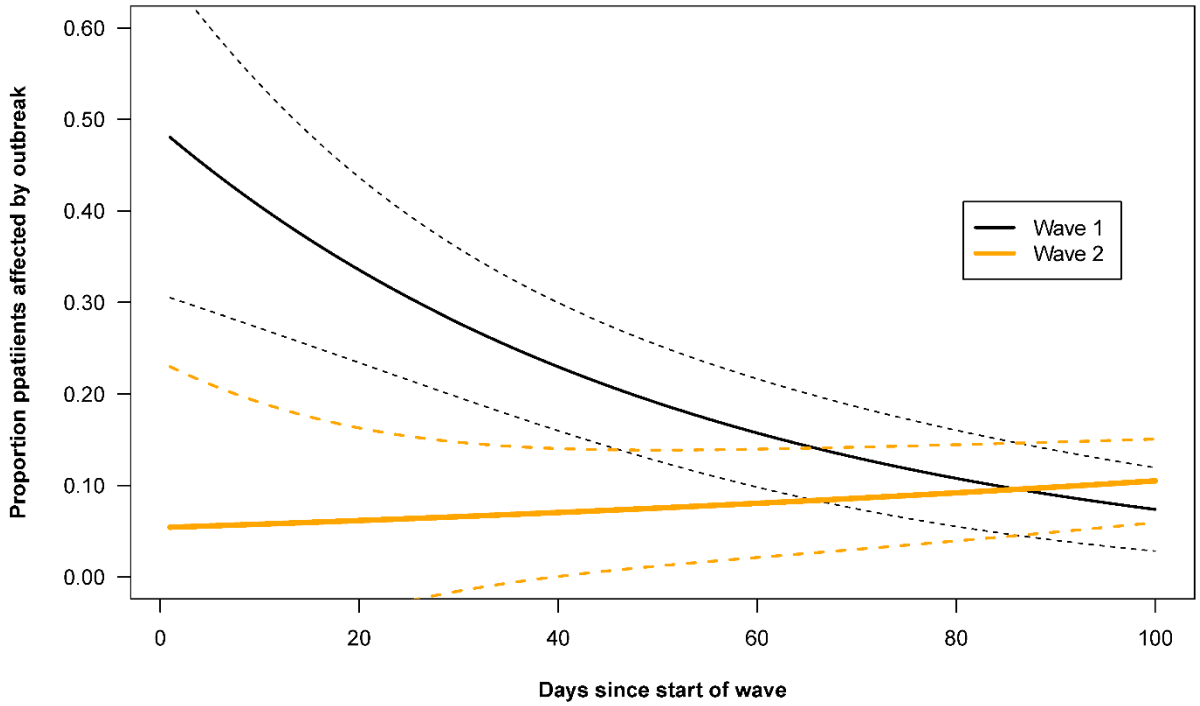
Footnote: example based on a privately operated nursing home in Dublin on day 32 of the first wave with a local incidence of 51 cases per 100,000 population.

Timing of the outbreak

The model estimates indicate that the extent of an outbreak decreased as the first wave progressed, but increased as the second wave progressed. This estimates the extent of an outbreak for a public nursing home in a town, assuming the typical size for a public nursing home in a town (65 beds) and average local incidence for such a home at the time of an outbreak in the first wave (46 cases per 100,000). Ten days into the first wave, the expected size of the outbreak is 28 cases (43%), while on day 70 the expected size is nine cases (14%). For the same home in the second wave, the average local incidence increases to 222 cases per 100,000 at the time of

the outbreak. Under those conditions, the extent of the outbreak is estimated to increase from four cases on day 10 (5%) to six cases on day 70 (9%). While the trend changes with time in the second wave, the magnitude of the rate is low and suggests a much smaller outbreak relative to the first wave (Figure 12).

Figure 12. Proportion of residents effected by an outbreak by days since start of wave

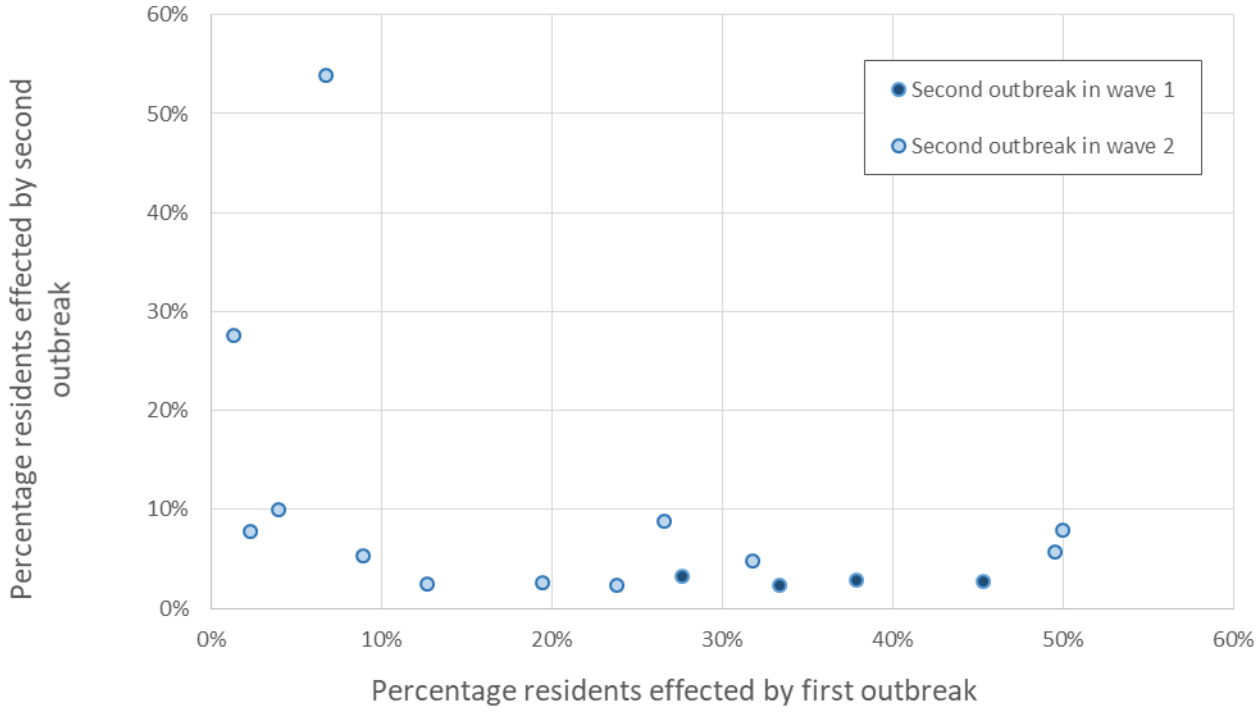


Footnote: example based on a publicly-operated nursing home in a city outside Dublin with 65 beds and a local incidence of 46 cases per 100,000 population at the time of the outbreak.

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 immunity among residents previously infected. Of the 16 homes that experienced a second outbreak among residents, all but two had 10% or fewer residents affected by the second outbreak (Figure 13). The two homes that had more extensive second outbreaks both had less than 10% of residents infected in the first outbreak. The generally low penetration of second outbreaks irrespective of extent of the first outbreak tends to suggest that immunity may not be playing an important role in limiting the extent of subsequent outbreaks. However, in the absence of data on occupancy and mortality, it is not possible to conduct a detailed analysis.

Figure 13. Comparison of extent of first and second outbreak in homes that had two or more outbreaks



Sensitivity analysis

To determine whether the analyses included in this report were robust to underlying assumptions, a range of sensitivity analyses were undertaken.

Neighbouring nursing homes and population density

The main analysis included a covariate of the count of neighbouring nursing homes. This covariate had a statistically significant association with the probability of a SARS-CoV-2 outbreak. An analysis was conducted to see if the number of neighbouring nursing homes might have been acting as a proxy for population density. Although population density was correlated with number of neighbouring nursing homes, it was not associated with outbreaks either when included in place of or in addition to the number of neighbouring nursing homes. It was therefore concluded that number of neighbouring nursing homes was not acting as a proxy for population density.

Neighbouring nursing homes and proportion population aged 65 years and older

Aside from population density, the number of neighbouring nursing homes might be a proxy for the proportion of the population aged 65 years and older. This proportion was added to the model as a covariate, however its inclusion did not impact substantively on the magnitude or direction of effect of the other covariates. An increased proportion population aged 65 years and older was associated with a

reduced probability of an outbreak. On further investigation, the proportion of the population aged 65 years and over is generally low in the Greater Dublin area where the outbreaks mostly occurred in the first wave. Rather than being a plausible risk factor, it is more likely that the covariate is acting as a spatial measure. The local dependency ratio (that is, ratio of those aged less than 18 years and over 64 years to those aged 18 to 64 years) was also investigated as a covariate, but was not found to be statistically significant.

Catchment size

The local catchment areas for nursing homes were used to calculate local incidence of COVID-19 in the community. The catchments were based on aggregations of EDs within a specified travel time of the nursing home. For the main analysis, the catchments were defined to contain a minimum of five and a maximum of 10 EDs. A sensitivity analysis was conducted allowing a minimum of 10 and a maximum of 15 EDs, thereby increasing the average catchment population from 24,394 persons to 33,800 persons. The change of catchment definitions did not change the magnitude or direction of effects in the logistic regression of probability of an outbreak.

Incidence by age group

The main analysis used the 14-day incidence of notified COVID-19 cases in the nursing home catchments. The incidence was calculated as the incidence across all ages. Given public health measures in relation to cocooning for the elderly and restrictions placed on visits to nursing homes, incidence in the working age population may be a more relevant risk factor than total incidence. To test this, incidence was split by age group (less than 65 years of age, and 65 years and older). Incidence in both age groups was similar in the first wave, reaching a similar peak per 100,000 population. In the second wave, incidence was markedly higher in the younger age group. Inclusion of separate incidence for the two age groups had a minor impact on the model overall: the fit was marginally improved in terms of AIC, but there was no substantive impact on the model coefficients. Both incidence measures were statistically significant and had the same direction of effect as total incidence: higher incidence was associated with a greater probability of an outbreak occurring.

Minimum extent of an outbreak

The definition of an outbreak is that it included two or more cases. This minimum extent could create a bias in the extent analysis. For example, in a nursing home with ten beds, an outbreak must affect at least 20% of residents. By contrast, in a 100 bed home the minimum outbreak would include only 2% of residents. To account for this, the analysis was rerun deducting two from both the number of affected cases and the number of beds in the home. In other words, the model estimated the extent over and above the minimum required for an outbreak. The

magnitude and direction of effects were effectively unchanged from the main analysis. The revised model was marginally better at estimating the extent of outbreaks in larger homes, but this was at the expense of an overall higher sum of squared errors.

4. Discussion

This 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. The results of this analysis indicate that, when adjusting for other factors, 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. In terms of the extent of an outbreak, while the absolute size of an outbreak increased with the number of beds in a home, it decreased as a proportion of residents infected. Having experienced a previous outbreak within a nursing home was associated with fewer residents infected in subsequent outbreaks. Within a given wave, the likelihood of an outbreak occurring and the size of outbreaks diminished over time in the first wave, while in the second wave there was a marginal increase over time in the probability and extent of outbreaks. Comparing waves, there was a reduced probability of occurrence and less extensive outbreaks in the second wave. Separate analyses for each wave suggest that outbreaks were more unpredictable in the second wave and did not clearly follow the patterns observed in the first. The associated measures within the analyses indicate that, although a reasonable fit to the data was achieved for both outcomes, important influencing factors exist that have not been included within the models. Such factors likely relate to resident-level and facility-level information which was either not present or inconsistent within the Irish data available.

The effect of the local incidence of COVID-19 within the surrounding community on the probability of an outbreak occurring within a nursing home has been extensively noted in the literature to date, with a rapid review by the National Collaborating Centre for Methods and Tools noting a consistently strong association across the literature.[13] Similarly, the size of the facility has been noted to increase the risk for infection and the likelihood of an outbreak occurring within these settings.[13] Conceivably, the increased risk seen with increasing number of beds may be a consequence of operational footfall with more staffing requirements and therefore greater opportunity for the virus to enter a facility.[14, 15] However, it has been noted in similar analyses that this factor is likely reliant on elements such as occupancy levels, density, layout of the facility, or staff to resident ratios, factors for which reliable Irish data were not available.[13] In terms of occupancy levels and the physical layout of a home, a large retrospective cohort study of Canadian nursing homes noted that crowding was common in the sampled homes (measured by the number of residents per bedroom and bathroom) and associated with overall COVID-19 incidence and mortality.[16] When considering the impact of the size of the nursing home, the model of care delivered may also be an important consideration.

A US study comparing non-traditional and traditional nursing homes cited notably lower incidence and mortality rates in residents of smaller ('Green House') homes compared with larger traditional model homes.[17] The finding of an increased odds of an outbreak occurring in a nursing home which is in close proximity to other nursing homes (independent of local incidence, area type or population density) may be a proxy measure for another factor; however, given the limited data available to this analysis, it is not possible to determine what that factor is. Furthermore, this association was observed to be limited in magnitude overall. Of note, no association was observed between the probability of an outbreak occurring and the type of nursing home (that is, publicly or privately operated). Within the international literature, for-profit status has previously been noted to be associated with an increased risk of outbreaks, infections and mortality rates within these settings.[13]

With regards to the extent of an outbreak once such an event occurs, the findings of this analysis indicate that although community incidence may influence the likelihood of SARS-CoV-2 entering a home, it does not appear to influence the number of residents likely to be infected. 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.[3, 5] Additionally, the finding of having experienced a previous outbreak within a nursing home being associated with a reduction in the extent of subsequent outbreaks may reflect that learning occurred following the first outbreak, with improvement and refinement of measures to contain outbreaks as the epidemic has progressed. However, this may also be an artefact of the extent and outcomes of the previous outbreak, for example development of protective immunity in those previously infected, mortality rates, or changes in occupancy levels and demography during the time elapsed. It may also be a consequential effect due to the majority of subsequent outbreaks occurring within the second wave where extent tended to be smaller overall.

Between the first and second waves of the epidemic, both a reduction in the probability of an outbreak occurring in a nursing home and the number of residents infected per outbreak were observed despite the increased national incidence of COVID-19 in the second wave. In the initial phases of the epidemic, the novelty of the SARS-CoV-2 virus presented an unprecedented time-sensitive challenge in terms of understanding the epidemiological characteristics and the effective methods for reducing transmission of the virus. This was particularly evident in nursing homes with the peak in outbreaks in these facilities preceding the peak of community incidence (see results section Figure 1). This likely reflects the observation of a reducing likelihood and extent as time passed in the first wave but not the second. Of note, an Irish survey of nursing home residents and staff conducted in the first wave observed that within an outbreak, there was a correlation between the number

of suspected or confirmed cases in residents and the proportion of staff with symptomatic COVID-19. The survey further identified that, on the basis of a point-prevalence testing programme, a quarter of staff with confirmed COVID-19 were asymptomatic. The authors concluded that this finding emphasises the requirement for systematic point-prevalence (serial) testing to reduce risk of transmission and manage outbreaks.[18]

As the epidemic has progressed in Ireland, strategies to reduce transmission risk in nursing homes have been increasingly developed, adopted and enhanced such as visitation restrictions, active monitoring of staff and residents for signs or symptoms, guidance for resident transfers, serial testing of staff and residents, personal protective equipment supply and use, and increased provision of training in infection prevention and control measures.[3] Such measures likely impacted the occurrence and extent of outbreaks of SARS-CoV-2, in conjunction with the changing demography of cases (see results section Figure 2) within the second wave of the epidemic. However, given the marked increase in incidence nationally, the strain on testing capacity and the emergence of a number of variants of concern since December 2020, it is not clear if such an effect will be maintained within the third wave. This wave may be further impacted by the rollout of the vaccination programme which commenced in January 2021 and is expected to be largely completed for nursing home residents and staff by the end of February 2021.

As noted, the exploration of factors associated with mortality in nursing home residents was outside the scope of this analysis. This form of analysis would be challenging given the current lack of available data for important factors; in particular, key resident-level data (for example, demography and functional dependency) which would serve as confounders within such an analysis. While such data may exist for some residents, such as those that were admitted to hospital for treatment, details of residents within the nursing home population as a whole are lacking, limiting the potential for comparison and appropriate interpretation of results.

Limitations

The overall results of this analysis were limited by the lack of potentially important data relating to resident-level and facility-level factors. A number of covariates 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), or the demography and dependency level of residents within a nursing home[13] were not available for all homes, were not presented consistently, or were in a format unsuitable for analysis. There was an absence of reliable data regarding staffing levels and skill-mix, the ratio of staff to residents, and the movement between nursing homes. These staffing factors have been cited as playing significant

roles as both risk and protective factors for the occurrence and extent of outbreaks in such facilities.[13, 19] Additionally, information relating to the transfer of residents to and from hospital environments may further inform these results with some international evidence to suggest that such movement may play a significant role in seeding initial infection in these settings.[20] Strict policies and guidance for such transfers exist in Ireland.[3, 21]

Data related to some variables, such as occupancy levels, staffing levels, and compliance with regulations related to infection prevention and control 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. Additionally, a number of explanatory variables included within the analyses may serve as proxies or have important interactions with such factors and may impact on the overall findings of this report. For example, the number of beds in a home was used as a proxy for the number of residents in a home. This may not be a suitable proxy if, for example, occupancy rates were typically lower in larger homes. However, an analysis of data collected periodically by HIQA's Regulation Directorate suggest that occupancy levels are not correlated with home size.

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, such as influenza. Such data collection should be uniform across public and private nursing homes to enable reliable assessments to be made and to ensure all homes are suitably supported to protect the health of residents. Any such data collection should be compliant with national data collection standards and be carefully considered in terms of the resources to collect and maintain the data compared to its usefulness to improve care and inform decision-making. If additional data are to be collected, relevant stakeholders should be consulted to ensure the feasibility of collection and relevance of the data. Formal study designs could also be considered within a sample of nursing homes, such as prospective case-control approaches, which may enable more detailed examination of risk and protective factors for these settings.

Privately operated nursing homes were categorised based on the provider operating one or more nursing homes within the dataset; however, this does not take into account that multiple providers (companies) may be owned by the same people. In essence, there may be homes categorised as single ownership which are in fact one of several owned by the same people; however, this information is not included within the available datasets. However, given the non-significant impact of nursing

home type within the analysis it is not anticipated that this would result in a considerable change to the overall findings.

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 an analysis of risk factors associated with the occurrence of those outbreaks. At the outset of the epidemic, some outbreaks were unconfirmed and did not have associated cases. The data include the date of notification for the first and last included case and, where available, the date of symptom onset. The lag between symptom onset and notification can be substantial depending on delays in having a sample taken, the sample being tested, and the notification being uploaded to the system. During March and April, due to capacity constraints some samples were sent to Germany for testing resulting in delays in notifications. Where possible, the date for the start of an outbreak was based on the earliest known date associated with that outbreak. In some cases this will be a date of onset while in others it may be the date on which the outbreak was recognised. For some outbreaks, the available data may under or over-estimate the true timing of the outbreak, but it is anticipated that the discrepancy should be of the order of days and have a limited impact on the analysis results. While cases in outbreaks are categorised as resident or healthcare worker, the category is unknown in 11% of cases. For the main analysis, only those confirmed as residents were included. For some outbreaks, treating those of unknown status as residents meant that the number of cases exceeded the number of beds in a home, indicating that those of unknown status includes healthcare workers. The analysis of extent was limited to confirmed outbreaks involving two or more residents. The data on cases was also split by those aged less than 65 years, and those aged 65 years and over. However, this was also found to be unreliable for distinguishing between residents and healthcare workers. In the absence of reliable data on staffing levels, it was not possible to analyse the extent of outbreaks among staff.

The local incidence in the vicinity of nursing homes was calculated using data on cases geocoded to small areas. 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. There are a variety of ways of defining spatio-

temporal models. For example, a multi-level model structure could have been used where homes are nested within counties, for example. A limitation of such an approach is that in large counties, there may be substantial heterogeneity in incidence across the county. The county-level incidence may not be representative of the incidence around a given nursing home. While homes near each other will have similar local incidence, the model does not capture the fact that homes close to each other geographically may be more likely to have outbreaks because of some other characteristic of the area. In the absence of other plausible area-level risk factors, it is unclear how a spatial model would in this instance improve our understanding of where outbreaks occurred.

It is also important to acknowledge the changing response to the epidemic over time. The public health measures have been adapted, including adoption of localised interventions in response to increased incidence and increased infection prevention and control support. Capacity for testing and the ability to carry out serial testing have increased over time, providing the prospect of limiting the risk of exposure to pre-symptomatic and asymptomatic individuals. There is likely to be much variability across nursing homes in terms of the layout which may impact on the ability to manage the risk of outbreaks occurring and in containing them once they have occurred. For example, a nursing home with multiple floors or living areas may be in a better position to ensure that infection is contained within one area of the home. It is unlikely that there are any quantifiable measures, collected routinely, that would adequately capture the conditions in a given home.

The analysis did not consider mortality. Across a nursing home system with 32,027 beds, there was an estimated 813 COVID-19 deaths in the first wave, and 105 deaths in the second wave. The loss of life resulted in reduced occupancy in nursing homes, and it is unclear if and when occupancy levels returned to pre-epidemic levels. While deaths in the first wave represent 2.5% of all nursing home residents, there is likely to have been substantial variation in mortality rates across homes that had outbreaks. A home with high mortality due to an outbreak of COVID-19 may have had a prolonged period of reduced occupancy after the outbreak, impacting on the likelihood and extensiveness of further outbreaks. It was outside the scope of this analysis to consider mortality.

As a number of linked data sources were utilised within this analysis, there were some challenges with the consistency of the data presented, for example the coding of healthcare worker infection. Additionally, given the unprecedented scale of the initial stages of the epidemic, a number of early outbreaks represented suspected rather than confirmed events. For the purposes of the main analysis, these outbreaks were excluded, however they are included, alongside those limited to healthcare workers, as supplementary analyses in Appendix 1. The inclusion of

healthcare workers in the analysis of the extent of an outbreak was limited by the previously mentioned lack of data on staffing levels.

Overall, causal risk factors could not be established due to the lack of availability of relevant data for establishing causal relationships. The results of the analysis should be considered to be descriptive in nature, and as such this report and the related findings are limited to a high level exploratory analysis.

Conclusions

This 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 and, where an outbreak occurs, what factors influence the extent of an outbreak overall. The findings of the analysis indicate 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. In terms of the extent of an outbreak, the absolute size of an outbreak increased with the number of beds in a home, however it decreased as a proportion of residents infected. Having experienced a previous outbreak was associated with smaller subsequent outbreaks, potentially as a consequence of the previous outbreak such as immunity or learning around outbreak management. There was both a reduced probability of an outbreak occurring, and smaller outbreaks in terms of extent, in the second wave of the epidemic compared with the first. No association was observed between nursing home type (that is publicly or privately operated) and either outcome within this analysis.

The analyses were limited by a lack of reliable local data for a number of potentially influential factors and, as such, should be considered as an exploratory analysis. Consideration should be given to the collection of such data; however, this should be compliant with national standards and carefully balanced between feasibility and utility. Given the notable epidemiological differences of the third wave, and the rollout of a comprehensive vaccination programme in nursing homes, it is unclear if the results of the present analysis will apply to the third wave or potential future waves.

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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 (all possible outbreaks)

Characteristic	All nursing homes	Affected by outbreak involving residents			
		Wave 1		Wave 2	
		Yes (outbreak)	No (no outbreak)	Yes (outbreak)	No (no outbreak)
Homes (n)	572	254	318	79	493
Beds, mean (SD)	56.0 (30.8)	69.9 (35.1)	44.9 (21.0)	70.6 (37.5)	53.6 (28.9)
Homes within 5km/15 minutes, mean (SD)	2.9 (4.6)	4.3 (5.6)	1.8 (3.2)	4.1 (5.2)	2.7 (4.5)
Home type, n (%)					
Public	113 (20%)	49 (37%)	64 (15%)	20 (50%)	93 (17%)
Private (single)	360 (63%)	151 (114%)	209 (48%)	43 (108%)	317 (60%)
Private (multi)	99 (17%)	54 (41%)	45 (10%)	16 (40%)	83 (16%)
Outbreak count, n (%)					
1	233 (145%)	234 (177%)		75 (188%)	
2	53 (33%)	18 (14%)		4 (10%)	
3	4 (2%)	2 (2%)		0 (0%)	
4	2 (1%)	0 (0%)		0 (0%)	
Local 14-day incidence per 100,000,* mean (SD)					
Average	58.9 (27.1)	35.0 (25.3)	22.5 (24.1)	111.9 (48.8)	93.3 (48.0)

Characteristic	All nursing homes	Affected by outbreak involving residents			
		Wave 1		Wave 2	
		Yes (outbreak)	No (no outbreak)	Yes (outbreak)	No (no outbreak)
Max	387.1 (269.3)	191.9 (184.9)	136.8 (189.6)	381.5 (220.1)	350.5 (244.3)
Area type, n(%)					
City (Dublin)	92 (16%)	72 (55%)	20 (5%)	15 (38%)	77 (14%)
City (other)	46 (8%)	12 (9%)	34 (8%)	8 (20%)	38 (7%)
Town	220 (38%)	99 (75%)	121 (28%)	40 (100%)	180 (34%)
Village	81 (14%)	23 (17%)	58 (13%)	7 (18%)	74 (14%)
Rural	133 (23%)	48 (36%)	85 (19%)	9 (23%)	124 (23%)
Deprivation quintile, n (%)					
1 (least deprived)	105 (18%)	57 (43%)	48 (11%)	14 (35%)	91 (17%)
2	77 (13%)	36 (27%)	41 (9%)	13 (33%)	64 (12%)
3	67 (12%)	29 (22%)	38 (9%)	15 (38%)	52 (10%)
4	112 (20%)	52 (39%)	60 (14%)	10 (25%)	102 (19%)
5 (most deprived)	211 (37%)	80 (61%)	131 (30%)	27 (68%)	184 (35%)

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

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

Variable	Unadjusted							Adjusted						
	OR	95%CI lower	95% CI upper	Estimate	Std. Error	z value	*p*-value	OR	95%CI upper	95% CI lower	Estimate	Std. Error	z value	*p*-value
(Intercept)	-	-	-	-	-	-	-	0.01	0.01	0.02	-4.32	0.28	-15.69	<0.001
Days since beginning of wave	0.99	0.99	0.99	-0.01	0.00	-8.49	<0.001	0.98	0.98	0.99	-0.02	0.00	-11.56	<0.001
Number of beds	1.17	1.14	1.20	0.15	0.01	11.62	<0.001	1.14	1.07	1.22	0.13	0.03	3.89	<0.001
Type (reference: public)														
Private (single)	0.95	0.73	1.26	-0.05	0.14	-0.34	0.737	0.77	0.57	1.04	-0.26	0.15	-1.73	0.083
Private (multi)	1.25	0.90	1.73	0.22	0.17	1.34	0.181	0.91	0.63	1.31	-0.09	0.18	-0.50	0.614
Area (reference: Dublin city)														
City	0.34	0.21	0.54	-1.07	0.25	-4.34	<0.001	0.54	0.31	0.94	-0.61	0.29	-2.12	0.034
Town	0.55	0.42	0.71	-0.60	0.13	-4.63	<0.001	0.89	0.58	1.37	-0.12	0.22	-0.55	0.583
Village	0.30	0.20	0.45	-1.19	0.21	-5.78	<0.001	0.62	0.35	1.09	-0.48	0.29	-1.67	0.094
Rural	0.38	0.27	0.51	-0.98	0.16	-6.08	<0.001	0.74	0.44	1.24	-0.31	0.26	-1.16	0.245
Local incidence	1.01	1.01	1.02	0.01	0.00	3.57	<0.001	1.03	1.02	1.03	0.03	0.00	6.72	<0.001
Deprivation score	0.95	0.90	1.01	-0.05	0.03	-1.69	0.092	0.94	0.88	1.00	-0.06	0.03	-1.88	0.060
Neighbour home	1.06	1.05	1.08	0.06	0.01	6.97	<0.001	1.03	0.99	1.06	0.03	0.02	1.60	0.109
Previous outbreak	1.12	0.51	2.11	0.11	0.36	0.32	0.751	1.08	0.46	2.22	0.07	0.40	0.18	0.854
Wave two (reference: one)	0.37	0.28	0.46	-1.01	0.13	-8.04	<0.001	0.06	0.03	0.11	-2.79	0.29	-9.68	<0.001

Interaction terms														
Number of beds x Private (single)								1.03	0.96	1.11	0.03	0.04	0.89	0.374
Number of beds x Private (multi)								0.97	0.89	1.06	-0.03	0.05	-0.63	0.527
Days since beginning of wave x wave two								1.03	1.02	1.04	0.03	0.00	6.50	<0.001
Number of beds x wave two								0.96	0.90	1.03	-0.04	0.03	-1.10	0.271
Local incidence x wave two								0.99	0.97	1.00	-0.01	0.01	-1.52	0.129

Appendix 2 – Supplementary model outputs: Main analysis of confirmed outbreaks involving residents

Table A2.1. Supplementary model outputs for factors associated with the occurrence of a confirmed outbreak involving residents

Variable	Unadjusted							Adjusted						
	OR	95%CI lower	95%CI upper	Estimate	Std. Error	z value	*p*-value	OR	95%CI lower	95% CI upper	Estimate	Std. Error	z value	*p*-value
Intercept	-	-	-	-	-	-	-	0.01	0.00	0.02	-4.91	0.38	-12.80	<0.001
Days since beginning of wave	0.98	0.98	0.98	-0.02	0.00	-9.15	<0.001	0.97	0.96	0.98	-0.03	0.00	-10.25	<0.001
Number of beds	1.19	1.15	1.23	0.18	0.02	9.99	<0.001	1.14	1.02	1.25	0.13	0.05	2.50	0.012
Type (reference: public)														
Private (single)	1.13	0.77	1.71	0.12	0.20	0.60	0.550	0.91	0.59	1.42	-0.10	0.22	-0.44	0.657
Private (multi)	1.54	0.97	2.48	0.43	0.24	1.82	0.069	1.16	0.69	1.94	0.15	0.26	0.57	0.571
Area (reference: Dublin city)														
City	0.32	0.16	0.59	-1.14	0.33	-3.46	0.001	0.66	0.30	1.39	-0.41	0.39	-1.06	0.290
Town	0.44	0.31	0.62	-0.83	0.18	-4.71	<0.001	0.89	0.50	1.61	-0.12	0.30	-0.40	0.689
Village	0.32	0.18	0.52	-1.15	0.26	-4.38	<0.001	0.86	0.40	1.84	-0.15	0.39	-0.40	0.691
Rural	0.22	0.13	0.35	-1.52	0.25	-6.11	<0.001	0.57	0.27	1.22	-0.56	0.38	-1.46	0.144
Local incidence	1.01	1.00	1.02	0.01	0.01	1.88	0.060	1.03	1.02	1.04	0.03	0.01	5.56	<0.001
Deprivation score	0.95	0.87	1.02	-0.06	0.04	-1.34	0.181	0.95	0.87	1.03	-0.05	0.04	-1.23	0.219
Neighbouring nursing homes	1.09	1.06	1.11	0.08	0.01	7.12	<0.001	1.05	1.00	1.10	0.05	0.02	2.08	0.038
Previous outbreak	2.71	0.45	8.49	1.00	0.71	1.40	0.162	2.19	0.35	7.59	0.78	0.75	1.05	0.296
Wave two (reference: wave one)	0.39	0.27	0.54	-0.94	0.17	-5.42	<0.001	0.05	0.02	0.11	-2.96	0.38	-7.75	<0.001
Interaction terms														

Number of beds x Type (Private- single)								1.07	0.96	1.19	0.07	0.05	1.23	0.220
Number of beds x Type (Private- multi)								0.96	0.84	1.09	-0.05	0.06	-0.70	0.485
Days since beginning of wave x Wave two								1.04	1.03	1.05	0.04	0.01	6.26	<0.001
Number of beds x Wave two								0.95	0.87	1.03	-0.05	0.04	-1.23	0.217
Local incidence x Wave two								0.98	0.95	1.00	-0.02	0.01	-1.86	0.062

Table A2.2. Supplementary model outputs for factors associated with the extent of a confirmed outbreak involving residents

	Unadjusted							Adjusted						
	IR	**95%CI lower**	**95%CI upper**	**Estimate**	**Std. Error**	**z value**	***p-value***	**IR**	**95%CI lower**	**95%CI upper**	**Estimate**	**Std. Error**	**z value**	***p-value***
(Intercept)	-	-	-	-	-	-	-	20.98	11.93	37.41	3.04	0.28	10.68	<0.001
Number of beds	0.99	0.99	1.00	-0.01	0.00	-4.02	<0.001	1.01	1.00	1.01	0.01	0.00	4.89	<0.001
Local incidence	0.99	0.98	1.00	-0.01	0.01	-1.26	0.207	0.99	0.97	1.01	-0.01	0.01	-0.89	0.373
Type (reference: public)														
Private (single)	0.93	0.66	1.29	-0.07	0.17	-0.43	0.668	0.95	0.71	1.26	-0.05	0.15	-0.37	0.713
Private (multi)	0.95	0.64	1.41	-0.05	0.20	-0.24	0.807	1.31	0.93	1.85	0.27	0.18	1.52	0.128
Area (reference Dublin city)														
City	0.75	0.45	1.34	-0.28	0.28	-1.02	0.307	0.64	0.38	1.11	-0.44	0.28	-1.61	0.108
Town	1.19	0.89	1.58	0.17	0.14	1.20	0.229	1.06	0.73	1.54	0.06	0.19	0.31	0.757
Village	1.37	0.90	2.12	0.31	0.22	1.45	0.148	1.11	0.68	1.84	0.11	0.25	0.42	0.674
Rural	1.73	1.17	2.61	0.55	0.20	2.69	0.007	1.52	0.91	2.53	0.42	0.26	1.59	0.111
Neighbour home	0.98	0.96	1.00	-0.02	0.01	-1.95	0.051	0.99	0.96	1.02	-0.01	0.02	-0.80	0.422
Previous outbreak	0.25	0.17	0.38	-1.38	0.20	-6.80	<0.001	0.49	0.28	0.84	-0.71	0.27	-2.60	0.009
Deprivation	0.98	0.92	1.04	-0.02	0.03	-0.79	0.432	0.99	0.93	1.05	-0.01	0.03	-0.48	0.630
Days since beginning of wave	1.00	1.00	1.00	0.00	0.00	-2.49	0.013	0.98	0.97	0.99	-0.02	0.00	-4.82	<0.001
Wave two (reference: one)	0.73	0.55	0.98	-0.32	0.15	-2.15	0.031	0.09	0.01	1.03	-2.37	1.13	-2.10	0.036
Interaction terms														
Number of beds x wave two								1.00	0.99	1.01	0.00	0.00	-0.07	0.945
Incidence x wave two								1.02	0.99	1.04	0.01	0.01	1.10	0.272
Days since beginning of wave x wave two								1.03	1.01	1.04	0.03	0.01	4.21	<0.001

Published by the Health Information and Quality Authority.

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