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Original Research

Investigating the association between COVID-19 vaccination and care home outbreak frequency and duration



D.T. Bradley ^{a,b}, S. Murphy ^{b,*}, P. McWilliams ^c, S. Arnold ^a, S. Lavery ^a, J. Murphy ^a, S. de Lusignan ^d, R. Hobbs ^e, R.S.M. Tsang ^d, A. Akbari ^f, F. Torabi ^g, J. Beggs ^h, A. Chuter ^h, T. Shi ⁱ, E. Vasileiou ⁱ, C. Robertson ^{j,k}, A. Sheikh ^{i,h}, H. Reid ^a, D. O'Reilly ^b

^a Public Health Agency, Belfast, UK

^b Centre for Public Health, Queen's University Belfast, Belfast, UK

^c Strategic Investment Board, Belfast, UK

^d Nuffield Department of Primary Care Health Sciences, University of Oxford, Oxford, UK

^e Nuffield Department of Health Care Sciences, University of Oxford, Oxford, UK

^f Population Data Science and Health Data Research UK, Swansea University, Swansea, UK

^g Population Data Science, Swansea University Medical School, UK

^h BREATHE- The Health Data Research Hub For Respiratory Health, UK

ⁱ Usher Institute, University of Edinburgh, Edinburgh, UK

^j Public Health Scotland, UK

^k University of Strathclyde, Glasgow, UK

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ABSTRACT

Objectives: At the end of 2020, many countries commenced a vaccination programme against SARS-CoV-2. Public health authorities aim to prevent and interrupt outbreaks of infectious disease in social care settings. We aimed to investigate the association between the introduction of the vaccination programme and the frequency and duration of COVID-19 outbreaks in Northern Ireland (NI).

Study design: We undertook an ecological study using routinely available national data.

Methods: We used Poisson regression to measure the relationship between the number of RT-PCR confirmed COVID-19 outbreaks in care homes, and as a measure of community COVID-19 prevalence, the Office for National Statistics COVID-19 Infection Survey estimated the number of people testing positive for COVID-19 in NI. We estimated the change in this relationship and estimated the expected number of care home outbreaks in the absence of the vaccination programme. A Cox proportional hazards model estimated the hazard ratio of a confirmed COVID-19 care home outbreak closure.

Results: Care home outbreaks reduced by two-thirds compared to expected following the introduction of the vaccination programme, from a projected 1625 COVID-19 outbreaks (95% prediction interval 1553–1694) between 7 December 2020 and 28 October 2021 to an observed 501. We estimated an adjusted hazard ratio of 2.53 of the outbreak closure assuming a 21-day lag for immunity.

Conclusions: These findings describe the association of the vaccination with a reduction in outbreak frequency and duration across NI care homes. This indicates probable reduced harm and disruption from COVID-19 in social care settings following vaccination. Future research using individual level data from care home residents will be needed to investigate the effectiveness of the vaccines and the duration of their effects.

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Introduction

COVID-19 has caused a disproportionately high number of deaths among the residents of care homes in the UK;¹ an experience shared by other countries.^{2–5} In Northern Ireland (NI), there

* Corresponding author.

E-mail address: siobhan.murphy@qub.ac.uk (S. Murphy).

have been 1127 COVID-19-related deaths among care home residents by the week ending 5 November 2021.⁶ Care home residents may be at high risk of exposure to SARS-CoV-2 because of outbreaks in these closed settings and greater vulnerability to severe outcomes because of age and comorbidities.^{2,3} A range of factors contribute to the risk, size and duration of outbreaks in care homes, including the background community incidence of infection, the prevalence of infection in care home staff, care home size, the use of bank and agency staff, regional variation and whether homes provided sick pay to their staff.^{5,7} Although comparison of mortality rates across different stages of the pandemic is difficult, international evidence demonstrates a lower level of excess deaths among care home residents in the second wave of the pandemic.⁸ This suggests that the enhancement of infection prevention and control measures, including the restriction of visiting, cohorting of staff and/or the increased testing of staff and residents may have reduced transmission compared to the earlier period, although there may also have been some displacement of the timing of deaths, bringing deaths forwards in time during the first wave.

In light of the exposure and vulnerability of care home residents to SARS-CoV-2, the UK Joint Committee on Vaccination and Immunisation recommended that residents and staff of the care home should be the first group to be offered vaccination when it became available in late 2020.⁹ On 8 December 2020, Health and Social Care (HSC) Trusts (public healthcare providers) began a vaccination programme for staff and residents in care homes in NI. The programme primarily used Pfizer BioNTech COVID-19 mRNA Vaccine BNT162b2 (with a small number of exceptions for *ad hoc* doses of the AstraZeneca COVID-19 vaccine given to those who missed vaccination at the time of the visit to the care home by those delivering the vaccination programme). In contrast to the other parts of the UK, NI delivered the great majority of the care home vaccination programme with a 21-day interval between doses, as most implementation occurred before the change in policy to a 12-week dosing interval, which was announced on 31 December 2020. In advance of individual-level data being available, we sought to investigate the association between the COVID-19 vaccination programme on the COVID-19 outbreak frequency and duration. The vaccination programme was introduced at a time when there were changes in non-pharmaceutical interventions (including a period of 'lockdown') in NI, which were associated with considerable changes in the growth of the epidemic. Investigation of the association between the vaccination programme and changes in COVID-19 outcomes, therefore, needed to use methods that would not be confounded by this changing context. The aim of our study was to assess the association of the COVID-19 vaccine programme and the frequency and duration of confirmed COVID-19 outbreaks in care homes.

Methods

Research ethics

This study was undertaken using routine data, accessed under pre-existing information governance arrangements, for the purpose of health protection surveillance and health and social care service delivery and evaluation. Research ethics approval was not required.

Study population

There were 480 operational care homes in NI on 18 November 2021 (Table 1).¹⁰ Care home occupancy is dynamic over time, although occupancy is high. The majority of homes were independent, with some directly operated by HSC Trusts.

Table 1
Number and size of care homes registered in NI on 18 November 2021.

Care home type	Number	Maximum approved places
Residential	235	5344
Nursing	245	10,710
Total	480	16,054

Definitions

Possible case of COVID-19

Any resident (or staff) with symptoms of COVID-19 (high temperature, new continuous cough or loss of taste/smell), or new onset of influenza-like illness or worsening shortness of breath. Symptoms may be more nuanced in older people with comorbidities in care homes who may present with Flu-Like Illness (FLI), respiratory illness, new-onset confusion, reduced alertness, reduced mobility, or diarrhoea and sometimes do not develop fever. This may be true for COVID-19, so such changes should alert staff to the possibility of new COVID infection.

Confirmed case of COVID-19

Any resident (or staff) with Reverse Transcription Polymerase Chain Reaction (RT-PCR) laboratory-confirmed diagnosis of COVID-19.

COVID-19 outbreak

Two or more cases in a facility, which meet the case definition of a possible or confirmed case of COVID-19, within a 14-day period among either residents or staff in the care home.

Confirmed COVID-19 outbreak

Identification of two or more confirmed COVID-19 cases (both symptomatic and asymptomatic detection), among either residents or staff in the care home, within a 14-day period.

Closed outbreaks

An outbreak was closed when there had been no new cases for 14 days after symptom onset of the most recent case, and a terminal clean was complete.

Data sources and preparation

Daily returns from care homes to the Regulation and Quality Improvement Authority

All care homes in NI participated in a monitoring scheme through which they submitted daily aggregate data to the Regulation and Quality Improvement Authority (RQIA). Summary information from these reports was made available to us in the Public Health Agency (PHA). The submissions from each care home for the previous calendar month, along with the maximum number of staff employed and the number of beds occupied during that month, were used to estimate the number of staff and residents for each care home.

Care home outbreak surveillance

The PHA health protection (HP) team was notified by care homes of cases of COVID-19. An outbreak was declared when two or more cases among care home residents or staff in a facility meet the case definition of a possible or confirmed case of COVID-19 within a 14-day period, according to the definitions above.¹¹ Once an outbreak was notified, the information was entered into the management information system, HP Zone. Data were extracted

from HP Zone by the HP surveillance team, cleaned and entered into a database.

Office for National Statistics (ONS) COVID-19 Infection Survey (CIS)

The ONS CIS tests approximately 5000 people for COVID-19 in NI over two-week time windows and provides openly available modelled estimates of the number of people in NI who would test positive if tested.¹² This is an estimate of community prevalence of COVID-19, which does not include care homes or hospitals. Full details of the survey methods are available from the ONS.¹² We used the 'Estimated number of people testing positive for COVID-19' from 'Official reported estimates of the percentage of the population testing positive for COVID-19, NI', from 17 October 2020 to 23 October 2020, to 31 October 2021 to 6 November 2021, which was the full range of results available that used a consistent method.

Testing practices

A regular programme of COVID-19 testing (screening) for all care home residents and staff in NI commenced on 3 August 2020. All asymptomatic residents were tested for COVID-19 every 28 days, and all asymptomatic staff were tested every 7 days with an RT-PCR test. Health and Social Care Trusts offered Loop-mediated isothermal amplification (LAMP) tests for residents for whom RT-PCR testing was unsuitable, but we were advised by the responsible team in PHA that this was used very rarely. If a single case was identified through a positive test result, the whole home was tested. Detailed guidance was provided to homes about the pattern of testing during and after outbreaks.

Statistical methods

Outbreak frequency

We used the ONS CIS estimated number of people testing positive for COVID-19 as a measure of the severity of the epidemic in the general population. We explored the relationship between this measure and the weekly frequency of new PCR-confirmed COVID-19 care home outbreaks by plotting these in a scatter plot. We used *ccf* in R v 4.0.2 for the cross-correlation function to assess the time lag between the variables and applied the time lag associated with the maximum correlation before fitting a Poisson regression model using *glm* in R v 4.0.2. We chose a Poisson model because the dependent variable was a count of events, and the low-value daily counts of care home outbreaks did not meet the assumptions required for linear regression. We divided the time series into a pre-vaccination period, before 7 December 2020, a 'washout' period from 7 December 2020 to 28 February 2021 inclusive, and a post-vaccination period from 1 March 2021 to 3 November 2021. The majority of care homes had their first vaccinations delivered during December 2020 (Fig. S1). Staff and residents were offered vaccination at the same time. Those that were in an outbreak at the time vaccination was due were deferred. By the end of December 2020, at least 356 (74%) had their first dose, and by the end of January 2021, at least 404 (84%) had their first dose (for these estimates, any incompleteness in reporting will bias the estimate downwards). This three-month 'washout' period conservatively allowed the great majority of care homes to have been given two visits for vaccination (with the 21-day dosing interval), with time for an immune response to the second dose. ONS CIS results were reported weekly as midpoint estimates of the reported week, so we added three to the first day of the reporting window to make the value represent the middle of the time period, and interpolated daily estimates using *spline(method = "fmm")* in R v4.0.2. Poisson generalised linear regression models were created for the pre-vaccination and postvaccination time periods separately to

investigate the relationship in each time period, then in a single multivariable model with the prevaccination time period as the reference category. This was conducted for all care homes and for nursing and residential homes separately. The expected number of care home outbreaks in the absence of the vaccination programme was projected from the observed number of community-acquired COVID-19 hospitalisations using *predict.glm* to estimate the daily and the total number of new care home outbreaks that would have been expected if the conditions of the prevaccination time period had continued. The total projected number of outbreaks for the time and its confidence limits were estimated by 1000 simulations that used *rpois* for random daily projections, summing the projected number of outbreaks in the time period for each simulation, and taking the median and the 2.5% and 97.5% quantiles of the simulated total outbreak counts.

Outbreak closure

A Cox proportional hazards model was used to produce the hazard ratios (HR) and 95% confidence intervals (CIs) to measure the hazard ratio for a care home COVID-19 outbreak being declared over. The likelihood of an outbreak is known to be directly related to care home size.^{5,13} For this analysis, residents in each home ranged from one to 100 and staff from three to 280. Community prevalence of COVID-19 affects the prevalence of the virus in care home settings.¹³ To adjust for this, the rolling 7-day prevalence of COVID-19 at Super Output Level (SOA) and care home size were adjusted for in the model.

Each of the homes with a reported outbreak represented a case with the time since the first visit at which COVID-19 vaccination was administered to staff and/or residents as the exposure and duration of the outbreak as the outcome. The exposure time was lagged by 21 days from the first visit to vaccinate the staff and residents to account for the lead time from vaccination to immunity. The 21-day lag period was chosen as a time point by which vaccine would be in effect (69% vaccine effectiveness at 14–20 days and 79% at 21–28 days after the first dose in people aged 80 years or older).¹⁴ A Kaplan Meier plot was produced showing 'survival' of outbreaks by care home vaccination status. The time lag was altered to 14, 28 and 35 days as a sensitivity analysis for the Cox regression (which includes the time period of the second dose of vaccine for most care homes). We considered only the effect of time from the first vaccine (rather than whether there was a second vaccine visit) as we had no way of separating any changes associated with the passage of time from the first dose from any change associated with a second dose. Most homes received their second visit at 21 days, and the presence of an outbreak was a potential reason for the second vaccine being delayed.

Results

Study population

The Northern Ireland Statistics and Research Agency (NISRA) estimated the population of NI on 30 June 2019 to be 1,893,700, of which 38,700 (2%) were over the age of 85.¹⁵ Total care home residents and staff were estimated to be 12,884 and 20,537, respectively. Using aggregate data provided by RQIA as of 8 April 2021, the overall vaccination coverage for residents was estimated to be 11,608 (90.1%) and 10,368 (80.5%) for first and second vaccines and 14,524 (70.7%) and 13,173 (64.1%) for staff respectively.

The frequency of COVID-19 outbreaks in care homes

There was a 7-day time lag between care home outbreaks and the estimated number of people who would have tested positive in

the community according to the ONS CIS (Fig. S2). The trends in care home outbreaks happened earlier than the community prevalence. The association between the number of people who would have tested positive and the daily number of new care home outbreaks with confirmed COVID-19 is shown, adjusted for the 7-day time lag. The gradient of this relationship was different in the prevaccination and postvaccination time periods (Fig. 1). The pattern was very similar in nursing and residential homes when shown separately (Figs. S3 and S4).

Poisson regression models for the prevaccination and postvaccination time periods are shown (Table 1), illustrating a change in the relationship. A multivariable Poisson regression model of the number of new care home outbreaks per day as the dependent variable and the modelled number of people who would have tested positive for COVID-19 showed a significant association between the postvaccination period and reduced care home outbreaks (incidence rate ratio [IRR] 0.28 (0.23–0.35)). When investigated separately, nursing homes (IRR 0.27 (0.21–0.35)) and residential homes (IRR 0.27 (0.19–0.40)) showed the same relative effect.

We used the relationship between the number of people who would have tested positive for COVID-19 in the Office for National Statistics COVID-19 Infection Survey and care home outbreaks from the prevaccination period to project the number of outbreaks expected in the washout and postvaccination period. The projection estimated 1625 (95% prediction interval 1553–1694) outbreaks would occur between 7 December 2020 and 28 October 2021, and we observed 501 outbreaks in that time period. The observed and projected number of care home outbreaks are shown as a time series (Fig. 2).

The duration of COVID-19 outbreaks in care homes

We used a Cox proportional hazards model to investigate whether care homes that had been offered the vaccination had a higher likelihood of outbreak closure than those homes that had not reached that immunity threshold. Between 7 December 2020 and 8 April 2021, there were 179 confirmed COVID-19 outbreaks in care homes following the first vaccination, 175 of which had ended at the time of analysis. The median outbreak duration was 29 days from notification to closure (Table S1). A Kaplan Meier plot

illustrates the divergence of the outbreak duration in vaccinated compared to unvaccinated care homes (Fig. 3).

The findings indicate that vaccinated homes had a significantly higher hazard ratio of experiencing outbreak closure over time than homes in which the vaccination programme had not yet been implemented (Table 2). These findings remain after adjusting for care home size and measures of community prevalence of COVID-19. The daily hazard ratios analysis illustrating the effect of using different time lags for immunity from vaccination shows the effect days postvaccination the likelihood of outbreak closure increases and appears to stabilise by day 28 (Fig. S5).

Discussion

The COVID-19 pandemic has had a severe impact on care home residents and staff worldwide. Consequently, residents and staff were amongst the first groups to be offered vaccination. Our findings suggest that the introduction of the COVID-19 vaccination programme in NI was associated with a two-thirds reduction in the frequency of confirmed COVID-19 outbreaks in care homes compared to the expected number. This relative effect was the same in nursing and residential homes. We showed that the outbreak duration was shorter in homes where the vaccine had been delivered. These findings provide evidence that the vaccination programme had a positive impact on outbreaks in care homes.

Outbreaks occurred in the postvaccination period, and there are many potential explanations for this. Not all residents and staff will have been vaccinated, and not all those vaccinated will have been fully protected against infection. Furthermore, the care home population is dynamic, with new residents arriving, many of whom would not have been vaccinated. The workforce is also dynamic, and staff may frequently move between care homes and not all were vaccinated. The social care working group of the Scientific Advisory Group for Emergencies (SAGE) have advised that in order to protect against outbreaks in care homes, vaccination uptake rates of 90% of residents and 80% of staff are required.¹⁶ As of 4 April 2021, 94% of all eligible people living in older adult care homes and 78.9% of all eligible workers in all in England have received at least their first vaccination.¹⁶ This had led the English Department of Health and Social Care to launch a consultation on COVID-19

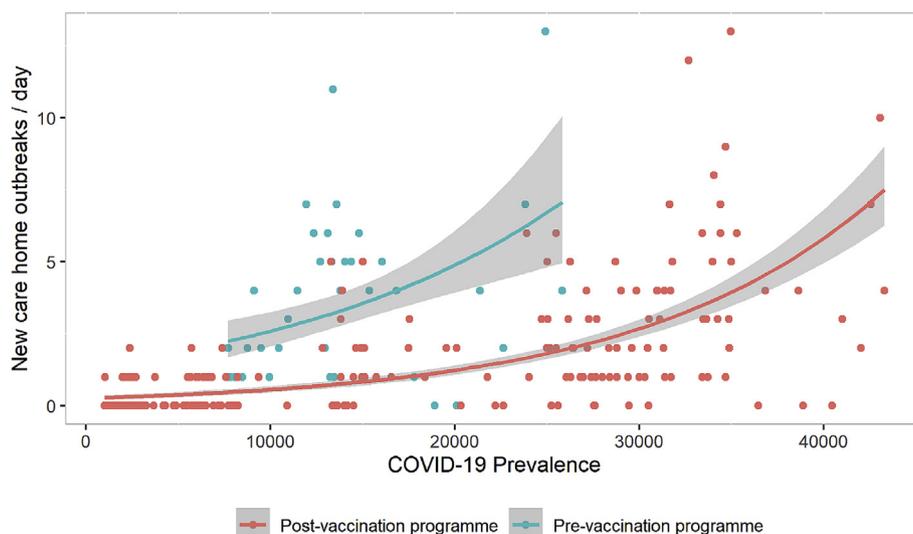


Fig. 1. Number of people who would have tested positive for COVID-19 in the Office for National Statistics COVID-19 Infection Survey (COVID-19 Prevalence) and incident care home outbreaks per day prevaccination and postvaccination programme.

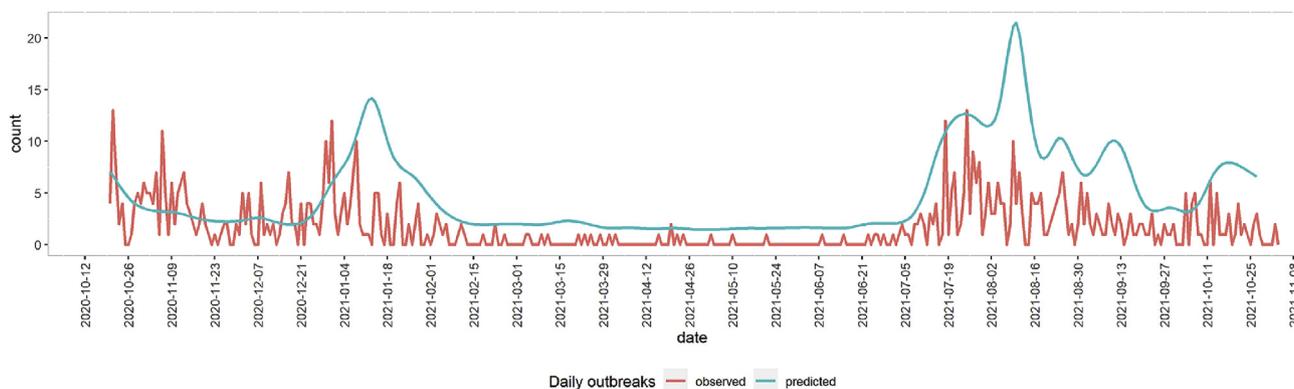


Fig. 2. Observed and predicted care home outbreaks per day.

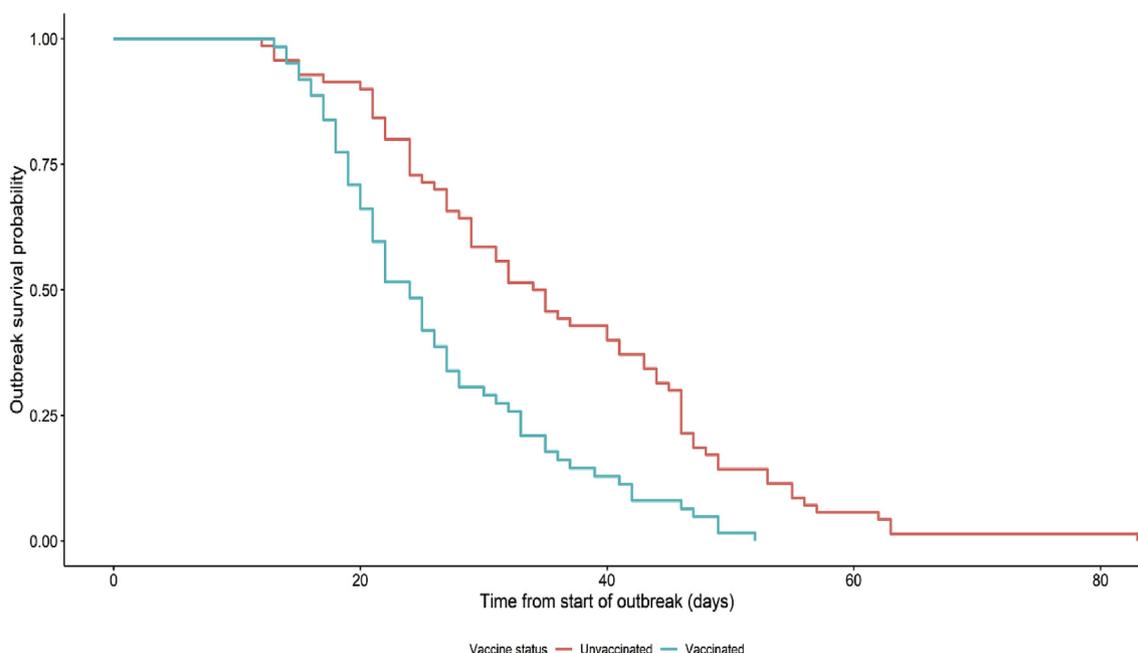


Fig. 3. Kaplan Meier plot illustrating survival of outbreaks by vaccination status.

vaccination as a condition of work for people who work in care homes.¹⁶ Other jurisdictions can be expected to observe these developments with interest.

The findings of this study should be interpreted in the context of its methodological limitations. We did not have access to individual vaccination status at the time of writing, and future work on individual-level data will be needed to validate our findings. We chose not to use aggregate counts of the number of individuals vaccinated within homes or the number of cases within outbreaks. Although these aggregate data were reported and collected, we were advised by PHA that these data were not suitable for statistical analysis due to variation in the completeness and quality of these between and within homes and over time. Therefore, we used the dates of events, which were considered more robust. Outbreak dates were recorded by PHA. We did not attempt to account for the potentially complex interactions between past outbreaks, delays to vaccination, and the resulting synergistic effects of vaccination on a background of recent infection, which would reduce the chance of future outbreaks. This warrants deeper exploration in future. Individual-level data would enable linkage across a range of administrative datasets to assess the effectiveness of the

vaccination programme against a range of outcomes. Reliable information about whether individuals are in a specific care home is elusive in administrative information systems, and the challenges of accurately identifying and following these individuals have been well-documented.^{17,18} The pandemic has also highlighted how investment in the development of minimum dataset for care home residents is needed to understand the health needs and outcomes of this vulnerable population. The association between community

Table 2
Hazard ratios and 95% confidence intervals for outbreak closure in homes according to time since first vaccination.

Time after vaccination	N (112)	Unadjusted Model		Adjusted Model ^a	
		HR (95% CI)	P	HR (95% CI)	P
14 days	79	2.22 (1.52–3.24)	<.001	2.44 (1.64–3.63)	<.001
21 days	62	2.24 (1.56–3.22)	<.001	2.53 (1.88–4.31)	<.001
28 days	42	2.57 (1.75–3.78)	<.001	2.84 (1.88–4.34)	<.001
35 days	32	2.27 (1.51–3.43)	<.001	2.55 (1.63–3.99)	<.001

Note: HR = hazard ratio; CI confidence interval.
^a =models adjusted for care home size and community prevalence.

prevalence and care home outbreaks measured in the prevaccination status might be sensitive to the fact that the ONS CIS data were not available for a period of very low community prevalence. Although we did not aim to measure the incremental benefit of the second dose that was delivered after a 21-day interval, there was no obvious increase at 28 or 35 days in sensitivity analyses or in the estimates of hazard ratio with time beyond 21 days in Fig. S5. This might be explained by the wide confidence limits (our study was not designed or powered to directly compare the effect of the second to first doses) that infection prevention and control measures in place during this period may have been sufficiently robust to mask the incremental benefit of the second dose, or that the benefit of the first dose may give a level of protection due to network effects that, at a group level, makes the effect of the second dose less evident.

By the end of 2020, the UK Medicines and Healthcare products Regulatory Agency (MHRA) approved two vaccines, Pfizer-BioNTech and Oxford-AstraZeneca, for administration. The speed with which these vaccines were available has been unprecedented. In the UK, as of 1 December 2021, 116 million COVID-19 vaccines have been administered.¹⁹ Public Health England recently reported that a single dose of the Pfizer vaccine was approximately 60–70% effective at preventing symptomatic disease, which increased to approximately 85–90% following two doses in over 70-year-olds.²⁰ For those vaccinated who later developed COVID-19 there was a 44% lower risk of hospitalisation and a 51% lower risk of death compared to unvaccinated people.²⁰ In looking specifically at care home residents, a large UK cohort study of 10,400 residents reported vaccine effectiveness estimates of 62% against PCR-confirmed infection following first vaccination.²¹ Furthermore, a recent preliminary study suggests that a single dose of vaccine may be sufficient to obtain a high level of S-protein IgG antibody in nursing home residents previously diagnosed with COVID-19.²² Collectively, these findings are encouraging and demonstrate the success of the vaccination programme in the early stages in reducing outbreaks across NI care homes. This evidences a significant degree of protection among a vulnerable and at-risk population against the severe consequences of COVID-19. Future research using individual-level data and across longer periods postvaccination will be needed to determine the magnitude and duration of this protection.

Author statements

Ethical approval

None declared.

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Competing interests

DTB is jointly employed by Queen's University Belfast and the Public Health Agency, NI; he is seconded to the NI Department of Health.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.puhe.2021.12.010>.

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