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Study protocol for the use of time series forecasting and risk analyses to investigate the effect of the COVID-19 pandemic on hospital admissions associated with new-onset disability and frailty in a national, linked electronic health data setting

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ABSTRACT

Introduction Older people were at particular risk of morbidity and mortality during COVID-19. Consequently, they experienced formal (externally imposed) and informal (self-imposed) periods of social isolation and quarantine. This is hypothesised to have led to physical deconditioning, new-onset disability and frailty. Disability and frailty are not routinely collated at population level but are associated with increased risk of falls and fractures, which result in hospital admissions. First, we will examine incidence of falls and fractures during COVID-19 (January 2020–March 2022), focusing on differences between incidence over time against expected rates based on historical data, to determine whether there is evidence of new-onset disability and frailty. Second, we will examine whether those with reported SARS-CoV-2 were at higher risk of falls and fractures.

Methods and analysis This study uses the Office for National Statistics (ONS) Public Health Data Asset, a linked population-level dataset combining administrative health records with sociodemographic data of the 2011 Census and National Immunisation Management System COVID-19 vaccination data for England. Administrative hospital records will be extracted based on specific fracture-centric International Classification of Diseases-10 codes in years preceding COVID-19 (2011–2020). Historical episode frequency will be used to predict expected admissions during pandemic years using time series modelling, if COVID-19 had not occurred. Those predicted admission figures will be compared with actual admissions to assess changes in hospital admissions due to public health measures comprising the pandemic response. Hospital admissions in prepandemic years will be stratified by age and geographical characteristics and averaged, then compared with pandemic year admissions to assess more granular changes. Risk modelling will assess risk of experiencing a fall, fracture or frail fall and fracture, if they have reported a positive case of COVID-19. The combination of these techniques will provide insight into changes in hospital admissions from the COVID-19 pandemic.

Ethics and dissemination This study has approval from the National Statistician's Data Ethics Advisory Committee (NSDEC(20)12). Results will be made available to other researchers via academic publication and shared via the ONS website.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The Office for National Statistics Public Health Data Asset represents a unique and comprehensive linked population data set, for England, that offers insight into a wide range of sociodemographic characteristics otherwise unavailable in electronic health records.
⇒ Reliance on Census 2011 metrics of sociodemographic variables limit focus to characteristics that are unlikely to vary temporally.
⇒ Data are based on the 2011 census, those living in England in 2011 but not taking part in the Census, those who could not be linked to the 2011–2013 National Health Service patient register, and migrants would be excluded from the study population.
⇒ Test and trace data only becomes reliable at the roll-out of public testing and its relevance diminishes over time due to periods in which tests were not readily available, and further when test kits cease to be free, limiting risk analysis to the delta wave.
⇒ Residence type is determined from Census 2011, and therefore, may not accurately reflect an individual's care home status at time of infection.

BACKGROUND

Older people have been particularly adversely affected by the COVID-19 pandemic because the likelihood of contracting SARS-Cov-2, and of experiencing adverse outcomes following infection, increase with both age and frailty.[1 2] This association between risk and age was well publicised. Consequently, many older people self-isolated more intensively and for more prolonged periods than mandated by government.[3] In addition, particular restrictions were introduced for cohorts of older, for example, care home residents where the median age is over 80 and where frailty is prevalent,[4] which led to time confined indoors and isolation from family and friends.

Periods of isolation are associated with physical and cognitive deconditioning[5] and it has been postulated that this, in association with persistent health problems post-COVID-19, might have led to an increase in the rate of new-onset disability and frailty among older people during the pandemic.[6] A causal link has not yet been established because data on prevalence of disability and frailty are not routinely collated either across the wider population, or within particular subpopulations such as care home residents.[7]

Understanding whether the pandemic was associated with an increase in the rate of new-onset disability and frailty among older people is important to facilitate service planning, and to target services to those most in need, to enable recovery and prevent further deterioration where possible. One way to assess evidence of emergent disability and frailty is to examine hospital admissions for conditions which are known proxy markers of these.

Falls and fractures are both associated with disability and frailty.[8] Almost all falls are multifactorial and become more common in frailty and disability due to failure of one or more homeostatic mechanisms regulating gait and posture. Fractures are a direct consequence of falls, including some 80 000 hip fractures and 200 000 non-hip fractures in the UK per annum.[9] Hip fractures are, in particular, associated with frailty. The average hip fracture patient is 82.5 years old,[10] with a mean (SD) admission frailty index of 0.34 (0.16),[11] indicating moderate frailty. It follows that the incidence of falls and hip fractures will vary as the incidence of disability and frailty differs over time, and that they can be used to detect and understand new-onset disability and frailty. Older people becoming more disabled at home may be difficult to detect as we have no routine mechanism for tracking onset of disability, but when they fall over and present to hospital this provides us with a statistic which we can usefully track over time.

With this in mind, we will aim to establish whether admissions to hospitals in England with falls and fractures varied significantly from their expected trajectory over the course of the COVID-19 pandemic and consider what this might tell us about the incidence of disability and frailty. We will also consider whether geographical differences in isolation policies adopted during the pandemic show any correlation with fall and fractures as markers of new-onset disability and frailty.

Study aims

Research hypothesis and aims

We hypothesise that hospital admission numbers for falls and fractures significantly deviated from their seasonal averages by consequence of COVID-19, starting in March 2020 and continuing to the most recently available records. Second, we anticipate deviations from the average number of admissions may vary in their extent across age demographics. Decreases in the number of fracture admissions across all age groups have been observed in regions of America and have been attributed to social distancing measures invoking a cessation of organised sports and decreased playground use in adolescents. There is, though evidence of some increase in fracture rates among older people during the pandemic.[12] This is likely because the most common fractures presenting in older people with frailty are low impact fractures associated with decreased bone density and falls triggered by postural instability or copathology[13]—this different aetiology is likely to be associated with different epidemiology from the more general high-impact fractures described in the US study. Third, we anticipate that differential policies adopted in different parts of the country, for example, around localised lockdowns in Leicester, and Kent and Greater London, in response to outbreaks of new SARS-Cov-2 variants, may have differentially influenced the timing of deviations from anticipated admissions for falls and fractures.

Fourth, older individuals reporting a SARS-CoV-2 infection may be at higher risk of fracture than uninfected individuals, because COVID-19 atypical symptoms which are more common in older populations—such as delirium, confusion, dizziness and unusual fatigue—could be anticipated to increase falls risk.[14] Persistent disability following an episode of COVID-19 could further contribute to this risk. Older people without COVID-19 might be at either an increased or decreased risk of fractures during the pandemic. On one hand, social isolation might reduce the likelihood of mobilising outdoors, which is an important cause of falls in older people. On the other hand, physical deconditioning due to immobility might increase the risk of falls over time, particularly during periods where isolation measures were lifted, and older people returned to outdoor activities.

To test our first hypothesis, we will use hospital admissions records for falls and fractures in prepandemic years to inform a time series model and project expected admissions from 2020 onwards in a business-as-usual scenario. For the second hypothesis, we will consider admissions stratified by age, and for the third by geography. Predicted admissions, based on prepandemic levels, will be compared with actual admissions for 2020 and 2021 to reveal any deviation from expected trends, thus revealing any differences in how people used services following onset of the pandemic. Further, 9-year baseline fall and

fracture admissions will be established to gain more granular insight into changes in the pattern of service use. To test the fourth hypothesis, we will determine if COVID-19 patients were more at risk of falls and fracture by assessing if those who returned a positive test result experienced a hospital episode for a fall or fracture in both the immediate and longer-term postinfection. We will compare this with a control group who have not experienced a SARS-CoV-2 infection using logistic regression.

METHODS AND ANALYSIS

Study protocol

Hospital admission numbers will be extracted from National Health Service (NHS) Digital's Hospital Episode Statistics (HES) database. A bespoke list of International Classification of Diseases-10 (ICD-10) codes pertinent to fall and fracture conditions often associated with frailty will be used to filter hospital episodes to admissions of interest. Admissions up until 23 January 2020 will constitute the prepandemic sample. Admissions after this date will represent actual admissions for pandemic years.

This study draws on data from the Office for National Statistics (ONS) Public Health Data Asset (PHDA), which is a linked dataset combining the 2011 Census, the General Practice Extraction Service data for COVID-19 pandemic planning and research, and the HES. To test hypotheses centred around patterns in hospital admissions, we will use 2011 Census data linked to HES. To obtain NHS numbers for the 2011 Census, we linked the 2011 Census to the 2011–2013 NHS Patient Registers using deterministic and probabilistic matching, with an overall linkage rate of 94.6%. Linkage of this nature allows for hospital admissions to be stratified by sociodemographic characteristics such as ethnicity, and disability status and geographical contexts. To test the hypothesis on risk of fracture following SARS-CoV-2 infection, we will draw on the previous data sources, additionally linked to vaccination data from the National Immunisation Management System and NHS Test and Trace were performed based on NHS numbers.

The PHDA cohort is composed of 53 483 456 adults aged, who were present at the 2011 Census. A total of 45 262 224 Census IDs can be matched to at least one record from HES. We will extract individuals with a hospital admission for fracture after the 24 January 2020, the onset of the COVID-19 pandemic in the UK.

Statistical analysis plan

Changes in patterns of hospital admissions for falls and fractures will be assessed using auto regressive integrated moving average (ARIMA) models. Autocorrelation and partial autocorrelation functions will be used to assess relationships between entries in the time series separated by defined time steps. Fracture admissions from 23 January 2011 to 23 January 2020, will be collated at a monthly frequency and used to predict admissions from 24 January 2020 to 31 March 2022. Time series modelling accuracy is typically assessed in a stepwise manner, validating the predicted value against known observations. The onset of the pandemic precludes our predicted values from such validation techniques. Model accuracy will, therefore, be assessed prior to pandemic onset using 2011–2017 admissions to generate forecasts and validated against 2018–2019 non-pandemic years using root mean squared error and mean absolute percentage error metrics.

Additional ARIMA models will be used to assess geographical and demographic variation in fall and fracture admissions. Hospital admissions will be stratified by regional and age demographics, and where possible ethnicity coded according to published standards and used to create a baseline admission frequency. Stratified observed and predicted admissions will be compared with provide more granular insights into healthcare provision disruptions.

Relative risk of falls or fractures in individuals reporting a positive COVID-19 infection will be assessed using Cox proportional hazards regression models using data from the ONS PHDA. SARS-CoV-2 infections will be modelled as a time-dependent exposure. Reinfections of SARS-CoV-2 will be treated as separate exposures. Time since infection, in which the risk of sustaining a fall or fracture will be assessed, will be treated as a time-interval exposure to consider the persistence of COVID-19 side effects and determine if there are periods of elevated risk of falls or fractures following infection. The follow-up period will commence on result of a positive test and curtail on the last available date of test and trace data, 21 November 2021. The outcome of this study is presentation at hospital with a fall, fracture or frail fall and fracture, so to be captured in treatment cohort, one must have had a positive test before presenting. Risk modelling will further account for an additional set of variables. The baseline model will account for age only, while the following iterations will account for residence type, geography, demographic and socioeconomic factors,[15] hospital admissions and the number of days spent in admitted patient care,[16] and vaccination status, respectively.[17] When adjusting for vaccination status, status will be obtained at the date on which the hospital episode occurred.

Methodological issues

- The ICD-10 code listed on HES records, either in primary or secondary diagnosis fields, may not be the same reason as a patient was admitted to hospital for. During pandemic hospital admissions, incidental COVID-19 was often recorded as the primary diagnosis for hospital attendance, even if the reason for admission was a fall or fracture.
- The PHDA only contains information on people who were enumerated at the 2011 Census. It, therefore, excludes people living in England in 2011 but not taking part in the 2011 Census (estimated to be about 5%), respondents who could not be linked to the 2011 to 2013 NHS Patient Registers (5.4% of Census

respondents), people who have immigrated since 2011, and people who registered with a general practitioner after the onset of the COVID-19 pandemic, as we only account for prepandemic health conditions.
- Some of the sociodemographic characteristics might have changed since the 2011 Census and may not accurately reflect individuals' circumstances during the COVID-19 pandemic.
- It is possible that fewer admissions for falls or fractures occurred during the pandemic due to reluctance of attending a hospital facility.
- Admissions data are inherently observational, so causal inference cannot be drawn.

Data management and oversight

All data for this project has been supplied to ONS under a data sharing agreement (DSA) with the respective data owner, which outlines the legal basis for data sharing and the permitted purposes for data use. Each individual dataset has an ONS Information Asset Owner (IAO) who is accountable for data management and use throughout the end-to-end data life-cycle. ONS has an established data management, retention and disposal processes in place to ensure all data are only kept for as long as necessary, in line with the relevant DSA conditions and legal requirements.

Access to data is granted only for the purposes of an approved, ethically assessed project, subject to IAO agreement and is via a restricted ONS data processing and statistical analysis environment with physical, technical and administrative controls applied in line with UK government security standards. All researchers within the project have undergone security and data protection training and have agreed to abide by the relevant security operating procedures as part of their conditions of access. All projects and data are subject to a regular audit cycle.

Data storage and security

Access to data held within the ONS Data Access Platform, which includes HES, Emergency Care Dataset (ECDS) and General Practice Extraction Service Data for Pandemic Planning and Research (GDPPR data, is granted to users on a need-to-know basis depending on their role, through a request process which provides a business justification. Staff requesting access to sensitive data such as these must be cleared to the appropriate National Vetting level, which is higher than the standard basic clearance required for all ONS staff. Deidentified participant data and a data dictionary are available via the secure research service for accredited researchers.

DISCUSSION

Understanding population trajectories for disability and frailty are important for two reasons. First, they can provide a perspective on the impact of policy decisions made during the pandemic to inform future decisions during this and subsequent pandemics. Second, they can enable effective resource allocation and service planning, both at present and in terms of future pandemic preparedness. An area of concern during the pandemic has been diversion of resource from rehabilitation services—particularly specialist services for older people—into other parts of patient care at a time when rehabilitation need is postulated to have increased.[18] More data are required to better project care needs amount these groups.

Ideally such activities can use population level disability and frailty prevalence data. While the NHS does collect data on frailty, in the form of the electronic frailty index,[19] and the national census collects information about disability, such data are collected with insufficient frequency to understand the impact of the pandemic with any nuance. In the absence of such data, proxy measures using the prevalence of frailty indicator conditions—in this case falls and fractures—can provide an approximation on which to base subsequent population modelling and service projections.

The strengths of the proposed series of analyses are multiple. We will use robustly collated national databases which are representative of the population as a whole. Historical data for hospital admissions will extend back to 2011, providing sufficient data to control for seasonal variation. We will use validated measures to look for statistically significant changes in trends over time. A limitation will be the extent to which falls and fragility fractures can be regarded to be indicator diagnoses for emergent disability. These are proxies and imperfect correlates of both disability and frailty. However, as outlined above, they are the most robust proxy measures available.

The NHS in 2022 faces unprecedented service pressures which have multifactorial contributors including healthcare bottlenecks introduced by service disruptions, pandemic related staffing shortages in health and social care and altered healthcare behaviours at a population level. Addressing these issues will require increased understanding of population healthcare need, and the planned series of analyses will contribute to the evidence base on this.

Patient and public involvement

This protocol was extensively discussed at a meeting of the East Midlands Research in Ageing Network which includes patients, carers and public representatives, many of whom are older, or care for older people with frailty. The group was supportive of the aims and was particularly keen to understand whether COVID-19-associated lockdown could have been detrimental to older people with COVID-19 during the pandemic. We will return to this group for advice on dissemination strategies and help with a lay-facing infographic that summarises key findings once the analyses have been completed.

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