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Developing social context factors associated with emergency hospital use from national administrative health data: a retrospective cohort study

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ABSTRACT

Objectives: To derive two social context factors, living alone and living in a two-person household with a person who is frail, from routine administrative health data and to assess their association with emergency hospital use.

Design: Retrospective cohort study using national pseudonymised hospital data and pseudonymised address data derived from a central database of all patient registrations in England

Setting: England-wide

Participants: 4,876,285 people aged 65 years or older registered at GP practices in England on 16 December 2018 who were living alone or in a household of up to six people, and with at least one hospital admission in the last three years.

Outcomes: Rates of emergency department (A&E) attendance and inpatient emergency admissions over a 1-year follow-up period.

Results: Older people living alone had higher rates of A&E attendances (adjusted rate ratio 1.09, 95% CI 1.09 to 1.10) and emergency admissions (1.14, 95% CI 1.14 to 1.15) than older people living in households of 2-6 people.
Older people living with someone with frailty in a two-person household had higher rates of A&E attendance (adjusted rate ratio 1.09, 95% CI 1.08 to 1.10) and emergency admissions (1.10, 95% CI 1.09 to 1.11) than other older people living in a two-person household.

Conclusions: We show that some social context factors can be derived from linked routine administrative health data and that these are strongly associated with higher emergency hospital use. Using social context factors can improve analyses, as well as support in the understanding of local population needs and in population health management.

Trial registration
Not applicable

STRENGTHS AND LIMITATIONS OF THIS STUDY:

- Two social context factors, living alone and living with someone with frailty, were derived from pseudonymised routinely collected data; this created valuable additional patient-level information without the need to collect new data.
- National data from approximately 4.9 million people aged 65 or over was used to examine the association of the social context factors and emergency hospital use.
- The analysis adjusted for common demographic and clinical factors predictive of emergency hospital use.
- The study was restricted to individuals aged 65 or over who had a hospital admission in the previous three years, limiting the generalisability of our study.

BACKGROUND

The 'social determinants of health'[1] - factors outside of the health and social care system that affect a person's health, such as social networks, housing, education and employment opportunities – have long been recognised in the UK [2,3] and globally.

There is some evidence that a person's social circumstances inform care: Stokes et al found that when identifying patients for multidisciplinary teams (MDTs), medical practitioners felt that the patients' needs were often primarily related to socio-economic factors such as isolation, poor housing or living arrangements, and other issues.[4] Some MDTs are aiming to address social, as well as health, needs [5] and others are even specifically targeting people with non-clinical needs, with the aim of addressing social needs which might otherwise lead to deteriorating health and escalating medical needs.[6]

However, unlike other risks observed by clinicians that are included in population health management tools,[7] social context is not routinely captured in NHS or social care datasets, and where these are collected, they are often recorded in free text fields. Information on patients' circumstances is therefore not readily retrievable to either hospital staff, or to analysts, commissioners or policy makers when analysing, planning or commissioning care, who often rely on the information coded in electronic health records.

The national health service (NHS) in England holds a central database of all patient registrations in England, which includes their address details. By assigning a Unique Property Reference Number (UPRN) to each address and pseudonymising the UPRN, it is possible to derive information on household composition while maintaining patients' anonymity. This information can be used to create proxies for some important social context factors that may affect people's health and health outcomes.

In this paper we demonstrate the value of deriving social context factors from routinely collected address data and of using them in analysis, in understanding local populations and in planning population health management. We do this by looking at two social context indicators: a) living alone, and b) living with one other person who is frail.

Living alone might be linked to social isolation, which has been found to be associated with both increased morbidity and mortality.[8,9] Living alone does not necessarily mean someone is socially isolated; for example, approximately one-third of people aged 65 or over live on their own[10] but many may have friends or family living nearby. However, living alone has been found to be associated with emergency (unplanned) hospital use within one GP practice in South East London,[11] indicating that living alone still signals important social context at population level and warrants further investigation.

Living with someone with frailty may imply informal care responsibilities. Informally caring for somebody else can have a detrimental effect on a person's own physical and mental health.[12–14] Informal carers may not only feel socially isolated,[9] but may also suffer from lack of sleep and neglect their own health and personal wellbeing,[15,16] or have difficulty accessing care.[17] A large England-wide survey of informal carers found they had worse health-related quality of life, with a disproportionate burden for already-marginalised groups.[17] According to the 2011 Census, 1.3 million (14%) people aged 65 or over living in households in England and Wales provided unpaid care in 2011, many of whom provided 50

hours or more unpaid care a week.[18] There may now be over 2 million people aged 65 or older who are carers, with a significant proportion of carers aged 85 and over caring for someone with multiple needs, often including dementia.[19]

This retrospective cohort study focuses on older people, as this population is at particular risk of emergency hospital admission. Although there are different groups of people at risk of social isolation, not least young people leaving home for the first time, older people are at more risk of social isolation as a result of loss of physical or mental ability, caring responsibilities and deaths of close family and friends.[9]

METHODS

Data sources and linkage

We accessed a minimised version of the Master Patient Index (MMPI), a health data set based on English GP registration data. This dataset included patient gender, month and year of birth (and death where applicable), lower super output area (LSOA) and pseudonymised UPRNs. UPRNs are the official unique identifier of every spatial address in Great Britain[20] and were applied to each address location in the MMPI data and pseudonymised by our data suppliers. We did not have access to actual patient addresses. Building on previous work to identify care home residents from UPRNs,[21] we also accessed a flag to indicate if a property was a care home. The individual's LSOA was used to link to small area statistics provided by the Office for National Statistics on socio-economic deprivation, rurality and region.

Study population and outcomes

Our study population consisted of all people aged 65 years or older registered at GP practices in England on 16 December 2018 who were living alone or in a household of up to six people. Household size was limited to six in order to exclude people living in establishments, as their care provision may differ from that of a single household. This restriction excluded less than 2% of households [10]. We excluded individuals without a valid pseudonymised UPRN or living in care homes at the study start date, and those living at properties containing seven or more people at any time in the year prior to the study start. People not admitted to hospital in the previous three years were also excluded, as hospital records were used to identify long-term conditions and ethnicities (Supplementary File 1).

Where both individuals in a two-person household were aged 65 or over, both individuals were included in the study population and contributed to the analysis; however, if one household member was under 65, this member was not included in the study population but did contribute to defining the social context of their cohabitee.

Using a common pseudonymised NHS number, we linked the MMPI data to Secondary Uses Service [SUS] hospital data from the previous three years. For any individual aged 65 or over with linked hospital records we identified their long-term conditions, secondary care use and top-level ethnicity (based on the mode of ethnicities recorded).

The maximum follow-up period (study length) was one year unless censored because the person died, moved into a care home or their household composition changed.

We examined rates of emergency department (A&E) attendance and inpatient emergency admissions in the follow-up period.

Social context factors

A person was defined as living alone if there was no other person with the same UPRN during the study period. For individuals living in two-person households we also linked the hospital records of their cohabitee, where these existed, to identify if the individual was living with someone recorded as frail. A person was identified as frail if they had any of the conditions or events in Soong et al's list of syndromes[22,23] coded in inpatient records in the previous three years. These include cognitive impairment, mobility problems and pressure ulcers, which may require care or support from their cohabitee.

Both social context factors may be proxies for social isolation. Social isolation reflects a lack of social ties, social integration or sense of community,[24] and can be due to a number of factors, including bereavement and constraints on mobility.[9] Social isolation is related but distinct from loneliness, which is a subjective feeling associated with actual or perceived isolation. However, both factors may also pick up on other unobserved confounders of health outcomes; for example living alone may also have a detrimental effect on personal nutrition, while living with someone with frailty may lead to neglecting one's own needs and care.

Statistical methods

We used multivariable regression to examine the association between emergency health care use (emergency department attendances and emergency hospital admissions, respectively) and a) living alone and b) living with someone with frailty. We did this by comparing living alone to living in a household of two to six people and, separately, comparing living in a two-person household with a person with frailty to living in a two-person household where the cohabitee was not recorded as frail.

We ran both crude and adjusted analyses. Adjusted analyses included age, gender, ethnicity, English region, socio-economic deprivation, rural/urban classification, a range of long-term conditions recorded in the previous three years: those predictive of emergency hospital use,[25,26] frailty indicators,[22,23] history of mental or serious mental ill-health[27] and historic emergency hospital use in the last twelve months, including emergency admissions for chronic ambulatory care sensitive and acute urgent care sensitive conditions (Supplementary File 2). We aimed to include as covariates as many variables as possible without overparametrising the model in order to remove any known confounding. We used a negative binomial model as the data was overdispersed. Rate ratios were produced to interpret the results.

Subgroup analysis

We investigated whether the emergency hospital use of people living with someone with frailty differed depending on if they were male or female, as women in general provide more informal care than men.[28] We also investigated whether the emergency hospital use of people living alone differed according to their level of deprivation, as this may affect a person's access to informal or formal care (neither of which we can determine in our data). Differences in the rate ratios between population subgroups was examined by fitting a

multivariable regression model including an interaction term between the social context factor and the population segment.

Sensitivity analysis

In the main analyses people were censored at the time their household composition changed. There is a risk that that household change could be driven by deteriorating health, for example if a person living alone had worsening illness and moved into a care home. This would underestimate a person's health care needs if they had continued living alone. Therefore, a sensitivity analysis examined only those whose household composition did not change over the year.

The main analyses adjusted for, among other covariates, emergency hospital use in the twelve months prior to the analysis period, as these variables may reflect the clinical severity of a patient's condition, which can be difficult to deduce from electronic health records. However, prior hospital use may also be affected by social context factors at that time (e.g. living alone or living with somebody with frailty), potentially underestimating the effect of these social context variables. Therefore, we performed analyses omitting prior hospital use as covariates.

Patient and public involvement

We sought input from a patient representative at the development stage, including on choice and relevance of social context factors. There was further engagement with this same and another representative on the interpretation of results and on an early draft of the paper.

RESULTS

Study populations

After applying the inclusion and exclusion criteria, there were 4,876,285 people aged over 65, registered with an English GP and living in England, with at least one hospital admission in the last three years and living in a household of up to six people (Supplementary File 1). The largest exclusion was due to no hospital admission in the previous three years (approximately 5m). Of the remaining individuals, 1,464,379 (30.03%) lived alone and 2,459,937 (50.45%) lived in a two-person household (Table 1).

People living alone were more often female (66% vs 47%) and on average older (median age 79 vs 74) compared with people living in households of 2-6 people (Table 1, Supplementary File 2). They also lived in more deprived areas; 19% lived in the most deprived quintile compared to 13% of individuals living in households of 2-6 people. Furthermore, more people living alone were frail (33% vs 21%, with on average 0.51 vs 0.30 frailty syndromes) and they had higher levels of multimorbidity (on average 2.30 vs 1.97 conditions) compared with people in households of 2-6 people. They also had greater numbers of A&E attendance and emergency admissions in the twelve months prior to our study period (0.74 vs 0.56 and 0.48 vs 0.34, respectively) than people in households of 2-6 people.

Among people aged 65 or over living in two-person households, people living with someone with frailty had a median age of 77, compared with 74 for people living with a cohabitee who was not recorded as frail (Table 1, Supplementary File 2). 54% (vs 52%) were male and

14% (vs 12%) lived in the most deprived quintile. People living with someone with frailty were on average themselves more likely to be frail (27% vs 20%), with on average 0.40 (vs 0.28) frailty syndromes, and had more long-term conditions (2.22 vs 1.92). They also had greater rates of A&E attendance and emergency admissions in the twelve months prior (0.67 vs 0.53 and 0.42 vs 0.32, respectively) compared with people living with a cohabitee who was not recorded as frail.

Table 1. Baseline characteristics. Created by the authors

	People 65+ years living in households up to 6 people*			People 65+ years living in households of 2 people*		
	All	Living Alone	Not living alone	All	Living with someone with frailty	Cohabitee not recorded as frail
Total study population (65 years+)	4,876,285	1,464,379	3,411,906	2,459,937	255,312	2,204,625
Male	47.04%	34.02%	52.63%	52.44%	53.84%	52.28%
Age, median [IQR]	75 [70, 81]	79 [72, 85]	74 [69, 79]	74 [70, 80]	77 [71, 83]	74 [70, 80]
Ethnicity						
White	80.96%	83.06%	80.06%	82.85%	84.64%	82.64%
Mixed	0.23%	0.23%	0.23%	0.17%	0.16%	0.17%
Asian	2.55%	1.12%	3.16%	1.53%	1.38%	1.55%
Black	1.11%	1.11%	1.11%	0.66%	0.54%	0.67%
Other	0.62%	0.51%	0.67%	0.46%	0.40%	0.46%
Not stated/missing	14.52%	13.96%	14.76%	14.33%	12.88%	14.50%
Deprivation						
Quintile #5 (least deprived quintile)	23.37%	19.71%	24.94%	26.19%	24.52%	26.38%
Quintile #4	22.87%	20.89%	23.72%	24.45%	23.27%	24.59%
Quintile #3	21.29%	20.97%	21.43%	21.51%	21.22%	21.54%
Quintile #2	17.68%	19.63%	16.84%	16.08%	17.03%	15.96%
Quintile #1 (most deprived quintile)	14.80%	18.80%	13.08%	11.77%	13.95%	11.52%
Rural location	22.27%	19.08%	23.64%	25.04%	22.56%	25.32%
Diagnosis history (previous three years)						
No. frailty syndromes, mean (SD)	0.36 (0.76)	0.51 (0.90)	0.30 (0.68)	0.29 (0.67)	0.40 (0.80)	0.28 (0.65)
No. Elixhauser conditions, mean (SD)	2.07 (1.90)	2.30 (1.99)	1.97 (1.85)	1.95 (1.83)	2.22 (1.96)	1.92 (1.81)
Frailty (1+ frailty related syndrome)	24.69%	32.72%	21.24%	21.05%	26.90%	20.37%
Multimorbidity (2+ Elixhauser conditions)	53.83%	58.93%	51.64%	51.15%	57.09%	50.46%
History of mental ill health	21.19%	26.18%	19.05%	18.30%	22.27%	17.84%
Rates of hospital usage (previous 12 months), mean (SD)						
A&E attendances	0.61 (1.27)	0.74 (1.50)	0.56 (1.16)	0.54 (1.14)	0.67 (1.30)	0.53 (1.11)

	People 65+ years living in households up to 6 people*			People 65+ years living in households of 2 people*		
	All	Living Alone	Not living alone	All	Living with someone with frailty	Cohabitee not recorded as frail
Emergency admissions	0.38 (0.88)	0.48 (1.01)	0.34 (0.81)	0.33 (0.80)	0.42 (0.93)	0.32 (0.79)

For more baseline characteristics, please see Supplementary File 2.

*Study population consisted of all people aged 65 years or older, registered at GP practices in England on 16 December 2018 and living in England, with a valid pseudonymised UPRN, not living in a care home, living in a household of 6 people or fewer, and with at least one hospital admission in the previous three years.

Statistical analysis

People aged 65 or over living alone had on average 0.78 A&E attendances per person per year in the follow-up period, compared with 0.56 for people living in households of 2-6 people. They had on average 0.51 emergency admissions per person per year, compared with 0.33 for people living in households of 2-6 people (Table 2). Without adjusting for observed differences in baseline characteristics, people living alone had substantially higher rates of both A&E attendance (unadjusted rate ratio 1.44, 95% confidence interval (CI) 1.43 to 1.44) and emergency admissions (unadjusted rate ratio 1.60, 95% CI 1.60 to 1.61) than people living in households of 2-6 people (Table 3).

Table 2. Crude rates of secondary use (number of events per person per year). Created by the authors

	People 65+ years living in households up to 6 people				People 65+ years living in households of 2 people			
	Living alone		Not living alone		Living with someone with frailty		Cohabitee not recorded as frail	
Outcomes over the follow-up period	**Events**	**Crude rate***	**Events**	**Crude rate***	**Events**	**Crude rate***	**Events**	**Crude rate***
Total number people	1,464,379		3,411,906		255,312		2,204,625	
Person-years of follow up	1,359,094		3,251,440		226,373		2,077,846	
A&E attendances	1,062,731	0.78	1,818,519	0.56	157,137	0.69	1,102,683	0.53
Emergency admissions	692,345	0.51	1,073,870	0.33	98,584	0.44	654,784	0.32

*Number of events per person, per year.

After adjusting for baseline characteristics, we found that people living alone still had statistically significantly higher rates of A&E attendances (adjusted rate ratio 1.09, 95% CI 1.09 to 1.10) and emergency admissions (1.14, 95% CI 1.14 to 1.15, Table 3).

People living with someone with frailty had on average 0.69 A&E attendances per person per year, compared with 0.53 for people living in two-person households where the cohabitee was not recorded as frail. They had on average 0.44 emergency admissions per person per year, compared with 0.32 for people living in two-person households where the cohabitee was not recorded as frail (Table 2). Before adjusting for observed differences in baseline characteristics, people living with someone with frailty had rate ratios of 1.33 (95% CI 1.32 to 1.34) and 1.42 (95% CI 1.41 to 1.44) for A&E attendances and emergency admissions, respectively, compared with people aged 65 or over living in two-person households where the cohabitee was not recorded as frail (Table 3).

After adjusting for baseline characteristics, people living with someone with frailty in a two-person household still had statistically significantly higher rates of both A&E attendance (adjusted rate ratio 1.09, 95% CI 1.08 to 1.10) and emergency admissions (1.10, 95% CI 1.09 to 1.11, Table 3).

Table 3. Results of unadjusted and adjusted regression models. Created by the authors

	Unadjusted model			**Adjusted model**		
	Rate ratio	**95%CI**	**P value**	**Rate ratio**	**95% CI**	**P value**
Living alone						
A&E attendances	1.44	(1.43 to 1.44)	<0.001	1.09	(1.09 to 1.10)	<0.001
Emergency admissions	1.60	(1.60 to 1.61)	<0.001	1.14	(1.14 to 1.15)	<0.001
Living with someone with frailty						
A&E attendances	1.33	(1.32 to 1.34)	<0.001	1.09	(1.08 to 1.10)	<0.001
Emergency admissions	1.42	(1.41 to 1.44)	<0.001	1.10	(1.09 to 1.11)	<0.001

Adjusted models included as covariates gender, age, deprivation, ethnicity, English region, rural location, history of a range of diagnoses in previous 3 years and historic emergency hospital use in the last 12 months (covariates listed in Supplementary File 2).

Subgroup analysis

There was no evidence that the adjusted rate ratio for A&E attendances or emergency admissions was statistically significantly different depending on if the person who was living with somebody with frailty was male or female (interaction test p=0.101 and p= 0.297, respectively, Supplementary File 3).

There was a statistically significant difference in the rate ratios of living alone for different levels of deprivation compared with the least deprived quintile (interaction tests p<0.02) in all but the third quintile (i.e. the middle group). While people living alone had higher rates of emergency hospital use than those not living alone in each of the five IMD quintiles, the rate ratio for the association between living alone and A&E attendances was lowest in the most deprived quintile (adjusted rate ratio 1.07, 95% CI 1.06 to 1.08) and highest in the least deprived quintile (adjusted rate ratio 1.11, 95% CI 1.10 to 1.11). Similarly, for emergency admissions, it varied between 1.10 (95% CI 1.09 to 1.11) in the most deprived quintile and 1.17 (95% CI 1.15 to 1.18) in the least deprived quintile (Supplementary File 3). In other words, the association between living alone and increased hospitalisation was stronger for *less* deprived groups.

Sensitivity analysis

Limiting the study population to individuals whose household composition did not change over the year, the adjusted rate ratio for living alone compared with households of 2-6 people for A&E attendance was 1.06 (95% CI 1.06 to 1.07) and for emergency admissions 1.10 (95% CI 1.09 to 1.10), (Supplementary File 4). For the analysis of living with someone with frailty, the adjusted rate ratio for A&E attendance was 1.08 (95% CI 1.07 to 1.09) and for emergency admissions 1.08 (95% CI 1.07 to 1.09).

Adjusting for baseline characteristics excluding prior emergency hospital use, the adjusted rate ratio for A&E attendance was 1.11 (95% CI 1.11 to 1.12) and for emergency admissions 1.16 (95% CI 1.15 to 1.16) (Supplementary File 4). For the analysis of living with someone with frailty in a two-person household, the adjusted rate ratio for A&E attendance was 1.11 (95% CI 1.10 to 1.12) and for emergency admissions 1.11 (95% CI 1.10 to 1.12).

DISCUSSION

Our analysis showed that both living alone and living with somebody with frailty are strongly associated with higher emergency hospital use. We found that differences in demographic characteristics and underlying health conditions explain most of this association but even after adjusting for baseline demographic and clinical characteristics, people living alone attend A&E 9% more often and are admitted to hospital in an emergency 14% more often than those living with others. Similarly, individuals living with someone who has frailty attend A&E 9% more often and are admitted to hospital as an emergency 10% more often than others in a two-person household.

It is important to note that these social context metrics are merely proxies for people's true social isolation. For example, an individual residing alone may have a rich social network of family and friends or have access to formal or informal care; routine administrative data cannot capture these nuances. Nevertheless, we have found a strong association between these two factors and emergency hospital use, even when correcting for other factors predictive of hospital use.

Ideally a person's level of social isolation and support needs should be assessed individually and in person, especially for their clinical management. However, this analysis demonstrates how existing administrative information can be used to derive social context proxies that can be used in the absence of such information being recorded. These social context factors could improve population risk algorithms, budget models, or initial service eligibility criteria. For instance, these factors could be used to help identify populations for targeted anticipatory care initiatives such as multidisciplinary teams (MDTs) that may be able to mitigate some social as well as medical risk factors to prevent later deteriorating health or hospitalisation.

Social context factors can also contribute to more robust research and evaluation by allowing for the adjustment of previously unobserved characteristics affecting health care outcomes, thereby decreasing the risk of bias in analyses.

This analysis found that, although higher levels of deprivation are associated with higher emergency hospital use, the interaction between level of deprivation and living alone was less predictable, with individuals living alone in the most deprived areas having a lower rate ratio (compared with those not living alone in the most deprived areas) than individuals living alone in the least deprived areas. It is not possible to determine from our analyses why this may be. It may be that there are differences in health-seeking behaviours, or different access to formal or informal care outside of the household, which in turn could lead to either more (if identifying need) or less (if addressing need) emergency hospital use. Qualitative research is needed in order to understand the mechanisms behind these results, and to provide context and nuance.

Strengths and limitations

While prior studies of social isolation have used survey or local data, this analysis uses routinely collected national data from approximately 4.9m people aged 65 or over, thereby providing robust findings. Through accessing other routine data collections, the analysis could control for common demographic and clinical factors predictive of emergency hospital use, including many long-term conditions. However, the study population was restricted to people in England aged 65 and over, who were admitted to hospital in the three years prior to our analysis. Although this allowed for the derivation of pre-existing conditions from previous hospital records, our analysis is restricted to people that are older and sicker compared with the overall population, limiting the generalisability of our findings. Furthermore, the analysis was restricted to households of up to 6 people, in order to exclude communal establishments such as care home or prisons. Excluding households of 7 or more people will likely disproportionately exclude people from certain ethnic backgrounds, who more often have multigenerational households.[29]

Our findings are nonetheless broadly consistent with other studies that have previously found strong links between older people living alone and their emergency hospital use.[11,30,31] To our knowledge, there are no studies on living with someone with frailty, although results are broadly consistent with the literature on informal carers. A study on multimorbidity within households found inconsistent results of cohabitees' multimorbidity status on emergency hospital use.[13]

The social context factors were derived from address information collected by general practices in England. For these to be accurate, address information needs to be up-to-date.

Anecdotal evidence suggests that address information is typically well recorded, particularly for the older population, but it is not possible to validate this.

Individuals' health conditions derived from hospital admission records may be underreported [32] and therefore not fully adjusted for in analysis. In particular, frailty may be underreported [22] or reported differently to general practice.[33]. If some individuals who have a cohabitee with frailty were misclassified, the association with emergency hospital use was potentially underestimated. IMD quintiles are based on an individual's local neighbourhood and may not reflect an individual's economic circumstances. Ethnicity was derived from hospital records, the best available source for large-scale linkage. However, SUS has known limitations: minority ethnic groups are under-represented compared with national census, there are substantial proportions of records with a code of 'not stated', 'not known' and 'other', and these are not uniformly distributed across ethnic groups.[34] SUS data does not include all mental health trust activity; therefore emergency admissions for mental health issues may be underreported.

The study only looks at hospital use over a one-year period due to data constraints. Although this allows for an accurate reflection of the population, and accounts for seasonality, the impact of social context may have materialised either earlier or later than the study period, and so would ideally have been estimated from a long-term cohort.

Future work

Other social context factors can be developed using the UPRNs derived from GP registration data including recent bereavement, recent change to living alone, moving into a care home or multiple moves within a period, which may be a proxy for unstable housing.

CONCLUSION

This study shows 'proof of concept' that nationally collected address data can be used to determine social context factors that provide important and useful information to understand patients' health and care needs, while maintaining patient confidentiality by using pseudonymised address information.

Both living alone and living with a person with frailty were shown to be strongly associated with higher emergency hospital use. Although other research shows similar links, this is, to our knowledge, the first time that an analysis on routine data on a national scale has been used, underlining the importance of these social context factors in understanding individuals' health risk, and demonstrating the value of harnessing these data when identifying individuals for targeted interventions, e.g. MDTs. Informal carers, who play a critical role in our health and social care system, are often overlooked; these analyses provide evidence that it is crucial to provide additional support to this group, as well as those living alone.

Although these metrics cannot replace a personal assessment of an individual's social context and support needs, our analyses demonstrate that these social context factors can be used not only to improve analyses, but also for planning, commissioning, and population health management.

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COMPETING INTERESTS

None

CONTRIBUTORS

TL and RB designed the study. RB derived the social context indicators and created the analysis dataset. LC performed the analysis. All authors contributed to the interpretation of the work. TL, RB and LC drafted the paper; all authors revised and contributed to the paper. All authors read and approved the final manuscript.

RESEARCH ETHICS APPROVAL

This study requires no ethics board approval as the analysis uses pseudonymised data transferred by the National Commissioning Data Repository to the Improvement Analytics Unit, which is a data processor on behalf of NHS England and NHS Improvement.

DATA SHARING

No additional data available

REFERENCES

1 The Health Foundation. Social determinants of health. https://www.health.org.uk/topics/social-determinants-of-health (accessed 12 Oct 2021).

2 Marmot M, Allen J, Goldblatt P, *et al.* Fair society, healthy lives: strategic review of health inequalities in England post-201. London: 2010. http://www.instituteofhealthequity.org/resources-reports/fair-society-healthy-lives-the-marmot-review/fair-society-healthy-lives-full-report-pdf.pdf (accessed 21 Jun 2018).

3 Marmot M, Wilkinson RG. *Social determinants of health*. 2nd ed. Oxford: : Oxford University Press 2005.

4 Stokes J, Riste L, Cheraghi-Sohi S. Targeting the 'right' patients for integrated care: Stakeholder perspectives from a qualitative study. *J Heal Serv Res Policy* 2018;**23**:243–51. doi:10.1177/1355819618788100

5 Stokes J, Panagioti M, Alam R, *et al.* Effectiveness of Case Management for 'At Risk' Patients in Primary Care: A Systematic Review and Meta-Analysis. *PLoS One* 2015;**10**:e0132340. doi:10.1371/journal.pone.0132340

6 Brown S. Qualitative evaluation of South Warwickshire Place Based Teams. 2021.https://www.sqw.co.uk/application/files/7116/3734/2876/SW_PBTS.pdf

7 Lewis G, Curry N, Bardsley M. Choosing a predictive risk model : a guide for commissioners in England. 2011;:20.

8 Holt-Lunstad J, Smith TB, Baker M, *et al.* Loneliness and Social Isolation as Risk Factors for Mortality: A Meta-Analytic Review. *Perspect Psychol Sci* 2015;**10**:227–37. doi:10.1177/1745691614568352

9 Aiden H. Isolation and Loneliness: An overview of the literature. 2016. https://www.redcross.org.uk/-/media/documents/about-us/research-publications/health-and-social-care/co-op-isolation-loneliness-overview.pdf

10 Sanders S. Families and households in the UK: 2019. 2019. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families/datasets/familiesandhouseholdsfamiliesandhouseholds

11 Dreyer K, Steventon A, Fisher R, *et al.* The association between living alone and health care utilisation in older adults : a retrospective cohort study of electronic health records from a London general practice. 2018;:15–7. doi:10.1186/s12877-018-0939-4

12 Bom J, Bakx P, Schut F, *et al.* The Impact of Informal Caregiving for Older Adults on the Health of Various Types of Caregivers: A Systematic Review. *Gerontologist* 2019;**59**:e629–42. doi:10.1093/geront/gny137

13 Stafford M, Deeny SR, Dreyer K, *et al.* Multiple long-term conditions within households and use of health and social care: a retrospective cohort study. *BJGP Open* 2021;**5**:1–14. doi:10.3399/BJGPO.2020.0134

14 Carers UK. State of Caring 2018. 2018. https://www.carersuk.org/for-professionals/policy/policy-library/state-of-caring-2018-2

15 Vasileiou K, Barnett J, Barreto M, *et al.* Experiences of loneliness associated with being an informal caregiver: A qualitative investigation. *Front Psychol* 2017;**8**:1–11. doi:10.3389/fpsyg.2017.00585

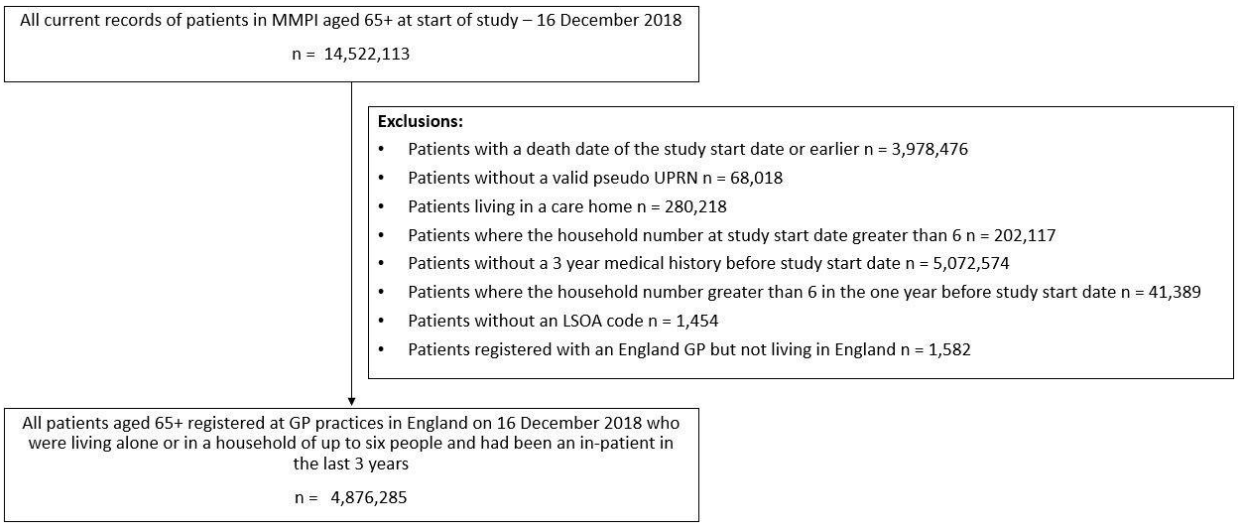
16 Harding R, Epiphaniou E, Hamilton D, *et al.* What are the perceived needs and challenges of informal caregivers in home cancer palliative care? Qualitative data to construct a feasible psycho-educational intervention. *Support Care Cancer* 2012;**20**:1975–82. doi:10.1007/s00520-011-1300-z

17 Thomas GPA, Saunders CL, Roland MO, *et al.* Informal carers' health-related quality of life and patient experience in primary care: Evidence from 195,364 carers in England responding to a national survey. *BMC Fam Pract* 2015;**16**:14–21. doi:10.1186/s12875-015-0277-y

18 Office for National Statistics. What does the 2011 Census tell us about older people. 2013.https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/ageing/articles/whatdoesthe2011censustellusaboutolderpeople/2013-09-06 (accessed 13 Oct 2021).

19 Carers UK. Facts about carers 2019. 2019. https://www.carersuk.org/images/Facts_about_Carers_2019.pdf
20 Ordnance Survey. OS Open UPRN. https://www.ordnancesurvey.co.uk/business-government/products/open-uprn (accessed 13 Oct 2021).
21 Santos F, Conti S, Wolters AT. A novel method for identifying care home residents in England: a validation study. *Int J Popul Data Sci* 2021;**5**.
22 Soong J, Poots AJ, Scott S, *et al.* Developing and validating a risk prediction model for acute care based on frailty syndromes Data source. Published Online First: 2015. doi:10.1136/bmjopen-2015-008457
23 Soong J, Poots AJ, Scott S, *et al.* Quantifying the prevalence of frailty in English hospitals. *BMJ Open* 2015;**5**. doi:10.1136/bmjopen-2015-008456
24 Hawkley LC, Cacioppo JT. Loneliness matters: a theoretical and empirical review of consequences and mechanisms. *Ann Behav Med* 2010;**40**:218–27. doi:10.1007/s12160-010-9210-8
25 Elixhauser A, Steiner C, Harris DR, *et al.* Comorbidity measures for use with administrative data. *Med Care* 1998;**36**:8–27. doi:10.1097/00005650-199801000-00004
26 Quan H, Sundararajan V, Halfon P, *et al.* Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Med Care* 2005;**43**:1130–9. doi:10.1097/01.mlr.0000182534.19832.83
27 Dorning H, Davies A, Blunt I. Quality Watch - Focus on : People with mental ill health and hospital use. 2015.
28 Department for Work and Pensions. Family Resources Survey 2018/2019. Published Online First: 2020.https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/791271/family-resources-survey-2017-18.pdf
29 Office for National Statistics. Households by age composition and ethnicity, UK, 2018. 2020.https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families/adhocs/12005householdsbyagecompositionandethnicityuk2018 (accessed 13 Oct 2021).
30 Mu C, Kecmanovic M, Hall J. Does Living Alone Confer a Higher Risk of Hospitalisation? *Econ Rec* 2015;**91**:124–38. doi:10.1111/1475-4932.12184
31 Hull SA, Jones IR, Moser K. Factors influencing the attendance rate at accident and emergency departments in East London: the contributions of practice organization, population characteristics and distance. *J Heal Serv Res Policy* 1997;**2**.
32 Lloyd T, Deeny SR, Steventon A. Weekend admissions may be associated with poorer recording of long-term comorbidities: A prospective study of emergency admissions using administrative data. *BMC Health Serv Res* 2018;**18**:1–12. doi:10.1186/s12913-018-3668-7
33 Hollinghurst J, Housley G, Watkins A, *et al.* A comparison of two national frailty scoring systems. *Age Ageing* 2021;**50**:1208–14. doi:10.1093/ageing/afaa252
34 Scobie S, Spencer J, Raleigh V. Ethnicity coding in English health service datasets. 2021. https://www.nuffieldtrust.org.uk/news-item/flawed-nhs-records-distort-our-view-of-ethnic-health-gaps-study-shows

Supplementary File 1. Inclusion and Exclusion Flow Chart. Created by the authors



Supplementary File 2. Baseline characteristics (full list). Created by the authors

	People 65+ years living in households up to 6 people[a]			People 65+ years living in households of 2 people[a]		
	All	Living Alone	Not living alone	All	Living with someone with frailty	Cohabitee not recorded as frail
Total study population (65 years+)	4,876,285	1,464,379	3,411,906	2,459,937	255,312	2,204,625
Male	47.04%	34.02%	52.63%	52.44%	53.84%	52.28%
Age, median [IQR]	75 [70, 81]	79 [72, 85]	74 [69, 79]	74 [70, 80]	77 [71, 83]	74 [70, 80]
Number living in household, mean (SD)	2.02 (0.99)					
Ethnicity						
White	80.96%	83.06%	80.06%	82.85%	84.64%	82.64%
Mixed	0.23%	0.23%	0.23%	0.17%	0.16%	0.17%
Asian	2.55%	1.12%	3.16%	1.53%	1.38%	1.55%
Black	1.11%	1.11%	1.11%	0.66%	0.54%	0.67%
Other	0.62%	0.51%	0.67%	0.46%	0.40%	0.46%
Not stated/missing	14.52%	13.96%	14.76%	14.33%	12.88%	14.50%
Deprivation						
Quintile #5 (least deprived quintile)	23.37%	19.71%	24.94%	26.19%	24.52%	26.38%
Quintile #4	22.87%	20.89%	23.72%	24.45%	23.27%	24.59%
Quintile #3	21.29%	20.97%	21.43%	21.51%	21.22%	21.54%
Quintile #2	17.68%	19.63%	16.84%	16.08%	17.03%	15.96%
Quintile #1 (most deprived quintile)	14.80%	18.80%	13.08%	11.77%	13.95%	11.52%
Rural location	22.27%	19.08%	23.64%	25.04%	22.56%	25.32%
Region						
East Midlands	8.94%	8.70%	9.04%	9.57%	9.18%	9.62%

East of England	11.69%	11.34%	11.84%	12.23%	11.61%	12.30%
London	10.07%	10.04%	10.09%	7.51%	7.93%	7.46%
North East	5.51%	6.02%	5.28%	5.61%	6.03%	5.57%
North West	14.10%	14.65%	13.86%	13.85%	15.13%	13.70%
South East	17.00%	16.57%	17.19%	17.36%	17.04%	17.40%
South West	11.89%	11.58%	12.02%	12.66%	12.11%	12.72%
West Midlands	10.62%	10.45%	10.69%	10.61%	10.64%	10.61%
Yorkshire and The Humber	10.19%	10.65%	9.99%	10.59%	10.33%	10.62%
Diagnosis history (previous three years)						
No. frailty syndromes, mean (SD)[b]	0.36 (0.76)	0.51 (0.90)	0.30 (0.68)	0.29 (0.67)	0.40 (0.80)	0.28 (0.65)
No. Elixhauser conditions, mean (SD)[b]	2.07 (1.90)	2.30 (1.99)	1.97 (1.85)	1.95 (1.83)	2.22 (1.96)	1.92 (1.81)
Frailty (1+ frailty related syndrome)[b]	24.69%	32.72%	21.24%	21.05%	26.90%	20.37%
Multimorbidity (2+ Elixhauser conditions)[b]	53.83%	58.93%	51.64%	51.15%	57.09%	50.46%
History of mental ill health	21.19%	26.18%	19.05%	18.30%	22.27%	17.84%
History of serious mental ill health	0.72%	1.18%	0.52%	0.48%	0.60%	0.47%
Elixhauser conditions (previous three years)						
Alcohol abuse	2.70%	3.29%	2.45%	2.36%	2.69%	2.32%
Blood loss anaemia	0.12%	0.15%	0.10%	0.10%	0.12%	0.10%
Deficiency anaemia	5.50%	6.65%	5.01%	4.84%	5.95%	4.71%
Cardiac arrhythmias	18.93%	21.61%	17.77%	18.14%	21.53%	17.75%
Coagulopathy	0.90%	0.92%	0.90%	0.89%	0.95%	0.88%
Depression	5.89%	7.71%	5.11%	4.97%	6.46%	4.80%
Diabetes, complicated	2.12%	2.20%	2.09%	1.90%	2.24%	1.86%
Diabetes, uncomplicated	15.85%	16.04%	15.76%	14.84%	16.76%	14.62%

Drug abuse	0.11%	0.18%	0.09%	0.07%	0.10%	0.07%
Fluid/electrolyte disorders	7.44%	9.82%	6.42%	6.22%	7.96%	6.01%
Hypertension, complicated	0.25%	0.26%	0.24%	0.23%	0.25%	0.22%
Hypertension, uncomplicated	52.18%	55.71%	50.66%	50.42%	54.70%	49.93%
Hypothyroidism	8.37%	10.17%	7.60%	7.64%	8.40%	7.56%
Liver disease	2.30%	2.39%	2.26%	2.17%	2.33%	2.15%
Lymphoma	0.97%	0.88%	1.01%	1.03%	1.04%	1.03%
Obesity	7.88%	7.19%	8.18%	7.92%	8.12%	7.90%
Other neurological disorders	4.26%	4.64%	4.10%	4.11%	4.88%	4.02%
Peptic ulcer disease excl. bleeding	1.54%	1.63%	1.50%	1.46%	1.63%	1.44%
Psychoses	0.42%	0.76%	0.27%	0.24%	0.32%	0.23%
Pulmonary circulation disorders	1.85%	2.20%	1.71%	1.69%	1.86%	1.67%
Peripheral vascular disease	4.96%	5.41%	4.76%	4.78%	5.74%	4.66%
Renal failure	9.99%	12.51%	8.91%	8.90%	11.31%	8.62%
Rheumatoid arthritis / collagen vascular diseases	5.57%	6.30%	5.26%	5.38%	5.94%	5.31%
Solid tumour without metastasis	7.30%	6.62%	7.59%	7.78%	7.89%	7.77%
Valvular disease	6.90%	8.05%	6.40%	6.46%	7.72%	6.32%
Weight loss	2.54%	2.99%	2.34%	2.27%	2.96%	2.20%
Congestive heart failure	7.15%	8.99%	6.36%	6.24%	8.04%	6.04%
Chronic pulmonary disease	19.67%	21.65%	18.82%	18.49%	20.95%	18.21%
Hemiplegia or paraplegia	1.18%	1.34%	1.11%	1.05%	1.28%	1.03%
Metastatic solid tumour / metastatic cancer	2.07%	1.89%	2.15%	2.17%	1.99%	2.19%
Frailty syndromes (previous three years)						
Anxiety or depression	8.51%	10.93%	7.46%	7.36%	9.14%	7.16%
Cognitive impairment	7.14%	9.95%	5.93%	5.80%	8.52%	5.49%

Functional dependence	1.32%	2.27%	0.91%	0.89%	1.57%	0.81%
Fall or significant fracture	11.80%	17.11%	9.52%	9.54%	12.65%	9.18%
Incontinence	1.78%	2.44%	1.50%	1.45%	2.00%	1.38%
Mobility problems	4.24%	6.31%	3.35%	3.25%	4.80%	3.07%
Pressure ulcers	1.36%	2.14%	1.03%	1.00%	1.47%	0.94%
Other conditions predictive of emergency admissions (previous three years)						
Miscellaneous cognitive dysfunction	6.35%	8.73%	5.33%	5.21%	6.97%	5.01%
Cerebral vascular disease	6.73%	8.33%	6.04%	5.97%	7.44%	5.80%
Dementia	3.09%	3.96%	2.72%	2.63%	4.05%	2.47%
Myocardial infarction	9.19%	9.59%	9.02%	8.91%	10.89%	8.68%
Any hospital usage (previous 12 months)[b]						
A&E attendance[b]	34.50%	39.42%	32.38%	31.73%	36.68%	31.15%
Emergency admission[b]	24.39%	29.48%	22.20%	21.81%	26.26%	21.29%
Chronic ACS emergency admission[b]	3.61%	4.48%	3.24%	3.14%	4.00%	3.04%
Acute ACS emergency admission[b]	6.07%	7.62%	5.40%	5.22%	6.92%	5.03%
Rates of hospital usage (previous 12 months), mean (SD)						
A&E attendances	0.61 (1.27)	0.74 (1.50)	0.56 (1.16)	0.54 (1.14)	0.67 (1.30)	0.53 (1.11)
Emergency admissions	0.38 (0.88)	0.48 (1.01)	0.34 (0.81)	0.33 (0.80)	0.42 (0.93)	0.32 (0.79)
Chronic ACS emergency admissions	0.05 (0.28)	0.06 (0.32)	0.04 (0.26)	0.04 (0.26)	0.05 (0.29)	0.04 (0.25)
Acute ACS emergency admissions	0.08 (0.36)	0.10 (0.42)	0.07 (0.33)	0.06 (0.32)	0.09 (0.38)	0.06 (0.31)

[a]Study population consisted of all people aged 65 years or older, registered at GP practices in England on 1 December 2018 and living in England, with a valid pseudonymized UPRN, not living in a care home, living in a household of 6 people or fewer, and with at least one hospital admission in the previous three years.
[b]Not adjusted for in the main analysis.

Supplementary File 3: Subgroup analyses: interaction results (a) living alone and deprivation and b) living with someone with frailty and gender. Created by the authors

	A&E attendance			Emergency admissions		
	Rate ratio	**95%CI**	**P value for interaction term**	**Rate ratio**	**95%CI**	**P value for interaction term**
Living alone[a]						
Living alone, IMD quintile 5 (least deprived, reference group)	1.11	(1.10 to 1.11)		1.17	(1.15 to 1.18)	
Living alone, IMD quintile 4	1.09	(1.08 to 1.10)	0.012	1.14	(1.13 to 1.16)	0.009
Living alone, IMD quintile 3	1.11	(1.10 to 1.12)	0.548	1.17	(1.15 to 1.18)	0.993
Living alone, IMD quintile 2	1.09	(1.08 to 1.10)	0.005	1.14	(1.13 to 1.15)	0.001
Living alone, IMD quintile 1 (most deprived)	1.07	(1.06 to 1.08)	<0.001	1.10	(1.09 to 1.11)	<0.001
Living with someone with frailty[b]						
Living with someone with frailty, female (reference group)	1.08	(1.07 to 1.10)		1.10	(1.09 to 1.12)	
Living with someone with frailty, male	1.10	(1.09 to 1.11)	0.101	1.09	(1.08 to 1.11)	0.297

[a]Adjusted for covariates listed in supplementary file 2, and interaction term for living alone and quintiles of deprivation.

[b]Adjusted for covariates listed in supplementary file 2, and interaction term for living with someone with frailty and gender.

Supplementary File 4. Sensitivity analyses: study population limited to individuals whose household composition did not change over the study period, and not adjusting for history of emergency hospital use. Created by the authors

	N	Rate ratio	95%CI	P value
Living alone: study population limited to individuals whose household composition did not change over the study period[a]				
A&E attendances	4,601,533	1.06	(1.06 to 1.07)	<0.001
Emergency admissions	4,601,533	1.10	(1.09 to 1.10)	<0.001
Living alone: not adjusting for history of emergency hospital use[b]				
A&E attendances	4,876,285	1.11	(1.11 to 1.12)	<0.001
Emergency admissions	4,876,285	1.16	(1.15 to 1.16)	<0.001
Living with someone with frailty: study population limited to individuals whose household composition did not change over the study period[a]				
A&E attendances[c]	2,266,187	1.08	(1.07 to 1.09)	<0.001
Emergency admissions[c]	2,266,187	1.08	(1.07 to 1.09)	<0.001
Living with someone with frailty: not adjusting for history of emergency hospital use[b]				
A&E attendances[d]	2,459,937	1.11	(1.10 to 1.12)	<0.001
Emergency admissions[d]	2,459,937	1.11	(1.10 to 1.12)	<0.001

[a]Adjusted for covariates listed in Supplementary File 2.

[b]Adjusted for covariates listed in Supplementary File 2 excluding emergency hospital use in the 12 months prior to analysis period.

[c]Note: A&E attendances: rate ratio 1.083 (95% CI 1.075 to 1.092). Emergency admissions: rate ratio 1.081 (95% CI 1.070 to 1.093).

[d]Note: A&E attendances: rate ratio 1.110 (95% CI 1.101 to 1.118). Emergency admissions: rate ratio 1.111 (95% CI 1.100 to 1.123).

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3-4
Methods			
Study design	4	Present key elements of study design early in the paper	4-5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4-5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4-5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4-5
Bias	9	Describe any efforts to address potential sources of bias	9-10, 12-13
Study size	10	Explain how the study size was arrived at	4, 6, Supplementary File 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4-5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4-6
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6, Supplementary File 1
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6-9, Supplementary File 1 & 2
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	

Outcome data	15*	Report numbers of outcome events or summary measures over time	9-10

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	5, 9-10, Supplementary File 2
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10-11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12-13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

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Association between household context and emergency hospital use in older people: a retrospective cohort study on indicators for people living alone or living with somebody with frailty, developed from routine healthcare data in England

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Association between household context and emergency hospital use in older people: a retrospective cohort study on indicators for people living alone or living with somebody with frailty, developed from routine healthcare data in England

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ABSTRACT

Objectives: To derive two household context factors, living alone and living in a two-person household with a person who is frail, from routine administrative health data and to assess their association with emergency hospital use in people aged 65 or over.

Design: Retrospective cohort study using national pseudonymised hospital data and pseudonymised address data derived from a minimised version of the Master Patient Index, a central database of all patient registrations in England.

Setting: England-wide.

Participants: 4,876,285 people aged 65 years or older registered at GP practices in England on 16 December 2018 who were living alone or in a household of up to six people, and with at least one hospital admission in the last three years.

Outcomes: Rates of emergency department (A&E) attendance and inpatient emergency admissions over a one-year follow-up period.

Results: Older people living alone had higher rates of A&E attendances (adjusted rate ratio 1.09, 95% CI 1.09 to 1.10) and emergency admissions (1.14, 95% CI 1.14 to 1.15) than older people living in households of 2-6 people. Older people living with someone with frailty in a two-person household had higher rates of A&E attendance (adjusted rate ratio 1.09, 95% CI 1.08 to 1.10) and emergency admissions (1.10, 95% CI 1.09 to 1.11) than other older people living in a two-person household.

Conclusions: We show that household context factors can be derived from linked routine administrative health data and that these are strongly associated with higher emergency hospital use in older people. Using household context factors can improve analyses, as well as support in the understanding of local population needs and in population health management.

STRENGTHS AND LIMITATIONS OF THIS STUDY

- Two household context factors, living alone and living with someone with frailty, were derived from pseudonymised routinely collected data; this created valuable additional patient-level information without the need to collect new data.
- National data from approximately 4.9 million people aged 65 or over was used to examine the association of the household context factors and emergency hospital use.
- The analysis adjusted for common demographic and clinical factors predictive of emergency hospital use.
- The study was restricted to individuals aged 65 or over who had a hospital admission in the previous three years, limiting the generalisability of our study.

INTRODUCTION

The 'social determinants of health'[1] – social context factors outside of the health and social care system that affect a person's health, such as social networks (eg family and friends), housing, education and employment opportunities – have long been recognised in the UK [2,3] and globally.

There is some evidence that a person's social context informs care: Stokes et al found that when identifying patients for multidisciplinary teams (MDTs), medical practitioners felt that the patients' needs were often primarily related to socio-economic factors such as isolation, poor housing or living arrangements, and other issues.[4] Some MDTs are aiming to address social, as well as health, needs.[5] Others are even specifically targeting people with non-clinical needs, with the aim of addressing social needs which might otherwise lead to deteriorating health and escalating medical needs.[6]

However, unlike other risks observed by clinicians that are included in population health management tools,[7] social context is not routinely captured in NHS or social care datasets, and where these are collected, they are often recorded in free text fields. Information on patients' circumstances is therefore not readily retrievable from electronic health records. This has implications not only for hospital staff but also analysts, commissioners or policy makers, who often rely on these data when analysing, planning or commissioning care.

The national health service (NHS) in England holds a central database of all patient registrations in England, which includes their address details. By assigning a Unique Property Reference Number (UPRN) to each address and pseudonymising the UPRN, it is possible to derive information on household composition while maintaining people's anonymity. This information can be used to create some important household context factors that may affect health and health outcomes, for example living alone or living with someone with frailty.

Living alone is a risk factor for social isolation and may therefore be a marker of social isolation.[8,9] Social isolation reflects a lack of personal ties, social integration or sense of community[10] and has been found to be associated with both increased morbidity and mortality.[8,11] There are different groups of people at risk of social isolation, not least young people leaving home for the first time. However, older people may be at greater risk of social isolation as a result of loss of physical or mental ability, or deaths of close family and friends.[11] Living alone does not necessarily mean someone is socially isolated; for example, approximately one-third of people aged 65 or over live on their own[12] but many may have friends or family living nearby. However, living alone has been found to be associated with higher emergency (unplanned) hospital use within one GP practice in South East London,[13] indicating that living alone still signals important social context at population level and warrants further investigation. Living alone may also have a detrimental effect on a person's mobility, nutrition and medication compliance.[9,14]

Living with someone with frailty may imply informal care responsibilities. Informally caring for somebody else can have a detrimental effect on a person's own physical and mental health.[15–17] Informal carers may not only feel socially isolated,[11] but may also suffer from lack of sleep and neglect their own health and personal wellbeing,[18,19] or have difficulty accessing care.[20] A large England-wide survey of informal carers found they had

worse health-related quality of life, with a disproportionate burden for already-marginalised groups.[20] According to the 2011 Census, 1.3 million (14%) people aged 65 or over living in households in England and Wales provided unpaid care in 2011, many of whom provided 50 hours or more unpaid care weekly.[21] There may now be over 2 million people aged 65 or older who are carers, with a significant proportion of carers aged 85 and over caring for someone with multiple needs, often including dementia.[22]

In this paper we demonstrate the value of deriving two household context factors from routinely collected address data: a) living alone, and b) living with one other person who is frail. We explore the association between these factors and emergency hospital use in people aged 65 or over, as this population is at particular risk of both emergency hospital admission and isolation.

METHODS

Data sources and linkage

We accessed a minimised version of the Master Patient Index (MMPI), a health dataset based on English GP registration data. This dataset included individuals' gender, month and year of birth (and death where applicable), lower super output area (LSOA) and pseudonymised UPRNs. UPRNs are the official unique identifier of every spatial address in Great Britain[23] and were applied to each address location in the MMPI and pseudonymised by our data suppliers. We did not have access to actual patient addresses. Building on our previous work to identify care home residents from UPRNs,[24] we also accessed a flag to indicate if a property was a care home. The individual's LSOA was used to link to small area statistics provided by the Office for National Statistics on socio-economic deprivation, rurality and geographical region.

Study population and outcomes

Our study population consisted of all people aged 65 years or older registered at GP practices in England on 16 December 2018 who were living alone or in a household of up to six people. Household size was limited to six in order to exclude people living in establishments, as their care provision may differ from that of a single household. This restriction excluded less than 2% of households.[12] We excluded individuals without a valid pseudonymised UPRN or living in care homes at the study start date, and those living at properties containing seven or more people at any time in the year prior to the study start. People not admitted to hospital in the previous three years were also excluded, as hospital records were used to identify long-term conditions and ethnicities (Supplementary File 1).

Where both individuals in a two-person household were aged 65 or older, both were included in the study population and contributed to the analysis. If one household member was under 65, this member was not included in the study population but did contribute to defining the household context of their cohabitee.

Using a common pseudonymised NHS number, we linked the MMPI data to Secondary Uses Service [SUS] hospital data from the previous three years. For any individual aged 65 or over with linked hospital records we identified their long-term conditions, secondary care use and top-level ethnicity (based on the mode of ethnicities recorded).

The maximum follow-up period (study length) was one year unless censored because the person died, moved into a care home or their household composition changed.

We examined rates of emergency department (A&E) attendance and inpatient emergency admissions in the follow-up period.

Household context factors

A person was defined as living alone if there was no other person with the same UPRN during the study period. For individuals living in two-person households we also linked the hospital records of their cohabitee, where these existed, to identify if the individual was living with someone recorded as frail. A person was identified as frail if they had any of the conditions or events in Soong et al's list of syndromes[25,26] coded in inpatient records in the previous three years. These include cognitive impairment, mobility problems and pressure ulcers, which may require care or support from the cohabitee.

Statistical methods

We used multivariable regression to examine the association between emergency health care use (emergency department attendances and emergency hospital admissions, respectively) and a) living alone and b) living with someone with frailty. We did this by comparing living alone to living in a household of two to six people and, separately, comparing living in a two-person household with a person with frailty to living in a two-person household where the cohabitee was not recorded as frail.

We ran both crude and adjusted analyses. Adjusted analyses included age, gender, ethnicity, geographical region (nine areas of England), socio-economic deprivation (Index of Multiple Deprivation – IMD – quintiles), rural/urban classification, historic emergency hospital use in the last twelve months (including emergency admissions for chronic ambulatory care sensitive and acute urgent care sensitive conditions), and a range of long-term conditions recorded in the previous three years. These conditions included frailty indicators,[25,26] history of mental or serious mental ill-health,[27] and other conditions predictive of emergency hospital use [28,29] (see Supplementary File 2 for full list of covariates). We aimed to include as covariates as many variables as possible without overparametrising the model in order to remove any known confounding. We used a negative binomial model as the data was overdispersed. Rate ratios were produced to interpret the results.

Subgroup analysis

We investigated whether the emergency hospital use of people living with someone with frailty differed depending on if they were male or female, as women in general provide more informal care than men.[30] We also investigated whether the emergency hospital use of people living alone differed according to their local deprivation quintile, as this may affect a person's access to informal or formal care (neither of which is observable in our data). Differences in the rate ratios between population subgroups were examined by fitting a multivariable regression model including an interaction term between the household context factor and the population segment.

Sensitivity analysis

In the main analyses people were censored at the time their household composition changed. There is a risk that that household change could be driven by deteriorating health, for example if a person living alone had worsening illness and moved into a care home. This would underestimate a person's health care needs if they had continued living alone. Therefore, a sensitivity analysis examined only those whose household composition remained stable, ie did not change over the year.

The main analyses adjusted for, among other covariates, emergency hospital use in the twelve months prior to the analysis period, as these variables may reflect the clinical severity of a patient's condition(s), which can be difficult to deduce from electronic health records. However, prior hospital use may also be affected by past household context factors (e.g. living alone or living with somebody with frailty), potentially underestimating the effect of these household context variables. Therefore, we performed sensitivity analyses omitting prior hospital use covariates.

Patient and public involvement

We sought input from a patient representative at the development stage, including on choice and relevance of household context factors. There was further engagement with this same and another representative on the interpretation of results and on an early draft of the paper.

RESULTS

Study populations

After applying the inclusion and exclusion criteria, there were 4,876,285 people aged over 65, registered with an English GP and living in England, with at least one hospital admission in the last three years and living in a household of up to six people (Supplementary File 1). The largest exclusion was due to no hospital admission in the previous three years (approximately 5m). Of the remaining individuals, 1,464,379 (30.03%) lived alone and 2,459,937 (50.45%) lived in a two-person household (Table 1).

People living alone were more often female (66% vs 47%) and on average older (median age 79 vs 74) compared with people living in households of 2-6 people (Table 1, Supplementary File 2). They also lived in more deprived areas; 19% lived in the most deprived quintile compared to 13% of individuals living in households of 2-6 people. Furthermore, more people living alone were frail (33% vs 21%, with on average 0.51 vs 0.30 frailty syndromes) and they had higher levels of multimorbidity (on average 2.30 vs 1.97 conditions) compared with people in households of 2-6 people. They also had greater numbers of A&E attendance and emergency admissions in the twelve months prior to our study period (0.74 vs 0.56 and 0.48 vs 0.34, respectively) than people in households of 2-6 people.

Among people aged 65 or over living in two-person households, people living with someone with frailty had a median age of 77, compared with 74 for people living with a cohabitee who was not recorded as frail (Table 1, Supplementary File 2). 54% (vs 52%) were male and 14% (vs 12%) lived in the most deprived quintile. People living with someone with frailty were on average themselves more likely to be frail (27% vs 20%), with on average 0.40 (vs 0.28) frailty syndromes, and had more long-term conditions (2.22 vs 1.92). They also had

greater rates of A&E attendance and emergency admissions in the twelve months prior (0.67 vs 0.53 and 0.42 vs 0.32, respectively) compared with people living with a cohabitee who was not recorded as frail.

Table 1. Baseline characteristics

	People 65+ years living in households up to 6 people*			People 65+ years living in households of 2 people*		
	All	Living Alone	Not living alone	All	Living with someone with frailty	Cohabitee not recorded as frail
Total study population (65 years+)	4,876,285	1,464,379	3,411,906	2,459,937	255,312	2,204,625
Male	47.04%	34.02%	52.63%	52.44%	53.84%	52.28%
Age, median [IQR]	75 [70, 81]	79 [72, 85]	74 [69, 79]	74 [70, 80]	77 [71, 83]	74 [70, 80]
Ethnicity						
White	80.96%	83.06%	80.06%	82.85%	84.64%	82.64%
Mixed	0.23%	0.23%	0.23%	0.17%	0.16%	0.17%
Asian	2.55%	1.12%	3.16%	1.53%	1.38%	1.55%
Black	1.11%	1.11%	1.11%	0.66%	0.54%	0.67%
Other	0.62%	0.51%	0.67%	0.46%	0.40%	0.46%
Not stated/missing	14.52%	13.96%	14.76%	14.33%	12.88%	14.50%
Deprivation						
Quintile #5 (least deprived quintile)	23.37%	19.71%	24.94%	26.19%	24.52%	26.38%
Quintile #4	22.87%	20.89%	23.72%	24.45%	23.27%	24.59%
Quintile #3	21.29%	20.97%	21.43%	21.51%	21.22%	21.54%
Quintile #2	17.68%	19.63%	16.84%	16.08%	17.03%	15.96%
Quintile #1 (most deprived quintile)	14.80%	18.80%	13.08%	11.77%	13.95%	11.52%
Rural location	22.27%	19.08%	23.64%	25.04%	22.56%	25.32%
Diagnosis history (previous three years)						
No. frailty syndromes, mean (SD)	0.36 (0.76)	0.51 (0.90)	0.30 (0.68)	0.29 (0.67)	0.40 (0.80)	0.28 (0.65)
No. Elixhauser conditions, mean (SD)	2.07 (1.90)	2.30 (1.99)	1.97 (1.85)	1.95 (1.83)	2.22 (1.96)	1.92 (1.81)
Frailty (1+ frailty related syndrome)	24.69%	32.72%	21.24%	21.05%	26.90%	20.37%
Multimorbidity (2+ Elixhauser conditions)	53.83%	58.93%	51.64%	51.15%	57.09%	50.46%
History of mental ill health	21.19%	26.18%	19.05%	18.30%	22.27%	17.84%
Rates of hospital usage (previous 12 months), mean (SD)						
A&E attendances	0.61 (1.27)	0.74 (1.50)	0.56 (1.16)	0.54 (1.14)	0.67 (1.30)	0.53 (1.11)

	People 65+ years living in households up to 6 people*			People 65+ years living in households of 2 people*		
	All	Living Alone	Not living alone	All	Living with someone with frailty	Cohabitee not recorded as frail
Emergency admissions	0.38 (0.88)	0.48 (1.01)	0.34 (0.81)	0.33 (0.80)	0.42 (0.93)	0.32 (0.79)

For more baseline characteristics, please see Supplementary File 2.

*Study population consisted of all people aged 65 years or older, registered at GP practices in England on 16 December 2018 and living in England, with a valid pseudonymised UPRN, not living in a care home, living in a household of 6 people or fewer, and with at least one hospital admission in the previous three years.

Statistical analysis

People aged 65 or over living alone had on average 0.78 A&E attendances per person per year in the follow-up period, compared with 0.56 for people living in households of 2-6 people. They had on average 0.51 emergency admissions per person per year, compared with 0.33 for people living in households of 2-6 people (Table 2). Without adjusting for baseline characteristics, people living alone had substantially higher rates of A&E attendance (unadjusted rate ratio 1.44, 95% confidence interval (CI) 1.43 to 1.44) than people living in households of 2-6 people (Table 3). They also had higher rates of emergency admissions (unadjusted rate ratio 1.60, 95% CI 1.60 to 1.61).

Table 2. Crude rates of secondary use (number of events per person per year)

	People 65+ years living in households up to 6 people				People 65+ years living in households of 2 people			
	Living alone		Not living alone		Living with someone with frailty		Cohabitee not recorded as frail	
Outcomes over the follow-up period	**Events**	**Crude rate***	**Events**	**Crude rate***	**Events**	**Crude rate***	**Events**	**Crude rate***
Total number people	1,464,379		3,411,906		255,312		2,204,625	
Person-years of follow up	1,359,094		3,251,440		226,373		2,077,846	
A&E attendances	1,062,731	0.78	1,818,519	0.56	157,137	0.69	1,102,683	0.53
Emergency admissions	692,345	0.51	1,073,870	0.33	98,584	0.44	654,784	0.32

*Number of events per person, per year.

After adjusting for baseline characteristics, we found that people living alone still had statistically significantly higher rates of A&E attendances (adjusted rate ratio 1.09, 95% CI 1.09 to 1.10) and emergency admissions (1.14, 95% CI 1.14 to 1.15, Table 3).

People living with someone with frailty had on average 0.69 A&E attendances per person per year, compared with 0.53 for people living in two-person households where the cohabitee was not recorded as frail. They had on average 0.44 emergency admissions per person per year, compared with 0.32 for people living in two-person households where the cohabitee was not recorded as frail (Table 2). Without adjusting for baseline characteristics, people living with someone with frailty had substantially higher rates of A&E attendances (unadjusted rate ratio 1.33, 95% CI 1.32 to 1.34) and emergency admissions (unadjusted rate ratio 1.42, 95% CI 1.41 to 1.44) than the comparison population (Table 3). After adjusting for baseline characteristics, people living with someone with frailty in a two-person household still had statistically significantly higher rates of both A&E attendance (adjusted rate ratio 1.09, 95% CI 1.08 to 1.10) and emergency admissions (1.10, 95% CI 1.09 to 1.11, Table 3).

Table 3. Results of unadjusted and adjusted regression models

	Unadjusted model			Adjusted model		
	Rate ratio	**95%CI**	**P value**	**Rate ratio**	**95% CI**	**P value**
Living alone						
A&E attendances	1.44	(1.43 to 1.44)	<0.001	1.09	(1.09 to 1.10)	<0.001
Emergency admissions	1.60	(1.60 to 1.61)	<0.001	1.14	(1.14 to 1.15)	<0.001
Living with someone with frailty						
A&E attendances	1.33	(1.32 to 1.34)	<0.001	1.09	(1.08 to 1.10)	<0.001
Emergency admissions	1.42	(1.41 to 1.44)	<0.001	1.10	(1.09 to 1.11)	<0.001

Adjusted models included as covariates gender, age, deprivation, ethnicity, geographical region, rural location, history of a range of diagnoses in previous three years and historic emergency hospital use in the last 12 months (covariates listed in Supplementary File 2).

Subgroup analysis

Gender

There was no evidence that the adjusted rate ratio for A&E attendances or emergency admissions was statistically significantly different depending on if the person who was living with somebody with frailty was male or female (interaction test p=0.101 and p= 0.297, respectively, Supplementary File 3).

Level of deprivation

There was a statistically significant difference in the rate ratios of living alone for different levels of deprivation compared with the least deprived quintile (interaction tests p<0.02) in all but the third quintile (i.e. the middle group). While people living alone had higher rates of emergency hospital use than those not living alone in each of the five IMD quintiles, the rate ratio for the association between living alone and A&E attendances was lowest in the most deprived quintile (adjusted rate ratio 1.07, 95% CI 1.06 to 1.08) and highest in the least deprived quintile (adjusted rate ratio 1.11, 95% CI 1.10 to 1.11). Similarly, for emergency admissions, it varied between 1.10 (95% CI 1.09 to 1.11) in the most deprived quintile and 1.17 (95% CI 1.15 to 1.18) in the least deprived quintile (Supplementary File 3). In other words, the association between living alone and increased hospitalisation was stronger for *less* deprived groups.

Sensitivity analysis

Stable household composition only

Limiting the study population to individuals whose household composition did not change over the year, the adjusted rate ratio for living alone compared with households of 2-6 people for A&E attendance was 1.06 (95% CI 1.06 to 1.07); for emergency admissions this was 1.10 (95% CI 1.09 to 1.10), (Supplementary File 4). For the analysis of living with someone with frailty, the adjusted rate ratio for A&E attendance was 1.08 (95% CI 1.07 to 1.09) and for emergency admissions 1.08 (95% CI 1.07 to 1.09).

Omitting covariates on prior emergency hospital use

Adjusting for baseline characteristics excluding prior emergency hospital use, the adjusted rate ratio for A&E attendance was 1.11 (95% CI 1.11 to 1.12) and for emergency admissions 1.16 (95% CI 1.15 to 1.16) (Supplementary File 4). For the analysis of living with someone with frailty in a two-person household, the adjusted rate ratio for A&E attendance was 1.11 (95% CI 1.10 to 1.12) and for emergency admissions 1.11 (95% CI 1.10 to 1.12).

DISCUSSION

Our analysis showed that both living alone and living with somebody with frailty are strongly associated with higher emergency hospital use in the one-year follow-up period. We found that differences in demographic characteristics and underlying health conditions explain most of this association; however, even after adjusting for baseline demographic and clinical characteristics, people living alone attend A&E 9% more often and are admitted to hospital in an emergency 14% more often than those living with others. Similarly, individuals living with someone who has frailty attend A&E 9% more often and are admitted to hospital as an emergency 10% more often than others in a two-person household. It is important to note that although older people living alone may be at higher risk of social isolation, this is an imperfect proxy at best. For example, an individual residing alone may have a rich social network of family and friends and/or have access to formal or informal care; routine

administrative data cannot capture these nuances. Similarly, individuals living in a two-person household with someone with frailty may have access to formal or informal support and care. Furthermore, this analysis does not provide insight into the mechanism by which these two household factors affect individuals' emergency health care needs.

Nevertheless, we have found a strong association between these two factors and emergency hospital use, even after correcting for other factors predictive of hospital use. This indicates that these metrics are picking up on an additional health care need that is not explained by commonly known predictors, such as prior hospital use or frailty.

Ideally a person's support needs should be assessed individually and in person, especially for their clinical management. However, this analysis demonstrates how existing administrative data can be used to derive household context factors that can be used in the absence of such information being recorded. These household context factors could improve population risk algorithms, budget models, or initial service eligibility criteria. For instance, these factors could be used to help identify populations for targeted anticipatory care initiatives such as MDTs that may be able to mitigate some social as well as medical risk factors to prevent later deteriorating health or hospitalisation.

Household context factors can also contribute to more robust research and evaluation by allowing for the adjustment of previously unobserved characteristics affecting health care outcomes, thereby decreasing the risk of bias in analyses.

This analysis found that, although higher levels of deprivation are associated with higher emergency hospital use, the interaction between level of deprivation and living alone was counterintuitive: individuals living alone in the most deprived areas had a lower increase in hospitalisation rates (compared with those not living alone in similar areas) than individuals living alone in the least deprived areas. It is not possible to determine from our analyses why this may be. It may be that there are differences in health-seeking behaviours, or different access to formal or informal care outside of the household, which in turn could lead to either more (if identifying need) or less (if addressing need) emergency hospital use. Qualitative research is needed to understand the mechanisms behind these results, and to provide context and nuance.

Strengths and limitations

While prior studies on living alone or informal carers have used survey or local data, this analysis uses routinely collected national data from approximately 4.9m people aged 65 or over, thereby providing robust findings. Through accessing other routine data collections, the analysis could control for common demographic and clinical factors predictive of emergency hospital use, including many long-term conditions. However, the study population was restricted to people in England aged 65 and over, who were admitted to hospital in the three years prior to our analysis. Although this allowed for the derivation of pre-existing conditions from previous hospital records, our analysis is restricted to people that are older and sicker compared with the overall population, limiting the generalisability of our findings. Furthermore, the analysis was restricted to households of up to 6 people, in order to exclude communal establishments such as care home or prisons. Excluding households of 7 or more people will likely disproportionately exclude people from certain ethnic backgrounds, who more often have multigenerational households.[31]

Our findings are nonetheless broadly consistent with other studies that have previously found strong links between older people living alone and their emergency hospital use.[13,32,33] To our knowledge, there are no statistical studies on living with someone with frailty, although results are broadly consistent with the literature on informal carers. A study on multimorbidity within households found inconsistent results of cohabitees' multimorbidity status on emergency hospital use.[16]

The household context factors were derived from address information collected by general practices in England. For these to be accurate, address information needs to be up to date. Anecdotal evidence suggests that address information is typically well recorded, particularly for the older population, but this could not be validated.

Individuals' health conditions derived from hospital admission records may be underreported [34] and therefore not fully adjusted for in analysis. In particular, frailty may be underreported [25] or reported differently to general practice.[35] If some individuals who have a cohabitee with frailty were misclassified, the association with emergency hospital use was potentially underestimated. IMD quintiles are based on an individual's local neighbourhood and may not reflect an individual's economic circumstances. Ethnicity was derived from hospital records, the best available source for large-scale linkage. However, SUS has known limitations: minority ethnic groups are under-represented compared with national census, there are substantial records with a code of 'not stated', 'not known' and 'other', and these are not uniformly distributed across ethnic groups.[36] SUS data does not include all mental health trust activity; therefore emergency admissions for mental health issues may be underreported.

The study only looks at hospital use over a one-year period due to data constraints. Although this allows for an accurate reflection of the population, and accounts for seasonality, the impact of household context may have materialised either earlier or later than the study period, and so would ideally have been estimated from a long-term cohort.

Future work

Other household context factors can be developed using the UPRNs derived from GP registration data, including recent bereavement, recent change to living alone, moving into a care home or multiple moves within a given period, which may be a proxy for unstable housing.

CONCLUSION

This study shows 'proof of concept' that nationally collected and pseudonymised address data can be used to determine household context factors that provide important and useful information to understand patients' health and care needs, while maintaining patient confidentiality. In particular, living in a two-person household with someone with frailty is a novel indicator, which has not previously been developed or analysed.

Both living alone and living with a person with frailty were shown to be strongly associated with higher emergency hospital use, underlining the importance of these household context factors in understanding individuals' health risk and the potential to harness these data for identifying individuals for targeted interventions like MDTs. Informal carers, who play a critical role in our health and social care system, are often overlooked; these analyses add to the evidence that it is crucial to provide support to this group, as well as those living alone.

Although other research, particularly on living alone, shows similar links, this is, to our knowledge, the first time that an analysis on routine data on a national scale has been used.

Although these metrics cannot replace a personal assessment of an individual's social context and support needs, our analyses demonstrate that these household context factors can be used not only to improve analyses, but also for planning, commissioning, and population health management.

ACKNOWLEDGMENTS

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COMPETING INTERESTS

None.

CONTRIBUTORS

TL and RB designed the study. RB derived the household context indicators and created the analysis dataset. EC performed the analysis. TL, EC, RB, JS and AW contributed to the interpretation of the work. TL, RB and EC drafted the paper; all authors revised and contributed to the paper. All authors read and approved the final manuscript.

ETHICS APPROVAL

This study requires no ethics board approval as the analysis uses pseudonymised data transferred by the National Commissioning Data Repository to the Improvement Analytics Unit, which is a data processor on behalf of NHS England and NHS Improvement.

DATA AVAILABILITY STATEMENT

No additional data are available.

REFERENCES

1 The Health Foundation. Social determinants of health. https://www.health.org.uk/topics/social-determinants-of-health (accessed 12 Oct 2021).

2 Marmot M, Allen J, Goldblatt P, *et al.* Fair society, healthy lives: strategic review of health inequalities in England post-201. London: 2010. http://www.instituteofhealthequity.org/resources-reports/fair-society-healthy-lives-the-marmot-review/fair-society-healthy-lives-full-report-pdf.pdf (accessed 21 Jun 2018).

3 Marmot M, Wilkinson RG. *Social determinants of health*. 2nd ed. Oxford: : Oxford University Press 2005.

4 Stokes J, Riste L, Cheraghi-Sohi S. Targeting the 'right' patients for integrated care: Stakeholder perspectives from a qualitative study. *J Heal Serv Res Policy* 2018;**23**:243–51. doi:10.1177/1355819618788100

5 Stokes J, Panagioti M, Alam R, *et al.* Effectiveness of Case Management for 'At Risk' Patients in Primary Care: A Systematic Review and Meta-Analysis. *PLoS One* 2015;**10**:e0132340. doi:10.1371/journal.pone.0132340

6 Brown S. Qualitative evaluation of South Warwickshire Place Based Teams. 2021.

7 Lewis G, Curry N, Bardsley M. Choosing a predictive risk model : a guide for commissioners in England. 2011;:20.

8 Holt-Lunstad J, Smith TB, Baker M, *et al.* Loneliness and Social Isolation as Risk Factors for Mortality: A Meta-Analytic Review. *Perspect Psychol Sci* 2015;**10**:227–37. doi:10.1177/1745691614568352

9 Bucholz EM, Rathore SS, Gosch K, *et al.* Effect of living alone on patient outcomes after hospitalization for acute myocardial infarction. *Am J Cardiol* 2011;**108**:943–8. doi:10.1016/j.amjcard.2011.05.023

10 Hawkley LC, Cacioppo JT. Loneliness matters: a theoretical and empirical review of consequences and mechanisms. *Ann Behav Med* 2010;**40**:218–27. doi:10.1007/s12160-010-9210-8

11 Aiden H. Isolation and Loneliness: An overview of the literature. 2016. https://www.redcross.org.uk/-/media/documents/about-us/research-publications/health-and-social-care/co-op-isolation-loneliness-overview.pdf

12 Sanders S. Families and households in the UK: 2019. 2019. https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families/datasets/familiesandhouseholdsfamiliesandhouseholds

13 Dreyer K, Steventon A, Fisher R, *et al.* The association between living alone and health care utilisation in older adults : a retrospective cohort study of electronic health records from a London general practice. 2018;:15–7. doi:10.1186/s12877-018-0939-4

14 Bucholz EM, Krumholz HM. Loneliness and living alone: What are we really measuring? *Arch Intern Med* 2012;**29**:997–1003. doi:10.1016/j.biotechadv.2011.08.021.Secreted

15 Bom J, Bakx P, Schut F, *et al.* The Impact of Informal Caregiving for Older Adults on the Health of Various Types of Caregivers: A Systematic Review. *Gerontologist* 2019;**59**:e629–42. doi:10.1093/geront/gny137

16 Stafford M, Deeny SR, Dreyer K, *et al.* Multiple long-term conditions within households and use of health and social care: a retrospective cohort study. *BJGP Open* 2021;**5**:1–14. doi:10.3399/BJGPO.2020.0134

17 Carers UK. State of Caring 2018. 2018. https://www.carersuk.org/for-professionals/policy/policy-library/state-of-caring-2018-2

18 Vasileiou K, Barnett J, Barreto M, *et al.* Experiences of loneliness associated with being an informal caregiver: A qualitative investigation. *Front Psychol* 2017;**8**:1–11. doi:10.3389/fpsyg.2017.00585

19 Harding R, Epiphaniou E, Hamilton D, *et al.* What are the perceived needs and challenges of informal caregivers in home cancer palliative care? Qualitative data to construct a feasible psycho-educational intervention. *Support Care Cancer* 2012;**20**:1975–82. doi:10.1007/s00520-011-1300-z

20 Thomas GPA, Saunders CL, Roland MO, *et al.* Informal carers' health-related quality of life and patient experience in primary care: Evidence from 195,364 carers in England responding to a national survey. *BMC Fam Pract* 2015;**16**:14–21. doi:10.1186/s12875-015-0277-y

21 Office for National Statistics. What does the 2011 Census tell us about older people. 2013.https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/ageing/articles/whatdoesthe2011censustellusaboutolderpeople/2013-09-06 (accessed 13 Oct 2021).

22 Carers UK. Facts about carers 2019. 2019. https://www.carersuk.org/images/Facts_about_Carers_2019.pdf

23 Ordnance Survey. OS Open UPRN. https://www.ordnancesurvey.co.uk/business-government/products/open-uprn (accessed 13 Oct 2021).

24 Santos F, Conti S, Wolters AT. A novel method for identifying care home residents in England: a validation study. *Int J Popul Data Sci* 2021;**5**.

25 Soong J, Poots AJ, Scott S, *et al.* Developing and validating a risk prediction model for acute care based on frailty syndromes Data source. Published Online First: 2015. doi:10.1136/bmjopen-2015-008457

26 Soong J, Poots AJ, Scott S, *et al.* Quantifying the prevalence of frailty in English hospitals. *BMJ Open* 2015;**5**. doi:10.1136/bmjopen-2015-008456

27 Dorning H, Davies A, Blunt I. Quality Watch - Focus on : People with mental ill health and hospital use. 2015.

28 Elixhauser A, Steiner C, Harris DR, *et al.* Comorbidity measures for use with administrative data. *Med Care* 1998;**36**:8–27. doi:10.1097/00005650-199801000-00004

29 Quan H, Sundararajan V, Halfon P, *et al.* Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Med Care* 2005;**43**:1130–9. doi:10.1097/01.mlr.0000182534.19832.83

30 Department for Work and Pensions. Family Resources Survey 2018/2019. Published Online First: 2020.https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/791271/family-resources-survey-2017-18.pdf

31 Office for National Statistics. Households by age composition and ethnicity, UK, 2018. 2020.https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families/adhocs/12005householdsbyagecompositionandethnicityuk2018 (accessed 13 Oct 2021).

32 Mu C, Kecmanovic M, Hall J. Does Living Alone Confer a Higher Risk of Hospitalisation? *Econ Rec* 2015;**91**:124–38. doi:10.1111/1475-4932.12184

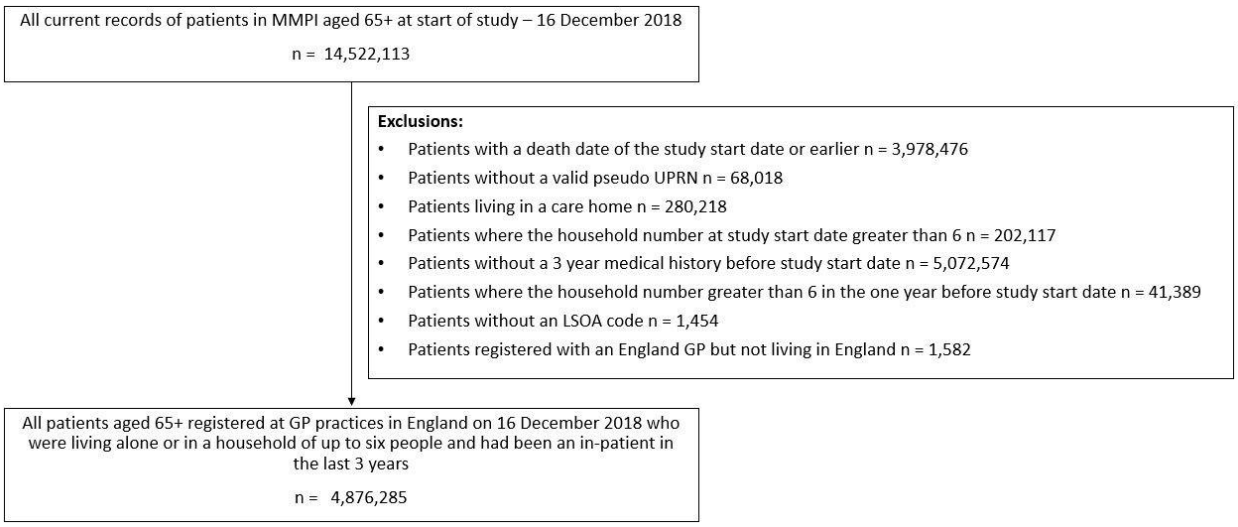
33 Hull SA, Jones IR, Moser K. Factors influencing the attendance rate at accident and emergency departments in East London: the contributions of practice organization, population characteristics and distance. *J Heal Serv Res Policy* 1997;**2**.

34 Lloyd T, Deeny SR, Steventon A. Weekend admissions may be associated with poorer recording of long-term comorbidities: A prospective study of emergency admissions using administrative data. *BMC Health Serv Res* 2018;**18**:1–12. doi:10.1186/s12913-018-3668-7

35 Hollinghurst J, Housley G, Watkins A, *et al.* A comparison of two national frailty scoring systems. *Age Ageing* 2021;**50**:1208–14. doi:10.1093/ageing/afaa252

36 Scobie S, Spencer J, Raleigh V. Ethnicity coding in English health service datasets. 2021. https://www.nuffieldtrust.org.uk/news-item/flawed-nhs-records-distort-our-view-of-ethnic-health-gaps-study-shows

Supplementary File 1. Inclusion and Exclusion Flow Chart. Created by the authors



Supplementary File 2. Baseline characteristics (full list). Created by the authors

	People 65+ years living in households up to 6 people[a]			People 65+ years living in households of 2 people[a]		
	All	Living Alone	Not living alone	All	Living with someone with frailty	Cohabitee not recorded as frail
Total study population (65 years+)	4,876,285	1,464,379	3,411,906	2,459,937	255,312	2,204,625
Male	47.04%	34.02%	52.63%	52.44%	53.84%	52.28%
Age, median [IQR]	75 [70, 81]	79 [72, 85]	74 [69, 79]	74 [70, 80]	77 [71, 83]	74 [70, 80]
Number living in household, mean (SD)	2.02 (0.99)					
Ethnicity						
White	80.96%	83.06%	80.06%	82.85%	84.64%	82.64%
Mixed	0.23%	0.23%	0.23%	0.17%	0.16%	0.17%
Asian	2.55%	1.12%	3.16%	1.53%	1.38%	1.55%
Black	1.11%	1.11%	1.11%	0.66%	0.54%	0.67%
Other	0.62%	0.51%	0.67%	0.46%	0.40%	0.46%
Not stated/missing	14.52%	13.96%	14.76%	14.33%	12.88%	14.50%
Deprivation						
Quintile #5 (least deprived quintile)	23.37%	19.71%	24.94%	26.19%	24.52%	26.38%
Quintile #4	22.87%	20.89%	23.72%	24.45%	23.27%	24.59%
Quintile #3	21.29%	20.97%	21.43%	21.51%	21.22%	21.54%
Quintile #2	17.68%	19.63%	16.84%	16.08%	17.03%	15.96%
Quintile #1 (most deprived quintile)	14.80%	18.80%	13.08%	11.77%	13.95%	11.52%
Rural location	22.27%	19.08%	23.64%	25.04%	22.56%	25.32%
Region						
East Midlands	8.94%	8.70%	9.04%	9.57%	9.18%	9.62%

East of England	11.69%	11.34%	11.84%	12.23%	11.61%	12.30%
London	10.07%	10.04%	10.09%	7.51%	7.93%	7.46%
North East	5.51%	6.02%	5.28%	5.61%	6.03%	5.57%
North West	14.10%	14.65%	13.86%	13.85%	15.13%	13.70%
South East	17.00%	16.57%	17.19%	17.36%	17.04%	17.40%
South West	11.89%	11.58%	12.02%	12.66%	12.11%	12.72%
West Midlands	10.62%	10.45%	10.69%	10.61%	10.64%	10.61%
Yorkshire and The Humber	10.19%	10.65%	9.99%	10.59%	10.33%	10.62%
Diagnosis history (previous three years)						
No. frailty syndromes, mean (SD)[b]	0.36 (0.76)	0.51 (0.90)	0.30 (0.68)	0.29 (0.67)	0.40 (0.80)	0.28 (0.65)
No. Elixhauser conditions, mean (SD)[b]	2.07 (1.90)	2.30 (1.99)	1.97 (1.85)	1.95 (1.83)	2.22 (1.96)	1.92 (1.81)
Frailty (1+ frailty related syndrome)[b]	24.69%	32.72%	21.24%	21.05%	26.90%	20.37%
Multimorbidity (2+ Elixhauser conditions)[b]	53.83%	58.93%	51.64%	51.15%	57.09%	50.46%
History of mental ill health	21.19%	26.18%	19.05%	18.30%	22.27%	17.84%
History of serious mental ill health	0.72%	1.18%	0.52%	0.48%	0.60%	0.47%
Elixhauser conditions (previous three years)						
Alcohol abuse	2.70%	3.29%	2.45%	2.36%	2.69%	2.32%
Blood loss anaemia	0.12%	0.15%	0.10%	0.10%	0.12%	0.10%
Deficiency anaemia	5.50%	6.65%	5.01%	4.84%	5.95%	4.71%
Cardiac arrhythmias	18.93%	21.61%	17.77%	18.14%	21.53%	17.75%
Coagulopathy	0.90%	0.92%	0.90%	0.89%	0.95%	0.88%
Depression	5.89%	7.71%	5.11%	4.97%	6.46%	4.80%
Diabetes, complicated	2.12%	2.20%	2.09%	1.90%	2.24%	1.86%
Diabetes, uncomplicated	15.85%	16.04%	15.76%	14.84%	16.76%	14.62%

Drug abuse	0.11%	0.18%	0.09%	0.07%	0.10%	0.07%
Fluid/electrolyte disorders	7.44%	9.82%	6.42%	6.22%	7.96%	6.01%
Hypertension, complicated	0.25%	0.26%	0.24%	0.23%	0.25%	0.22%
Hypertension, uncomplicated	52.18%	55.71%	50.66%	50.42%	54.70%	49.93%
Hypothyroidism	8.37%	10.17%	7.60%	7.64%	8.40%	7.56%
Liver disease	2.30%	2.39%	2.26%	2.17%	2.33%	2.15%
Lymphoma	0.97%	0.88%	1.01%	1.03%	1.04%	1.03%
Obesity	7.88%	7.19%	8.18%	7.92%	8.12%	7.90%
Other neurological disorders	4.26%	4.64%	4.10%	4.11%	4.88%	4.02%
Peptic ulcer disease excl. bleeding	1.54%	1.63%	1.50%	1.46%	1.63%	1.44%
Psychoses	0.42%	0.76%	0.27%	0.24%	0.32%	0.23%
Pulmonary circulation disorders	1.85%	2.20%	1.71%	1.69%	1.86%	1.67%
Peripheral vascular disease	4.96%	5.41%	4.76%	4.78%	5.74%	4.66%
Renal failure	9.99%	12.51%	8.91%	8.90%	11.31%	8.62%
Rheumatoid arthritis / collagen vascular diseases	5.57%	6.30%	5.26%	5.38%	5.94%	5.31%
Solid tumour without metastasis	7.30%	6.62%	7.59%	7.78%	7.89%	7.77%
Valvular disease	6.90%	8.05%	6.40%	6.46%	7.72%	6.32%
Weight loss	2.54%	2.99%	2.34%	2.27%	2.96%	2.20%
Congestive heart failure	7.15%	8.99%	6.36%	6.24%	8.04%	6.04%
Chronic pulmonary disease	19.67%	21.65%	18.82%	18.49%	20.95%	18.21%
Hemiplegia or paraplegia	1.18%	1.34%	1.11%	1.05%	1.28%	1.03%
Metastatic solid tumour / metastatic cancer	2.07%	1.89%	2.15%	2.17%	1.99%	2.19%
Frailty syndromes (previous three years)						
Anxiety or depression	8.51%	10.93%	7.46%	7.36%	9.14%	7.16%
Cognitive impairment	7.14%	9.95%	5.93%	5.80%	8.52%	5.49%

Functional dependence	1.32%	2.27%	0.91%	0.89%	1.57%	0.81%
Fall or significant fracture	11.80%	17.11%	9.52%	9.54%	12.65%	9.18%
Incontinence	1.78%	2.44%	1.50%	1.45%	2.00%	1.38%
Mobility problems	4.24%	6.31%	3.35%	3.25%	4.80%	3.07%
Pressure ulcers	1.36%	2.14%	1.03%	1.00%	1.47%	0.94%
Other conditions predictive of emergency admissions (previous three years)						
Miscellaneous cognitive dysfunction	6.35%	8.73%	5.33%	5.21%	6.97%	5.01%
Cerebral vascular disease	6.73%	8.33%	6.04%	5.97%	7.44%	5.80%
Dementia	3.09%	3.96%	2.72%	2.63%	4.05%	2.47%
Myocardial infarction	9.19%	9.59%	9.02%	8.91%	10.89%	8.68%
Any hospital usage (previous 12 months)[b]						
A&E attendance[b]	34.50%	39.42%	32.38%	31.73%	36.68%	31.15%
Emergency admission[b]	24.39%	29.48%	22.20%	21.81%	26.26%	21.29%
Chronic ACS emergency admission[b]	3.61%	4.48%	3.24%	3.14%	4.00%	3.04%
Acute ACS emergency admission[b]	6.07%	7.62%	5.40%	5.22%	6.92%	5.03%
Rates of hospital usage (previous 12 months), mean (SD)						
A&E attendances	0.61 (1.27)	0.74 (1.50)	0.56 (1.16)	0.54 (1.14)	0.67 (1.30)	0.53 (1.11)
Emergency admissions	0.38 (0.88)	0.48 (1.01)	0.34 (0.81)	0.33 (0.80)	0.42 (0.93)	0.32 (0.79)
Chronic ACS emergency admissions	0.05 (0.28)	0.06 (0.32)	0.04 (0.26)	0.04 (0.26)	0.05 (0.29)	0.04 (0.25)
Acute ACS emergency admissions	0.08 (0.36)	0.10 (0.42)	0.07 (0.33)	0.06 (0.32)	0.09 (0.38)	0.06 (0.31)

[a]Study population consisted of all people aged 65 years or older, registered at GP practices in England on 1 December 2018 and living in England, with a valid pseudonymized UPRN, not living in a care home, living in a household of 6 people or fewer, and with at least one hospital admission in the previous three years.
[b]Not adjusted for in the main analysis.

Supplementary File 3: Subgroup analyses: interaction results (a) living alone and deprivation and b) living with someone with frailty and gender. Created by the authors

	A&E attendance			Emergency admissions		
	Rate ratio	**95%CI**	**P value for interaction term**	**Rate ratio**	**95%CI**	**P value for interaction term**
Living alone[a]						
Living alone, IMD quintile 5 (least deprived, reference group)	1.11	(1.10 to 1.11)		1.17	(1.15 to 1.18)	
Living alone, IMD quintile 4	1.09	(1.08 to 1.10)	0.012	1.14	(1.13 to 1.16)	0.009
Living alone, IMD quintile 3	1.11	(1.10 to 1.12)	0.548	1.17	(1.15 to 1.18)	0.993
Living alone, IMD quintile 2	1.09	(1.08 to 1.10)	0.005	1.14	(1.13 to 1.15)	0.001
Living alone, IMD quintile 1 (most deprived)	1.07	(1.06 to 1.08)	<0.001	1.10	(1.09 to 1.11)	<0.001
Living with someone with frailty[b]						
Living with someone with frailty, female (reference group)	1.08	(1.07 to 1.10)		1.10	(1.09 to 1.12)	
Living with someone with frailty, male	1.10	(1.09 to 1.11)	0.101	1.09	(1.08 to 1.11)	0.297

[a]Adjusted for covariates listed in supplementary file 2, and interaction term for living alone and quintiles of deprivation.

[b]Adjusted for covariates listed in supplementary file 2, and interaction term for living with someone with frailty and gender.

Supplementary File 4. Sensitivity analyses: study population limited to individuals whose household composition did not change over the study period, and not adjusting for history of emergency hospital use. Created by the authors

	N	Rate ratio	95%CI	P value
Living alone: study population limited to individuals whose household composition did not change over the study period[a]				
A&E attendances	4,601,533	1.06	(1.06 to 1.07)	<0.001
Emergency admissions	4,601,533	1.10	(1.09 to 1.10)	<0.001
Living alone: not adjusting for history of emergency hospital use[b]				
A&E attendances	4,876,285	1.11	(1.11 to 1.12)	<0.001
Emergency admissions	4,876,285	1.16	(1.15 to 1.16)	<0.001
Living with someone with frailty: study population limited to individuals whose household composition did not change over the study period[a]				
A&E attendances[c]	2,266,187	1.08	(1.07 to 1.09)	<0.001
Emergency admissions[c]	2,266,187	1.08	(1.07 to 1.09)	<0.001
Living with someone with frailty: not adjusting for history of emergency hospital use[b]				
A&E attendances[d]	2,459,937	1.11	(1.10 to 1.12)	<0.001
Emergency admissions[d]	2,459,937	1.11	(1.10 to 1.12)	<0.001

[a]Adjusted for covariates listed in Supplementary File 2.

[b]Adjusted for covariates listed in Supplementary File 2 excluding emergency hospital use in the 12 months prior to analysis period.

[c]Note: A&E attendances: rate ratio 1.083 (95% CI 1.075 to 1.092). Emergency admissions: rate ratio 1.081 (95% CI 1.070 to 1.093).

[d]Note: A&E attendances: rate ratio 1.110 (95% CI 1.101 to 1.118). Emergency admissions: rate ratio 1.111 (95% CI 1.100 to 1.123).

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	3-4
Methods			
Study design	4	Present key elements of study design early in the paper	4-5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	4-5
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4-5
Bias	9	Describe any efforts to address potential sources of bias	4-6, 10-11
Study size	10	Explain how the study size was arrived at	4, 6, Supplementary File 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4-5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	4-6
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6, Supplementary File 1
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6-9, Supplementary File 1 & 2
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	

Outcome data	15*	Report numbers of outcome events or summary measures over time	8-9

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	5, 8-9, Supplementary File 2
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9-10
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	11-12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	11
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	13

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.