



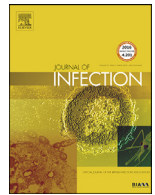
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Disparities in the excess risk of mortality in the first wave of COVID-19: Cross sectional study of the English sentinel network

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SUMMARY

Objectives: Few studies report contributors to the excess mortality in England during the first wave of coronavirus disease 2019 (COVID-19) infection. We report the absolute excess risk (AER) of mortality and excess mortality rate (EMR) from a nationally representative COVID-19 sentinel surveillance network including known COVID-19 risk factors in people aged 45 years and above.

Methods: Pseudonymised, coded clinical data were uploaded from contributing primary care providers ($N = 1,970,314$, ≥ 45 years). We calculated the AER in mortality by comparing mortality for weeks 2 to 20 this year with mortality data from the Office for National Statistics (ONS) from 2018 for the same weeks. We conducted univariate and multivariate analysis including preselected variables. We report AER and EMR, with 95% confidence intervals (95% CI).

Results: The AER of mortality was 197.8/10,000 person years (95%CI:194.30–201.40). The EMR for male gender, compared with female, was 1.4 (95%CI:1.35–1.44, $p < 0.00$); for our oldest age band (≥ 75 years) 10.09 (95%CI:9.46–10.75, $p < 0.00$) compared to 45–64 year olds; Black ethnicity's EMR was 1.17 (95%CI:1.03–1.33, $p < 0.02$), reference white; and for dwellings with ≥ 9 occupants 8.01 (95%CI: 9.46–10.75, $p < 0.00$). Presence of all included comorbidities significantly increased EMR. Ranked from lowest to highest these were: hypertension, chronic kidney disease, chronic respiratory and heart disease, and cancer or immunocompromised.

Conclusions: The absolute excess mortality was approximately 2 deaths per 100 person years in the first wave of COVID-19. More personalised shielding advice for any second wave should include ethnicity, comorbidity and household size as predictors of risk.

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Introduction

The UK, particularly England, has experienced significant increases in all-cause mortality during the COVID-19 pandemic. England and Spain appear to have fared worst among European countries in terms of COVID-19 related mortality.¹ However, cross-country mortality comparisons are difficult since some countries, like the UK, collect more complete contemporaneous mortality data, not all countries report total deaths that include community based events, and data need adjustment for population demographics. The Office for National Statistics (ONS) reported 262,237 registered deaths in England and Wales between the 10th Jan and 15th May 2020 (weeks 2 - 20). There were 49,059 additional deaths compared with the five-year average. COVID-19 was included on the death certificate in 41,105 of these deaths, leaving 7954 unaccounted deaths.²⁻⁴ These unaccounted deaths may also be related to COVID-19 infection which has not been tested for or detected.

Significant differences in risk of COVID-19 related mortality have been observed with male gender, increasing age, ethnicity, socioeconomic status, and chronic conditions such as cancer.^{5,6} Early discharge from hospital and spread of disease by asymptomatic staff members may have been contributing factors to the increased mortality rates observed in shared dwellings such as residential care homes.⁷⁻⁹ It is unclear whether these or other risk factors also predict excess mortality rates in 2020.

The English Oxford-Royal College of General Practitioners (RCGP) Research and Surveillance Centre (RSC) is a nationally representative infectious diseases sentinel surveillance network of general practices with over 4 million registered patients, established over 50 years ago providing weekly influenza and respiratory illness surveillance reports to Public Health England.¹⁰ The RCGP RSC network has adapted to include COVID-19 surveillance, including a self-swabbing programme and collecting samples for sero-surveillance.¹¹

We report for the first time the excess mortality during the first wave of COVID-19 infection in England in the adult population 45 years old and over across the RCGP RSC. We compared mortality rates with ONS data to test representativeness, report absolute excess mortality, and excess mortality hazard ratios (EMR) for a range of demographic and clinical factors reported to be associated with increased COVID-19 related mortality, also including household size.

Research in context

Evidence before this study

We searched PubMed and Google Scholar for publications between Jan 1, 2020, and June 23rd, 2020, using combinations of the following terms: ("COVID-19") AND ("relative risk" OR "excess mortality" OR "mortality risk") and did not identify any estimates of the relative risk (RR) of mortality from COVID-19.

There were two publications which aimed to model COVID-19 mortality prior to the peak of the pandemic, particularly to guide policy measures. These papers aimed to model the excess mortality risk in multiple scenarios with an estimate for the RR between 1.5 and 3.0.¹² The case fatality rate has also been presented across many countries and healthcare systems, however, this is subject to wide variation with rates reported between 0.3–15%,¹³ possibly reflecting different testing strategies and background demography.

We also searched the same sources for COVID-19 and ("absolute excess risk" OR "AER" OR "attributable risk" OR "mortality risk") and did not identify any estimates of the absolute excess risk (AER) of mortality from COVID-19. We identified one pre-print manuscript of a study which estimated excess mortality for Eng-

land and Wales in 2020, by week and region. This study utilised aggregated ONS data to report an estimated 47,243 excess deaths between March 7 and May 8, of which 9948 were not associated with COVID-19.¹⁴ Whilst an important finding on the overall impact of the COVID-19 pandemic on mortality, the underlying data relies on the reporting clinician's certification of COVID-19 and does include further investigation.

Added value of this study

This is the first study to describe risk factors associated with excess mortality during the COVID-19 pandemic in a nationally representative English population. These include male gender, increasing age, Black ethnicity, larger household size and the presence of comorbidities known to be associated with increased risk, in the population over 45 years old. Importantly, our study which presents the excess risk of COVID-19 mortality at a population level is the first to present detailed findings on mortality within patient groups, irrespective of COVID-19 status. This methodology is less liable to selection bias as it does not depend on local testing strategies, presenting a more overarching impact of the pandemic period on mortality by patient group.

Implications of all the available evidence

This study reports an absolute excess risk (AER) of mortality during the COVID-19 pandemic in the English population, at approximately 2 excess deaths per 100 person years. This is higher than the previously reported rates of confirmed COVID-19-related mortality based on hospital admissions. This study confirms previously reported disparities in confirmed COVID-19 related mortality which include male gender, older age-groups, Black ethnicity (compared to white); larger household size (which would include care homes), those in the most deprived socioeconomic quintile, and people with chronic disease being at increased relative risk of mortality. By quantifying excess risk of mortality in the first wave of infection, we can better prepare for the next.

Methods

Setting

The study population includes 4413,734 patients registered at the general practices contributing to the RCGP RSC. The Oxford RCGP RSC extracts pseudonymised data from primary health care computerised medical records (CMR) of member practices twice a week and is recruited to be nationally representative. UK general practice is a registration-based system, on patient registers with a single practice. Data includes demographics, clinical conditions, medications, and laboratory results.¹⁵

Study population

We included individuals aged 45 years old and over contributing CMRs to the RCGP RSC with at least one year's complete records prior to 6th January 2020. We selected this age, because we wanted to understand mortality in the older age-group, and our online mortality observatory, which compares the current year with the sentinel network rolling average appeared to show a difference in mortality above this age.¹⁶ We excluded 47 records due to the records being incomplete (absent dates during our observation period). The study period was between weeks 2 and 20 of 2020, the period of the first wave of COVID-19 in England.

Study variables

Variable selection was guided by our previous study of groups likely to test positive to COVID-19 and our literature review.^{17–19} The main outcome was all-cause mortality.

Demographic and personal characteristics included gender, age, and ethnicity divided into white, Asian, Black, mixed and other, using an established ontology,²⁰ household size (1, 2–4, 5–8 and 9+),^{15,21,22} and socioeconomic status as determined by the Index of Multiple Deprivation (IMD).²³ We used the following body mass index (BMI) categories: (1) under weight and normal weight were grouped into “normal” (BMI <25 kg/m²); (2) overweight or pre-obese (BMI 25–29 kg/m²); (3) obese class I (BMI 30–34 kg/m²); and (4) obese class II and III (BMI ≥35 kg/m²).²⁴

The following disease groups were included as they have been reported to be associated with poorer outcomes: hypertension, chronic kidney disease (CKD) defined as stage 3 to 5,²⁵ heart disease (including myocardial infarction, other forms of coronary artery disease and heart failure), chronic respiratory disease (asthma, chronic obstructive pulmonary disease, bronchiectasis, and other chronic lung conditions), people undergoing treatment for cancer or who may be immunocompromised due to taking medications for inflammatory conditions.

Statistical methods

We report counts and percentage (%) for each variable included in the study cohort.

We compared mortality in the Oxford RCGP-RSC population with ONS mortality data by plotting the death rate per 100,000 population for each week during the study period – and by visually comparing survival rates using a Kaplan-Meier plot.

To calculate the AER of mortality per 10,000 population we compared the expected number of deaths between weeks 2 and 20 (reported in ONS mortality life tables for 2018)²⁶ with the number observed deaths from the same period of 2020 (using RCGP RSC data). To calculate EMRs we fitted constant exponential Poisson survival models.²⁷

We used the ONS mortality life tables to calculate background mortality risk for 2018. We measured excess mortality using an additive hazard model. The observed hazard of our cohort was expressed as the sum of the expected or background hazard and the excess hazard due to COVID-19, assuming that the observed and expected deaths follow Poisson distributions.²⁸

We imputed missing data on covariates, using multiple imputation with chained equations,²⁹ imputing five datasets (using all model covariates including outcome status) and employed Rubin's rule to pool model estimates.³⁰

R version 3.5.3³¹ was used for all statistical analyses together with the survival package version 2.43–3; we used the mice package version 3.9.0 for multiple imputation.

Ethical considerations

The Oxford RCGP RSC surveillance system and its work with respect to COVID-19 are approved by Public Health England's Caldicott Guardian Committee under Regulation 3 of the Health Service Control Patient Information Regulations 2002. The study was also approved by RCGP.

Results

Table 1 presents the characteristics of the study population and the amount of missing data prior to imputation. A total of 1970,314 individuals met the inclusion criteria, 48.75% were male, median

age 62.95 years (IQR 53–72 years), 70.30% white, and the majority (60.64%) living in dwellings of 2–4 residents. The most common comorbidities were hypertension (33.88%) followed by CHD (13.56%) and malignancy or immunosuppression (12.06%).

Comparison of surveillance system mortality with national statistics

The mortality with the first wave of COVID-19 infection peaked in weeks 15 and 16 (Fig. 1) and followed the peak in incidence seen in the sentinel network (Supplementary file) and nationally.³² The mortality rates reported across the sentinel network were very similar to that reported nationally by ONS for the last three years (Fig. 1). The mortality rates for the three age-bands used in the study: 45 to 64 years old, 65 to 74 years, and 75 years old and over showed similar agreement with ONS (Supplementary file) mortality rates.

Absolute excess risk (AER) of mortality

We found the AER of mortality was just under 2 per 100 person years, in our cohort of people 45 years and older. There were 16,636 deaths in the sentinel population accrued over 703,958 person years, the average incidence was 2623 per 100,000. Based on the background mortality for the same period in 2019, we would have expected 2710.4. The absolute excess risk in this cohort was therefore 197.8 (95% CI: 194.3–201.4) per 10,000 person years. We report the AER for the whole population in our supplementary file.

Univariate analysis showed disparities in mortality

Our univariate analysis showed male gender, older age-band, large household size (9 or more residents), the most deprived quintile and a range of long-term conditions were all associated with increase mortality (Table 2). The highest rates were age 75 years or above, EMR 22.95 (95%CI: 21.61–24.37, $p < 0.0001$) compared to people age 45 years to 64, and household occupancy of ≥9, where the EMR compared to singly occupancy was 13.11 (95% CI: 12.58–13.67, $p < 0.0001$). Non-white ethnicities, compared with white, and obesity were not associated with increased risk in this analysis.

Excess mortality risk estimates from multivariate analyses

The results from the multivariable analysis showed male gender, increasing age, Black ethnicity (compared with white), poorer socioeconomic group (IMD Quintile 1), household size above 4 (compared with single occupancy), and presence of all studied comorbidities was associated with excess mortality (i.e. worse relative survival, Table 3). Among the chronic diseases, hypertension has a lower EMR, than CKD. CKD in turn has a lower EMR than chronic respiratory and heart disease. People with cancer and who were immunocompromised had the highest EMR.

Discussion

Principal findings

This community-based study reports the absolute excess mortality in the population of 45 years and older was approximately 2 per 100 person years in the first wave of COVID-19 infection. In multivariate analyses, male gender, increasing age, deprivation, Black ethnicity and chronic disease were associated with an increased risk of excess mortality, confirming findings of previous studies which have focussed on confirmed COVID-19 related mortality. This study also shows that those living in a single occupancy household and those in larger households (5 or more people) have

Table 1

Characteristics of people 45 years old and above in the RCGP RSC cohort, N = 1970,314.

Variable	Category	Number (n)	Percentage (%)
Sex	male	960,609	(48.75)
	female	1009,705	(51.25)
Age band	45–64	1149,621	(58.35)
	65–74	436,617	(22.16)
	75+	384,076	(19.49)
Ethnicity	White	1385,108	(70.30)
	Asian	78,243	(3.97)
	Black	44,327	(2.25)
	Mixed, Other	25,659	(1.30)
	Missing	436,977	(22.18)
Household Size	1	568,530	(28.85)
	2–4	1194,782	(60.64)
	5–8	129,538	(6.57)
	9+	30,558	(1.55)
	Missing	46,906	(2.38)
Index of multiple deprivation (IMD) quintile	1 (Most Deprived)	350,500	(17.79)
	2	448,426	(22.76)
	3	375,423	(19.05)
	4	424,037	(21.52)
	5 (least Deprived)	371,928	(18.88)
Body Mass Index (BMI) band	Normal weight	637,287	(32.34)
	Overweight	695,239	(35.29)
	Obese class I	455,990	(23.14)
	Obese class II or III	61,321	(3.11)
	Missing	120,477	(6.11)
Hypertension	Yes	667,469	(33.88)
	No	1302,845	(66.12)
Chronic Kidney Disease (CKD)	Yes	110,877	(5.63)
	No	1859,437	(94.37)
Chronic Heart Disease	Yes	267,107	(13.56)
	No	1703,207	(86.44)
Chronic Respiratory Disease	Yes	108,799	(5.52)
	No	1861,515	(94.48)
Malignancy or immunocompromised	Yes	237,660	(12.06)
	No	1732,654	(87.94)

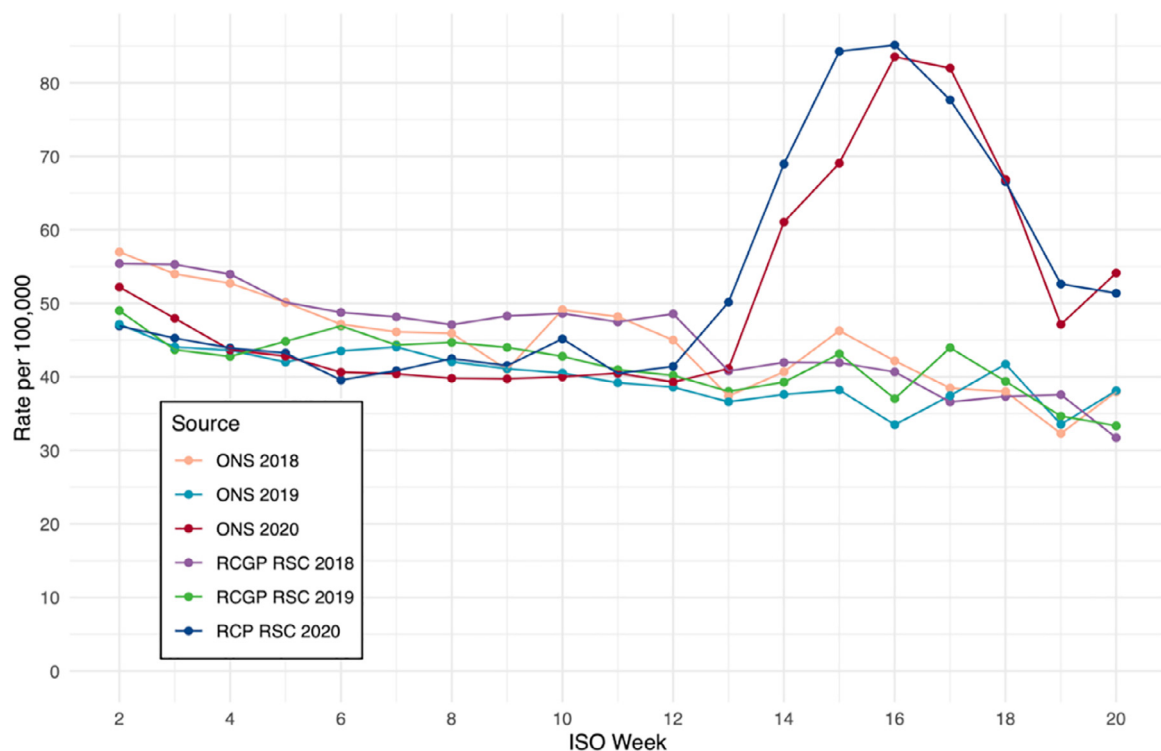
**Fig. 1.** Mortality in people aged ≥ 45 years old per 100,000 between ISO Weeks 2 – 20 of 2018, 2019 and 2020 from sentinel network (RCGP RSC) and Office of National Statistics (ONS).

Table 2

Results of the univariate analysis of associations with mortality rate (%) and excess mortality rate (EMR) reporting 95% confidence intervals (95%CI) and probability (p) in the RCGP RSC cohort of people aged 45 years and older.

	Category	Deaths	Denominator	Mortality rate (%)	EMR	95% CI	P
Sex	Female	8356	1009,705	0.83	1		
	Male	8280	960,609	0.86	1.04	(1.01–1.07)	0.02
Age band	45–64	1887	1149,621	0.16	1		
	65–74	2611	436,617	0.60	4.12	(3.84–4.42)	
	75+	12,138	384,076	3.16	22.95	(21.61–24.37)	<0.00
Ethnicity	White	15,823	1822,085	0.87	1		
	Asian	408	78,243	0.52	0.58	(0.53–0.65)	
	Black	267	44,327	0.60	0.68	(0.60–0.78)	
	Mixed, Other	138	25,659	0.54	0.61	(0.51–0.73)	<0.00
Household Size	1	5899	573,292	1.03			
	2–4	6164	1236,926	0.50	0.47	(0.45–0.48)	
	5–8	795	129,538	0.61	0.58	(0.54–0.63)	
	9+	3778	30,558	12.36	13.11	(12.58–13.67)	<0.00
IMD Quintile	1	3138	350,500	0.90	1		
	2	3940	448,426	0.88	0.98	(0.93–1.03)	
	3	3049	375,423	0.81	0.90	(0.86–0.95)	
	4	3514	424,037	0.83	0.92	(0.88–0.97)	
	5	2995	371,928	0.81	0.89	(0.85–0.94)	<0.00
Body Mass Index (BMI)	Normal	8070	681,190	1.18	1		
	Overweight	5231	771,813	0.68	0.56	(0.54–0.58)	
	Obese class I	2831	455,990	0.62	0.51	(0.49–0.53)	
	Class II/III	504	61,321	0.82	0.68	(0.62–0.75)	<0.00
Hypertension	No	6683	1302,845	0.51	1		
	Yes	9953	667,469	1.49	3.0	(2.93–3.10)	<0.00
Chronic Kidney Disease (CKD)	No	12,492	1859,437	0.67	1		
	Yes	4144	110,877	3.74	5.84	(5.64–6.10)	<0.00
Chronic Heart Disease	No	9357	1703,207	0.55	1		
	Yes	7279	267,107	2.73	5.22	(5.10–5.39)	<0.00
Chronic Respiratory Disease	No	13,650	1861,515	0.73	1		
	Yes	2986	108,799	2.74	3.89	(3.89–4.05)	<0.00
Malignancy or Immunocompromised	No	10,841	1732,654	0.63	1		
	Yes	5795	237,660	2.44	4.07	(3.94–4.21)	<0.00

Table 3

Multivariable adjusted excess mortality rates for all-cause mortality across the Oxford RCGP RSC cohort of people 45 years and older including covariates contributing to excess mortality.

Variable	Category	EMR	CI.95	p-value
Sex	Female	Ref		
	Male	1.40	(1.35–1.44)	<0.00
Age band	45–64	Ref		
	65–74	3.24	(3.02–3.48)	<0.00
	75+	10.09	(9.46–10.75)	<0.00
Ethnicity	White	Ref		
	Asian	0.74	(0.66–0.82)	<0.00
	Black	1.17	(1.03–1.33)	0.02
	Mixed, Other	1.13	(0.94–1.35)	0.18
Index of Multiple Deprivation (IMD) Quintile	1 (most deprived)	Ref		
	2	0.88	(0.84–0.92)	<0.00
	3	0.80	(0.76–0.84)	<0.00
	4	0.85	(0.81–0.90)	<0.00
	5 (least deprived)	0.81	(0.77–0.86)	<0.00
Household size	1	Ref		
	2–4	0.70	(0.67–0.73)	<0.00
	5–8	1.63	(1.51–1.77)	<0.00
	9+	8.01	(7.67–8.35)	<0.00
Body Mass Index (BMI)	Normal weight	Ref		
	Overweight	0.65	(0.63–0.67)	<0.00
	Obese class I	0.62	(0.59–0.65)	<0.00
	Obese class II or III	1.08	(0.98–1.19)	0.11
Hypertension	No	Ref		
	Yes	1.17	(1.13–1.22)	<0.00
Chronic Kidney Disease (CKD)	No	Ref		
	Yes	1.46	(1.41–1.52)	<0.00
Chronic Heart Disease	No	Ref		
	Yes	1.73	(1.68–1.79)	<0.00
Chronic Respiratory Disease	No	Ref		
	Yes	1.62	(1.56–1.69)	<0.00
Malignancy/ immuno-compromised	No	Ref		
	Yes	2.06	(1.99–2.13)	<0.00

a higher risk of excess mortality compared to dwellings of 2 to 4 people. Such associations may represent older people living on their own, multigenerational occupancy or care homes which are known to be at increased risk. All of the chronic conditions examined in this cohort were associated with increased risk and further work is needed to identify how combinations of these conditions might affect an individuals' risk, to enable better targeting of shielding strategies and vaccination programmes to prevent excess mortality if future waves of the pandemic occur.

Implications of the findings

The excess mortality over the study period of 18 weeks, is just under a quarter (23%) of the mortality for the whole of our reference year 2018, and very similar for 2019. The mortality from the whole of 2018 in people age 45 years and above was 8.81 per 100 person years and from 2019 was 8.56 per 100 person years.³³

Our findings show that risk factors for excess mortality (regardless of COVID status) are similar to those reported in studies focussing on COVID-19 confirmed mortality. This suggests unaccounted deaths captured in the present study may also be related to undetected COVID-19 infection or indirect effects of COVID-19 lockdown measures. These data also suggest that policy about staying at home may need to be more nuanced. People in single occupancy housing may have greater risk. This could be because they are less likely to have outside space or they have to break their isolation more frequently. Larger households of 5 to 8 people are also at greater risk as well as dwellings with 9 people or more. Whilst risks about care homes have been well articulated,^{7,8} increase risk within moderately large dwellings has not.

Household size, in addition to information about an individual's socio-demographic status and pre-existing conditions should be incorporated into a clinical prediction model which would enable a more personalised approach to shielding strategies and vaccination programmes if future waves of the pandemic occur.

Comparison with the literature

Several previous studies have attempted to predict excess mortality from COVID-19 in the UK. These have suggested likely age-based case fatality rates,³⁴ relative risk (RR) of mortality,³⁵ concluding that the increased mortality due to COVID-19 may be equivalent to "packing a year's risk of mortality into a week or two."³⁶ Our data suggests that over an eight week period, mortality rates were 25% higher than would usually be expected for the time of year. The mortality reported here was higher than previously reported in studies focussing on confirmed COVID-19 related mortality following hospital admission.³⁷

In the UK, it has been suggested that those with dementia are among those who have experienced an increase in mortality despite not having a confirmed COVID-19 infection.² Explanations for this rise include mortality from COVID-19 being present but not recorded on the death certificate, indirect causes (collateral damage) or statistical artefacts. Premature death may occur as a result of reduced hospital capacity leading to delays in people receiving life-saving care, or from people choosing not to or being prevented from seeking care.³⁸

There seem to be consistent reports about increased risk in people of Black ethnicity, but less certainty if there is increase risk in Asian ethnicity compared to white.^{39,40} There is however, increased test positivity and hospitalisation.^{41,15,42}

There are suggestions in the literature that household transmission is one of the ways COVID-19 is spread,⁴³ that household transmissions is greatest from younger to older people,⁴⁴ and that people who know they are quarantined are less likely to pass it on.⁴⁵

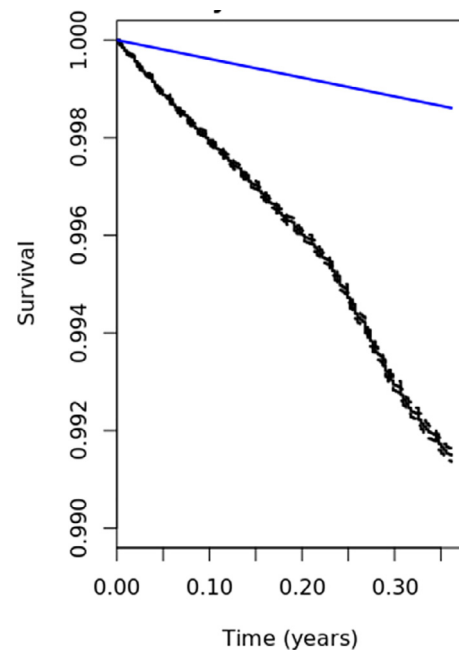


Fig. 2. Kaplan Meier Estimates of overall survival in the RCGP RSC cohort age 45 years and above and relative survival.

Our data confirm this but also show an increase risk for those living in single occupancy households, perhaps because they are less likely to have outside space or they have to break their isolation more frequently.

There are a number of reports of confirmed COVID-19 related mortality during the first wave of COVID-19 infection. Risk factors include hypertension, cardiovascular disease, diabetes,⁴⁷ respiratory disease,^{46,48} and cancer.⁴⁹ These studies are primarily based on data from secondary care and speciality based rather than able to compare relative rates across a population. Our data show similar risk factors for all excess mortality, regardless of whether a COVID-19 test is given or infection is confirmed.

Strengths and limitations

The strengths of our study is that it is based on individual level data, collected from a representative national primary care surveillance network, with an emphasis on good data quality.^{14,50} We did consider a number of chronic conditions within our models, but this list was not exhaustive. For example, we did not include dementia and Alzheimer's disease in our analysis, and these conditions have since been reported as being associated with mortality, non-attributable to COVID-19 infection.² Similarly, we did not include diabetes in our analysis, again a condition known associated with increased risk.⁵¹ There may be a small lag between death date (sentinel network) and the date death certificates were issued (ONS data).

For our estimation of excess mortality, we compared rates within the RCGP RSC to ONS Life Tables for 2018,²⁴ the last year for which they were available. Whilst it may have been possible to construct life tables using our own data, this is unlikely to have been significantly different since mortality rates observed in the RCGP RSC were very similar to those within ONS (Fig. 1).

Fig. 2.

Conclusions

These data show an excess in mortality rates across the first wave of COVID-19 infection, equivalent to two extra deaths per

hundred person years. They also show that single occupancy and larger households are important predictors of mortality, an observation not previously seen in analyses of routine electronic health records. Household size, in addition to information about an individual's socio-demographic status and pre-existing conditions should be incorporated into a clinical prediction model to enable better targeting of strategies to prevent excess mortality in future waves of the pandemic.

Data sharing

The RCGP RSC data set can be accessed by researchers, approval is on a project-by-project basis (www.rcgp.org.uk/rsc). Ethical approval by an NHS Research Ethics Committee is needed before any data release/other appropriate approval. Researchers wishing to directly analyse the patient-level pseudonymised data will be required to complete information governance training and work on the data from the secure servers at the University of Surrey. Patient-level data cannot be taken out of the secure network. We encourage interested researchers to attend the short courses on how to analyse primary-care data/RCGP RSC data offered twice a year.

Declaration of Competing Interest

SdeL is the director of RCGP RSC. He has unrelated projects funded by GSK, Seqirus and has been a member of Global Advisory Boards for Seqirus and Sanofi.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.jinf.2020.08.037](https://doi.org/10.1016/j.jinf.2020.08.037).

References

- larger person years. They also found that single occupancy and larger households are important predictors of mortality, an observation not previously seen in analyses of routine electronic health records. Household size, in addition to information about an individual's socio-demographic status and pre-existing conditions should be incorporated into a clinical prediction model to enable better targeting of strategies to prevent excess mortality in future waves of the pandemic.
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