What explains the spatial variation in COVID-19 mortality across Scotland?

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Main points

- Areas of Scotland’s Central Belt have experienced markedly higher COVID-19 mortality rates than other parts of the country. The reasons for this very wide spatial variation in rates are not yet clear, although discussions have identified some potential explanations related to geographic and socio-economic factors. These include remoteness and rurality, income deprivation, household overcrowding, and the timing of the first COVID-19 death within the local area.

- The objective of this report is to investigate why some areas of Scotland have thus far experienced higher mortality from COVID-19 than others, specifically considering the role of remoteness and rurality, income deprivation, household overcrowding, and the timing of the first COVID-19 death. The role of ethnicity and clinical risk factors have been the subject of other, specific studies and we do not consider them further here.

- We analysed the relationship between these factors and the number of both COVID-19 and non-COVID-19 deaths in Scottish datazones (areas with a median population of c.700 people).

- We found that more remote and rural areas were associated with having fewer COVID-19 deaths at Scottish datazone level, while income deprivation, household overcrowding and earlier first COVID-19 deaths were associated with increased COVID-19 deaths.

- When we looked at non-COVID-19 deaths, we found similarities and differences in these relationships. No association was found between factors relating to remoteness and household overcrowding and non-COVID-19 deaths. Near identical effect sizes were estimated for income deprivation for both COVID-19 and non-COVID-19 deaths. A small association was also found between the timing of the first COVID-19 death within a datazone and non-COVID-19 deaths.

- We also found that council areas’ expected COVID-19 mortality rates varied from their observed rates once these four factors had been taken into account, with some areas having a higher or lower COVID-19 mortality rate than expected. Additional analysis to identify risk factors for COVID-19 mortality would help further understand the variation between council areas.
Introduction

Some areas of Scotland have experienced markedly higher COVID-19 mortality rates than others. Between 1 March and 30 June 2020, the highest age-standardised mortality rates with COVID-19 recorded as the underlying cause on the death certificate have been experienced in West Dunbartonshire, Glasgow City, Midlothian and Inverclyde local authority areas (with 470, 435, 434 and 406 age-standardised deaths per 100,000 population)\(^1\). In contrast, among the three island council areas, Na h-Eileanan Siar had no COVID-19 deaths, while Orkney and Shetland had fewer than 10 deaths. Three other rural council areas (Highland, Moray and Dumfries & Galloway) all had age-standardised mortality rates below 100 per 100,000 population\(^2\). Age-sex standardised mortality rates where COVID-19 was the underlying cause of death have also been shown to vary by the Scottish Index of Multiple Deprivation (SIMD), an area-based classification of multiple deprivation\(^3\).

The reasons for this wide spatial variation in rates are not yet clear, although there has been discussion which has identified some potential explanations. First, the extent to which different areas have been ‘seeded’ by infection, and at what stage in the pandemic, may also have influenced the number of deaths. Second, areas which are more spatially connected, with greater population density (and particularly greater household overcrowding) are theoretically more likely to have seen greater person-to-person spread of the infection, which would be expected to lead to higher deaths. Third, socio-economic position and the risks this confers directly through exposure (for example working in a low-paid caring role) – or through the underlying background risks and health of people who have low incomes, who are working class, and those who have fewer qualifications – may increase mortality risk\(^4\). This is partially captured in routine data by area-level deprivation measures\(^5\). In addition, the age-sex structure of the local population is likely to be a factor given the clear exponential

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\(^5\) Modifiable and non-modifiable risk factors for COVID-19: Results from UK Biobank [preprint]. Ho FK, Celis-Morales CA et al. doi: [https://doi.org/10.1101/2020.04.28.20083295](https://doi.org/10.1101/2020.04.28.20083295)
relationship between COVID-19 mortality and increased age\textsuperscript{6}. Thus, areas with older populations may experience higher mortality rates. We have treated age and sex as confounding factors in this analysis rather than exposures of interest in their own right.

The objective of this report is to investigate why some areas of Scotland have thus far had higher mortality from COVID-19 than others, specifically investigating the role of remoteness and rurality, income deprivation, household overcrowding, and the timing of the first COVID-19 deaths. The role of ethnicity and clinical risk factors have been the subject of other, specific studies and we do not consider them further here.

Methodology

We extracted National Records of Scotland deaths data for the period from first certified COVID-19 death to the point at which all-cause mortality returned within the weekly range observed over the previous five years (weeks 12–25 of 2020)\(^7\). The unit of analysis was datazone (areas with a median population of c.700 people). Deaths were categorised as COVID-19 or non-COVID-19 depending on whether COVID-19 was the underlying cause (ICD-10 code U07), and aggregated counts were calculated by datazone, based on postcode or residence at time of death. The deaths data were matched by datazone to SIMD 2020\(^8\) and the Scottish Government Urban-Rural Index\(^9\) (six-fold version). Datazones recorded as having no residents, as a result of housing demolition since the datazones were last refreshed in 2011, were removed from the analysis (n = 3). Definitions of the exposures included in our analysis are presented in Table 1. Descriptive statistics for datazones are included in Appendix 1 (Supplementary table 1).

We specified models for each exposure of interest (remoteness and rurality, income deprivation, household overcrowding\(^10\), and the timing of the first COVID-19 death within datazone), taking account for potential confounding in each instance, including area-level distribution of age and sex. Subsequently for each of the four exposures of interest, a statistical model (called a negative binomial regression model) was run to estimate the effect of each exposure of interest on counts of COVID-19 and non-COVID-19 deaths per datazone. Regression modelling is a statistical technique that allows us to investigate the relationship between an outcome and one of more explanatory variables. We tested three types of regression model (Poisson, Poisson inverse Gaussian and negative binomial) and found that negative binomial was the type most appropriate for modelling these data.

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\(^9\) Scottish Government Urban Rural Classification: [www2.gov.scot/Topics/Statistics/About/Methodology/UrbanRuralClassification](http://www2.gov.scot/Topics/Statistics/About/Methodology/UrbanRuralClassification)

\(^10\) Household overcrowding compares the number of rooms in the dwelling to the number of rooms required by the household, based on the relationships between residents and their ages; details at: [www.gov.scot/collections/scottish-index-of-multiple-deprivation-2020/](http://www.gov.scot/collections/scottish-index-of-multiple-deprivation-2020/)
We then calculated the difference between the expected and observed COVID-19 mortality rate for Scottish council areas, with expected rate based on the regression model that adjusted for the full set of explanatory variables.
### Table 1: Exposures included in study and data source

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Definition</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Percentage of population aged 75 years and over</td>
<td>National Records of Scotland</td>
</tr>
<tr>
<td>Sex</td>
<td>Percentage of population who are male</td>
<td>National Records of Scotland</td>
</tr>
<tr>
<td>Remoteness/rurality</td>
<td>Large urban areas – Settlements of 125,000 or more people.</td>
<td>Scottish Government (Urban-Rural Index 6 class version)</td>
</tr>
<tr>
<td></td>
<td>Other urban areas – Settlements of 10,000 to 124,999 people.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accessible small towns – Settlements of 3,000 to 9,999 people and within 30 minutes' drive of a settlement of 10,000 or more.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Remote small towns – Settlements of 3,000 to 9,999 people and with a drive time of over 30 minutes to a settlement of 10,000 or more.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accessible rural – Areas with a population of less than 3,000 people, and within a 30 minute drive time of a settlement of 10,000 or more.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Remote rural – Areas with a population of less than 3,000 people, and with a drive time of over 30 minutes to a settlement of 10,000 or more.</td>
<td></td>
</tr>
<tr>
<td>Income deprivation</td>
<td>Percentage of population income deprived.</td>
<td>Scottish Government (SIMD 2020)</td>
</tr>
<tr>
<td>Overcrowding</td>
<td>Percentage of people in households that are overcrowded.</td>
<td>Scottish Government (SIMD 2020)</td>
</tr>
<tr>
<td>Timing of first death</td>
<td>Number of days between first recorded COVID-19 death and end of study period.</td>
<td>National Records of Scotland</td>
</tr>
</tbody>
</table>
Results and commentary

Figure 1 visually presents the variation in COVID-19 mortality by Scottish council areas as a timeline for weeks 12 to 25. The largest COVID-19 mortality rate over this period was recorded in Inverclyde council area (36 per 100,000 in week 15). Inverclyde’s peak happened relatively early in the study period and has since reduced to levels similar to other Scottish council areas. The next highest peak in COVID-19 mortality was in Midlothian (33 per 100,000 in week 18).

Figure 2 and Figure 3 present the effect estimates for each exposure of interest for COVID-19 and non-COVID-19 mortality respectively. Each exposure of interest was associated with significant differences in datazone incidence rate ratio (IRR) for COVID-19 mortality. It can be interpreted as a percentage increase or decrease in the outcome. For example, an IRR of 1.11 would indicate an 11% increase, while an IRR of 0.89 would indicate an 11% decrease. Compared to large urban areas, all other urban-rural classifications were associated with a reduced IRR, ranging from 30% lower COVID-19 mortality rates in other urban areas (IRR=0.70) to 75% lower in remote rural areas (IRR=0.25). A 10 percentage point increase in the population classed as income deprived was associated with an 11% higher COVID-19 mortality rate per (IRR=1.11). A 10 percentage point increase in household overcrowding was associated with an 8% higher COVID-19 mortality rate per (IRR=1.08). Timing of first COVID-19 death within a datazone was associated with a 23% higher COVID-19 mortality rate per 10 additional days between the first COVID-19 death certified in a datazone and the end of the study period (IRR=1.23). In comparison, only accessible rural areas (IRR = 0.90), income deprivation (IRR = 1.11) and timing (IRR = 1.01) were associated with significantly different IRRs for non-COVID-19 deaths during the same period.

Figure 4 compares the expected and observed COVID-19 mortality rates by council area for the whole study period, with expected rates from the model adjusted for age, sex and all four exposures of interest. Positive values represent a higher observed rate than the expected rate, and negative values represent a lower than expected rate. For Scotland as a whole, the observed COVID-19 mortality rate was 5 per 100,000 population higher than expected by the model (represented as a dotted vertical line in Figure 2). Divergence from the expected rate increased as the observed rate increased, with some councils substantially above or substantially below their expected levels. Inverclyde – the council area with the largest
observed rate – diverged the most from its expected rate, with 59 fewer deaths occurring per 100,000 population than would have been expected based on the explanatory variables included in our model. The four council areas with the next highest observed COVID-19 mortality rates (West Dunbartonshire, Midlothian, East Dunbartonshire and Renfrewshire) conversely had higher than expected rates.
Figure 1: Timeline of COVID-19 mortality; crude mortality count and age-sex-standardised mortality rate per week per 100,000 population in Scottish Council Areas. 1, 2

1. Council areas are sorted in descending order of maximum weekly mortality rate.
2. Dots indicate the week with the first COVID-19 death in each area.
Figure 2: Effect estimates of selected exposures on COVID-19 mortality (offset by population). 3, 4, 5, 6, 7

3. Urban-rural classification effects adjusted for age, sex.
4. Income deprivation effects adjusted for age, sex, urban/rural classification.
5. Overcrowding effects adjusted for age, sex, urban/rural classification, income deprivation.
6. Timing effects adjusted for age, sex, urban/rural classification, income deprivation, overcrowding.
7. Dot represents incidence rate ratio estimate; horizontal bars represent 95% confidence interval for the incidence rate ratio.
Figure 3: Effect estimates of selected exposures on non-COVID-19 mortality (offset by population). 8, 9, 10, 11, 12

8. Urban-rural classification effects adjusted for age, sex.
9. Income deprivation effects adjusted for age, sex, urban/rural classification.
10. Overcrowding effects adjusted for age, sex, urban/rural classification, income deprivation.
11. Timing effects adjusted for age, sex, urban/rural classification, income deprivation, overcrowding.
12. Dot represents incidence rate ratio estimate; horizontal bars represent 95% confidence interval for the incidence rate ratio.
Figure 4: Difference between expected rates from our model and observed COVID-19 mortality rates (crude rate per 100,000 population); by Scottish council area (sorted in descending order by observed rate).  

13. The dotted vertical line represents difference between expected and observed rates for Scotland overall from our model.

14. Expected rates adjusted for age, sex, urban/rural classification, income deprivation, overcrowding.

15. Dot represents the difference between predicted and observed rates; horizontal bars represent 95% confidence interval for the difference between expected and observed COVID-19 mortality rate.
Conclusions

We found that more remote and rural areas were associated with having fewer COVID-19 deaths at Scottish datazone level, while income deprivation, household overcrowding and earlier first COVID-19 deaths were associated with increased COVID-19 deaths. We found that these factors are important explanations for the variation in COVID-19 mortality across Scotland, but that some of the variation between areas remains unexplained.

We found similarities and differences in these relationships when we looked at non-COVID-19 deaths. Factors relating to remoteness and household overcrowding set COVID-19 deaths apart from the typical trends in mortality rates across the country, as may be expected for the spread of a contagious virus. The near-identical effect size estimates for income deprivation for both COVID-19 and non-COVID-19 deaths indicate its importance not only for COVID-19 pandemic planning, but also for improving Scotland's overall mortality trends and for reducing health inequalities. The significant association between the timing of the first COVID-19 death within a datazone and non-COVID-19 deaths is weak but also of note. This finding suggests that local seeding of COVID-19 may have had small indirect effects on non-COVID-19 deaths, such as excess demand on local health services or people delaying health service use.

We also found that council areas’ expected COVID-19 mortality rates varied from their observed rates once these four factors had been taken into account, with some areas having a higher or lower COVID-19 mortality rate than expected. Additional analysis to identify of risk factors for COVID-19 mortality would help further understand the variation between council areas.
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Further information

Further information and data for this publication are available from the publication page on our website.

Open data

Data from this publication are available to download from the Scottish Health and Social Care Open Data Portal.

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Acknowledgements

Prof Jim Lewsey and Prof Danny MacKay (University of Glasgow) provided advice on statistical analyses presented in this report. Figure 1 in this report was based on code developed by Dr Colin Angus (University of Sheffield). The authors would like to thank Julie Ramsay (National Records of Scotland) and Gregor Boyd (Scottish Government) for their comments on the draft report. Particular thanks to Dr Andrew Fraser (Special Adviser, Public Health Scotland) for signing off the final version of the briefing.
# Appendices

## Appendix 1 – Background information

**Supplementary table 1: Descriptive statistics for Scottish datazones**

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>25th percentile</th>
<th>Median</th>
<th>75th percentile</th>
<th>Maximum</th>
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<tbody>
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<td>Population</td>
<td>256</td>
<td>633</td>
<td>755</td>
<td>886</td>
<td>3658</td>
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<tr>
<td>% population aged 75+</td>
<td>0</td>
<td>5</td>
<td>8</td>
<td>11</td>
<td>42</td>
</tr>
<tr>
<td>% population male</td>
<td>37</td>
<td>47</td>
<td>49</td>
<td>50</td>
<td>85</td>
</tr>
<tr>
<td>% population income deprived</td>
<td>0</td>
<td>4</td>
<td>10</td>
<td>18</td>
<td>59</td>
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<tr>
<td>% households overcrowded</td>
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<td>5</td>
<td>9</td>
<td>15</td>
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</tr>
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<td>Number of deaths (all)</td>
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<td>1</td>
<td>2</td>
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<tr>
<td>Number of deaths (COVID-19)</td>
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<td>0</td>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>Number of deaths (non-COVID-19)</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>27</td>
</tr>
<tr>
<td>Days between first COVID-19 death and end of study</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>39</td>
<td>96</td>
</tr>
</tbody>
</table>

### 6 fold Urban-Rural Classification:

<table>
<thead>
<tr>
<th>Classification</th>
<th>n Datazones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Urban Areas</td>
<td>2291</td>
</tr>
<tr>
<td>Other Urban Areas</td>
<td>2615</td>
</tr>
<tr>
<td>Accessible Small Towns</td>
<td>609</td>
</tr>
<tr>
<td>Remote Small Towns</td>
<td>257</td>
</tr>
<tr>
<td>Accessible Rural</td>
<td>774</td>
</tr>
<tr>
<td>Remote Rural</td>
<td>427</td>
</tr>
</tbody>
</table>
Appendix 2 – Early access details

Pre-Release Access

Under terms of the ‘Pre-Release Access to Official Statistics (Scotland) Order 2008’, PHS is obliged to publish information on those receiving Pre-Release Access (‘Pre-Release Access’ refers to statistics in their final form prior to publication). The standard maximum Pre-Release Access is five working days. Shown below are details of those receiving standard Pre-Release Access.

Standard Pre-Release Access:

Scottish Government Health Department

NHS Board Chief Executives

NHS Board Communication leads

Early access for management information

These statistics will also have been made available to those who needed access to ‘management information’, for example as part of the delivery of health and care.

Early access for quality assurance

These statistics will also have been made available to those who needed access to help quality assure the publication.
Appendix 3 – PHS and Official Statistics

About Public Health Scotland (PHS)

PHS is a knowledge-based and intelligence-driven organisation with a critical reliance on data and information to enable it to be an independent voice for the public’s health. It leads collaboratively and effectively across the Scottish public health system, is accountable at local and national levels, and provides leadership and focus for achieving better health and wellbeing outcomes for the population. Our statistics comply with the Code of Practice for Statistics in terms of trustworthiness, high quality and public value. This also means that we keep data secure at all stages, through collection, processing, analysis and output production, and adhere to the ‘five safes’.