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Response to "Re: Long-term exposure to air-pollution and COVID-19 mortality in England: A hierarchical spatial analysis"

We thank Goldberg and Villeneuve for their interest in our study. The authors argue that our modelling framework is not appropriate to capture the complex dynamics of the infection. However, our goal was to examine the effect of long-term exposure to air pollution on COVID-19 mortality accounting for factors that may affect infections such as population density, socioeconomic position and temperature. The point estimates presented reflect ecological associations with some evidence for NO_2 (the posterior probability of an effect is 0.93). This study reports risk of death from COVID-19; with the data available, we are not able to separate risk of infection from risk of death following infection. We stress that any public health messages regarding COVID-19 transmission/incidence or individual-level risk factors for disease severity are out of the scope of our paper and are not supported by the results.

Comparing the number of COVID-19 deaths in our analysis with another study in England and Wales (Kontis et al., 2020), the authors suggest that our study suffers from significant under ascertainment (~20,000 deaths), which could cause appreciable bias. In a sensitivity analysis we include suspected deaths (with mention of COVID-19 in the death certificate but no confirmatory test), resulting in 50,787 COVID-19 deaths, a figure in line with the 47,104 COVID-19 deaths reported in Kontis et al. (2020). The results are consistent with the main analysis (that considers 38,573 deaths with a positive COVID-19 test), showing no signs of differential misclassification (Supplementary Tables S10-11).

We also agree that it is essential to account for the areal level clustering between COVID-19 incidence and mortality (Villeneuve and Goldberg 2020). Individual behaviours (for instance face mask wearing) that are not reflected in the areal level (as means of deprivation or areal level clustering for instance) are not expected to bias the ecological associations reported in the manuscript. To account for the clustering, among other confounders, we incorporate the number of positive cases at the areal level, a figure that underestimates the true number of infections. We also include spatial random effects that capture residual spatial confounding and clustering (Konstantinoudis et al., 2020; Lee and Sarran, 2015; Riebler et al., 2016). Our results suggest strong residual spatial variation and clustering which are not adequately captured by the confounders (Figure 4). These patterns are consistent with the geographical patterns identified by the community level prevalence of COVID-19 in England during May 2020 (Riley et al., 2020). The spatial random effects for the pre-lockdown period suggest different spatial patterns showing that population living in the areas around Birmingham and London had up to 5-times higher mortality risk compared to the rest of England, capturing the areas of the first outbreaks (Supplementary Figures S21-22). Considering the above, we believe that our approach largely captures the effect of clustering.

We perform downscaling using population information about age, sex and ethnicity at a small areal scale. Although more elaborate groupings can be incorporated (using population density, dwelling type, etc.), we select the above-mentioned factors, as they are three of the most important contributors of COVID-19 mortality (Williamson et al., 2020). The goal of downscaling is not to identify the model that best describes COVID-19 deaths at a small areal level, but to describe more accurately the effect of air-pollution on COVID-19 mortality, as air-pollution varies at high geographical resolution. We do not provide simulations to examine how the downscaling affects the air-pollution effect estimates, nevertheless, as a proof of concept, we compare results using a model without it and the results are in large overlap and in line with our interpretation (Supplementary Tables S6-7 and Supplementary Figures S19-20). In addition, our results are in large agreement with an independent study by the Office for National Statistics that has a higher spatial resolution available (place of residence of COVID-19 deaths) and focuses on the period from 7 March to 12 June 2020 in England (Office for National Statistics, 2020).

Our study provides preliminary evidence of a weak association between COVID-19 mortality and long-term exposure to air-pollution (specifically NO_2). In the long term, a range of individual level data sources will become available to decouple the transmission and individual/environmental risk in a more complete way.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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