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A Global Perspective**

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COVID-19 Mortality and the Overweight: A Global Perspective

We conduct the first cross-country study of plausible associations between COVID-19 mortality and the share of the overweight among nearly 5.5 billion adults around the globe. A statistically significant positive association is observed between COVID-19 mortality and the proportion of the overweight in adult populations spanning 154 countries. This association holds across countries belonging to different income groups and is not sensitive to a population's median age, proportion of the elderly, and/or proportion of females. The estimated elasticities of COVID-19 mortality, with respect to the proportion of the overweight in adult populations, are consistently higher for sub-samples of countries that belong to a higher income group. While limits of confidence intervals around the point estimates of these elasticities range between 1.5 and 5.4, on an average, every percentage point increment in the proportion of the overweight in adult populations contributes to an additional 3.5 percentage points to COVID-19 mortality for high income countries. With due caution, our findings call for an effective alignment of public policy regulations with public health priorities.

Keywords: Public Health, COVID-19, Pandemic, Mortality, Weight.

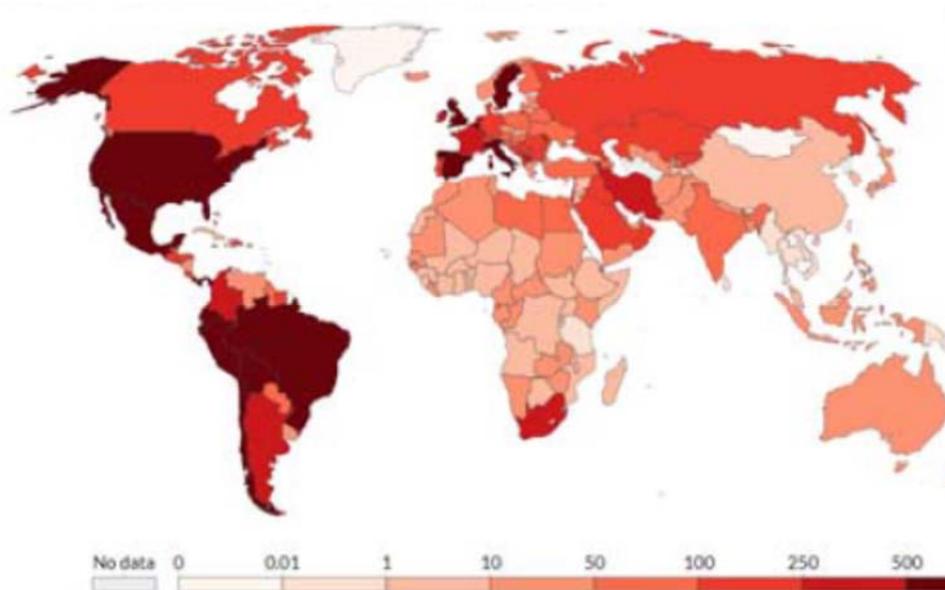
“We’re in a terrifying and confusing pandemic, with new and sometimes conflicting information about COVID-19 emerging all the time.”
Scientific American (September 5, 2020)

1. Introduction

A striking association between excess body weight and mortality, in the face of a viral infection, has surfaced since the earliest pandemic of the 21st century. It is not surprising that such a pattern has been confirmed during subsequent outbreaks of influenza, since excess body weight can predispose to a greater viral shedding that leads to a higher exposure. *Cell* has unveiled a molecular architecture of the severe acute respiratory syndrome coronavirus 2 (COVID-19) that can be linked to body weight, *Nature* has reported that the risk of dying from COVID-19 is linked to excess body weight, and *Science* has drawn attention to the fact that the sickest of COVID-19 patients were obese (ref. Mallapaty (2020), Wadman (2020), and Yao (2020)). While scientific research identifying the role of excess body weight in mortality among patients diagnosed with COVID-19 is at its infancy, emerging evidence points to a reasonable hypothesis that a population suffering from excess body weight is likely to experience a higher mortality from COVID-19. Our primary point of reference is the relevant medical literature while our main

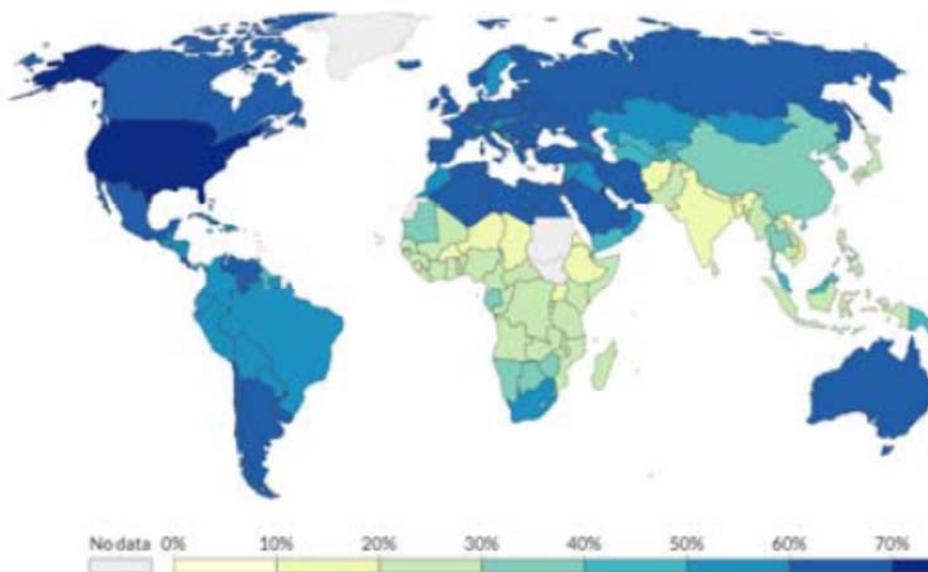
contribution is in conducting, to the best of our knowledge, the first cross-country analysis of a plausible association between COVID-19 mortality and the share of the overweight among nearly 5.5 billion adults around the globe.

Figure 1. Global Distribution of COVID-19 Deaths Per Million People



Source: European Centre for Disease Prevention and Control

Figure 2. Global Distribution of the Overweight Adult Population



Source: Global Health Observatory, World Health Organization

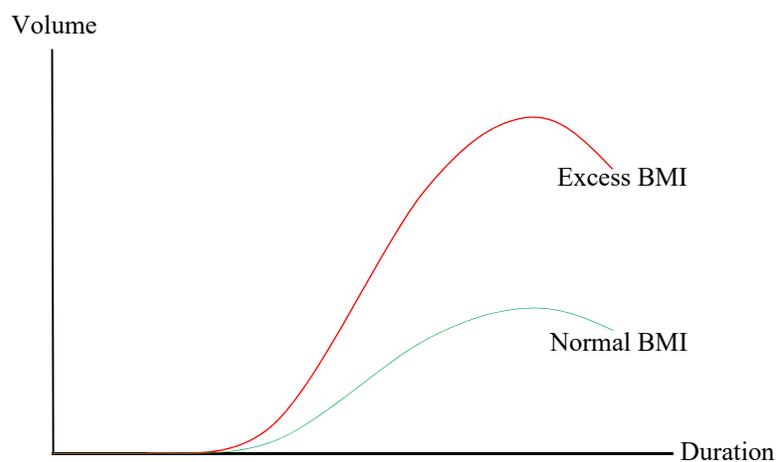
While body mass index (BMI) is clinically defined as a person's weight in kilograms divided by his or her height in meters squared, an individual is identified as being overweight if his/her BMI exceeds a clinical threshold: current guidelines from the US Centers for Disease Control and Prevention and the World Health Organization define a normal BMI range as 18.5 to 24.9 and overweight as a BMI of 25 or higher (ref. Berrington et al. (2010)). Figures 1 and 2 (mapping the spatial distribution of COVID-19 mortality and that of the overweight adult population, across countries, respectively) reflect a remarkable resemblance: overweight adults are concentrated mostly in relatively rich countries while lower income countries host leaner adults; COVID-19 mortality is typically higher in richer countries and lower in lower income countries. Nearly two-thirds of adults are overweight in most high-income countries while low-income and lower-middle income countries, that make up nearly half of the global population, have accounted for only 2 percent of the global death toll attributed to COVID-19. We take a cue from this pattern in conducting a cross-country analysis of any association between COVID-19 mortality and the proportion of the adult population that is overweight. In the next section, we place our contribution in the context of the relevant literature. We report all findings from our analysis in section 3. The final section concludes with due caution and a recommendation for aligning public policy with public health priorities. All data used are publicly available and are described in the appendix.

2. Context

Anecdotal evidence aside, in the absence of any previous analysis of associations between COVID-19 mortality and the proportion of the overweight in adult populations

across countries, our contribution may be placed in context of the relevant medical literature that has explored plausible pathological mechanisms through which excess body weight can affect COVID-19 mortality. See Bhatraju et al. (2020), Caussy et al. (2020), Chen et al. (2020), Mahase et al. (2020), Muscogiuri G et al. (2020) for evolving data suggesting that outcomes with COVID-19 are worse among those suffering from excess body weight while hospital reports, though not conclusive, have been indicative of the fact that the likelihood of survival is relatively low among the overweight COVID-19 patients. Clinically, excess body weight is related to several comorbidities that can lead to an increasingly severe course of and consequent death from COVID-19: metabolic disorders (such as hypertension, insulin resistance, dyslipidemia or prediabetes, which frequently occur in overweight patients) predispose to a poorer COVID-19 outcome.

Figure 3. Volume and Duration of Viral Shedding: Excess vs. Normal BMI



Source: Authors' adaptation of Honce and Stacey (2019)

Since excess body weight can result in a greater volume and longer duration of viral shedding, as shown in figure 3 (which is adapted from Honce and Stacey's (2019) model based on Maier et al. (2018) and Yan et al. (2018)), it can lead to a higher level of exposure

as well. However, the most recent meta-analysis, conducted by Hussain et al. (July – August, 2020), documents that a vast majority of COVID-19 studies did not include excess body weight, not even obesity, as a mortality risk factor in their reports. The authors attribute such apparent oversight to a lack of awareness and/or an absence of access to reliable data on body mass index (BMI). We draw attention to the clinical studies, relevant to our work, that have identified mechanisms linking COVID-19 mortality and excess body weight.

Simonnet et al. (2020) were among the earliest to point out the conspicuous absence of any mention of high BMI in clinical reports on significant risk factors for COVID-19. They conducted a retrospective cohort study to analyze the relationship between BMI and the requirement for invasive mechanical ventilation, involving 124 patients in intensive care at a French center for COVID-19, and concluded that the severity of COVID-19 increased with BMI. Subsequently, in a population cohort study, Ho et al. (2020) analyzed clinical observations on 340 confirmed COVID-19 patients and detected high BMI as a risk factor for COVID-19 mortality. Their study identified a dose-response relation between excess body weight and severity of COVID-19: the relative risk of critical illness from COVID-19 increased by 44% for people who were overweight. Sattar et al. (2020) studied a subsample of UK Biobank participants and reported consistent findings on a strong positive association between BMI and the risk of death related to COVID-19. Tartof et al. (2020), based on observed patterns in data from an integrated health care system, also reported a strong association between BMI and risk for death among patients diagnosed with COVID-19. Collectively, these studies point toward multiple mechanisms that can clinically link COVID-19 mortality to excess body weight. For instance, the mass of human angiotensin-

converting enzyme II (a putative receptor for the entry of COVID-19) is relatively high among the overweight. Moreover, being overweight impairs immunity by altering the response of cytokines. This results in a decline in the cytotoxic cell response of immunocompetent cells which have a key anti-viral role in addition to causing an imbalance between endocrine hormones affecting the interplay between metabolic and immune systems. Excess body weight can also trigger the involvement of adipose tissue-specific molecules in the generation of an environment that is favorable for diseases with an immune cause. There are negative impacts, as well, on the ability of dendritic cells (that link innate and adaptive immunity) to mature and elicit appropriate responses from white blood cells in the face of a general stimulus (such as, a viral infection like COVID-19). With this backdrop, we enquire if any association between COVID-19 mortality and the proportion of the overweight is observed in nearly 5.5 billion adults residing across 154 countries.

3. Findings

Since mortality is likely to be higher among older populations, due to a decline in immune and inflammatory responses with aging (*ceteris paribus*), we begin with an exposition of a regression surface to visualize any association that COVID-19 mortality (M) bears with our key variable of interest i.e. percentage of the overweight in the adult population (O) alongside the median age of the population (A). To construct this regression surface, with ε capturing any error(s), we estimate the following non-parametric model

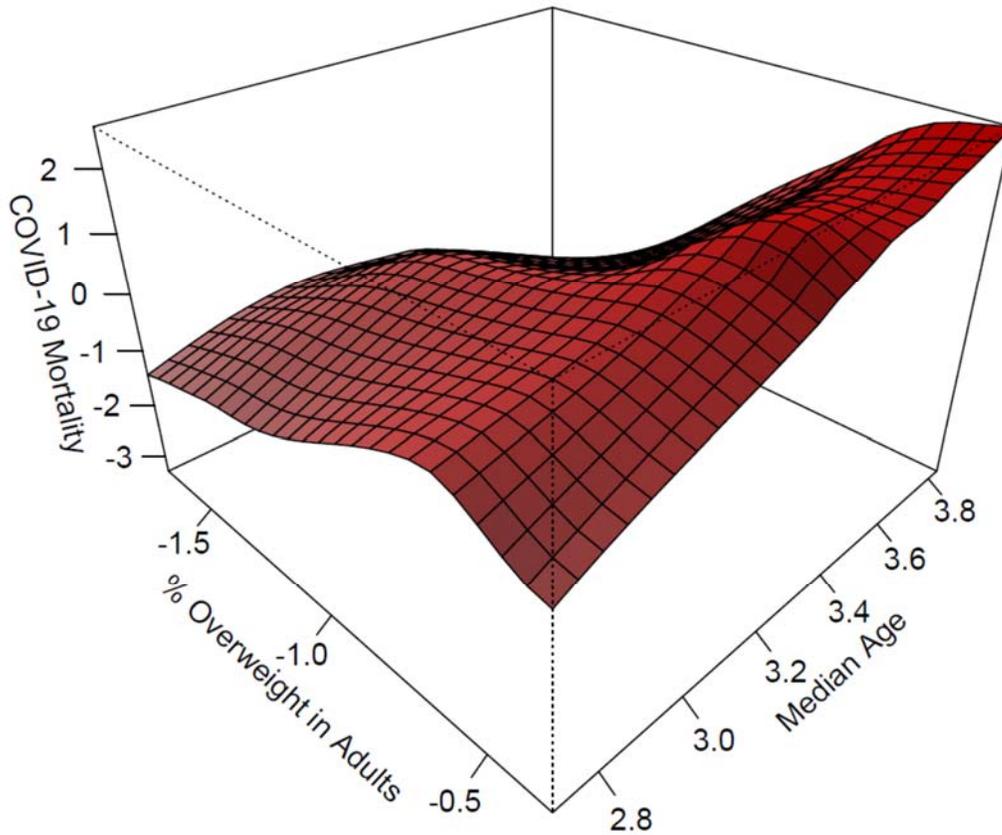
$$\log M = f(\log O, \log A) + \varepsilon$$

for which a multivariate neighborhood around a focal point $(\log O_0, \log A_0)$ is defined using Euclidean distances

$$D = \sqrt{\sum_{j=1}^c (\log \hat{O}_j - \log O_0)^2 + \sum_{j=1}^k (\log \hat{A}_j - \log A_0)^2}$$

where c is the number of countries (observations) indexed by j ; and $(\log \hat{O}_j, \log \hat{A}_j)$ represents vectors of standardized regressors.

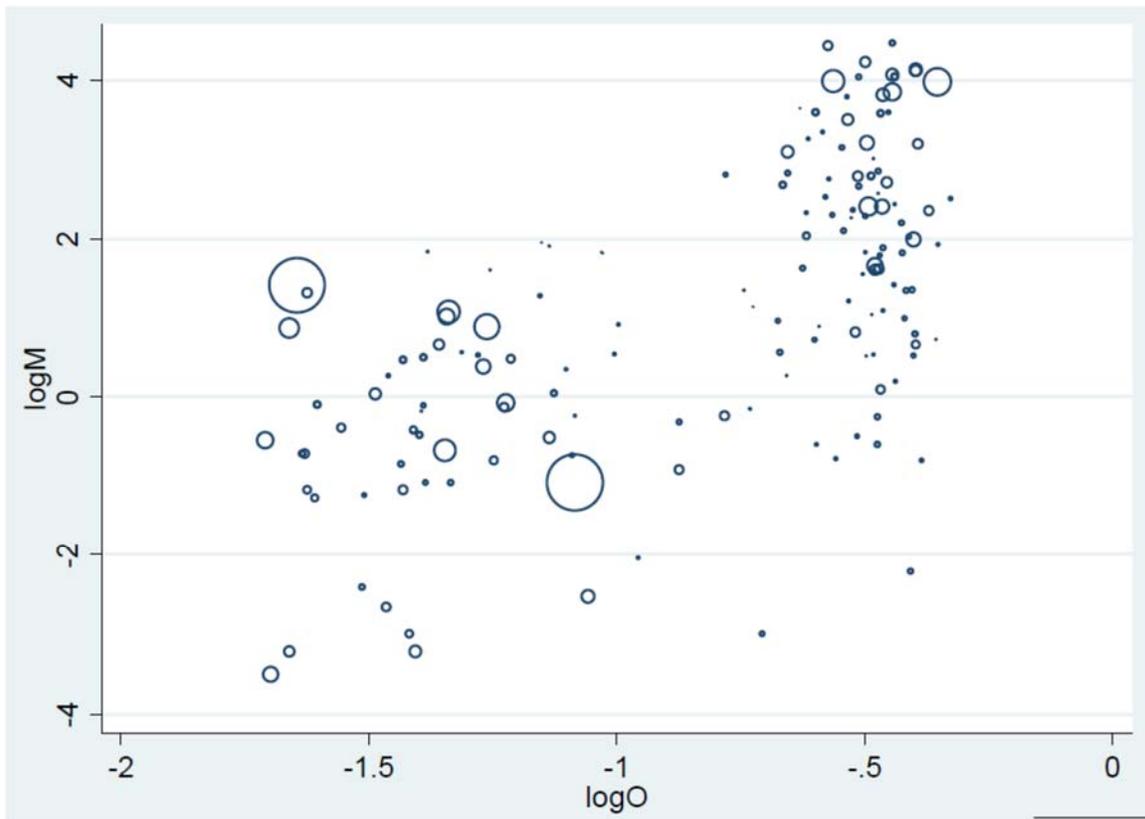
Figure 4. COVID-19 Mortality with Weight and Age



A weighted polynomial regression is run, with weights $\left(\frac{D}{h}\right)$ where h is the half-width of the neighborhood. This procedure is repeated for representative combinations of predictor values to build up a plot of the regression surface. We create a data frame

containing combinations of values of $\log O$ and $\log A$: we take 50 values, for each regressor, evenly spaced along the range of the variable. Next, the corresponding fitted values on the regression surface are compute. These predicted values are then reshaped into a 50 by 50 matrix which, along with the values of the predictors, are used to generate the regression surface shown in figure 4: the `expand.grid` function is used in R (ref. Lenth and Weisberg (2014)). While an association between COVID-19 mortality and the proportion of the overweight in a country's adult population transpires from an inspection of the regression surface, it is apparent that a partial regression in the direction of either of the regressors is not likely to be affected much by a variation in the other.

Figure 5. COVID-19 Mortality and Proportion of the Overweight in Adult Populations (154 countries hosting more than 7.5 billion people)



Note: Each circle, with radius proportional to population size, represents a country

Figure 5 plots COVID-19 mortality against the proportion of the overweight in each country’s adult population. While this lends credibility to our conjecture based on the regression surface, to circumvent any limitation that non-parametric estimation may impose (e.g. the commonly confounding “curse of dimensionality” with expanding continuous variable space) we present, in tables 1 through 4, the results from a parametric estimation of

$$\log M = \beta_0 + \beta_1 \log O + \beta_2 \log A + \epsilon$$

Table 1. COVID-19 Mortality and Proportion of the Overweight in Adult Population

Regression	1	2
Constant	3.2*** (<.0001)	3.3
log (percentage of overweight adults in the population)	2.6*** (<.0001)	2.6*** (<.0001)
log (median age)		-0.03
Sample size	154	154
Adjusted R-squared	0.4	0.4
F-statistic	90.8	45.1

Notes: Dependent variable is log of COVID-19 Mortality.

*** indicates that a regression coefficient is statistically significant at 1% level.
p-values in parenthesis.

Column 1 of table 1 confirms a positive and significant partial correlation between COVID-19 Mortality and the proportion of the overweight in adult populations across countries. This association is upheld, as shown in column 2 of table 1, after controlling for the median age of each country’s population. Tables 2 through 4 show that the positive and significant association between COVID-19 Mortality and the proportion of the overweight in adult populations, before and after controlling for the median age of each country’s population, is stronger for high income countries.

Table 2. COVID-19 Mortality and Proportion of the Overweight in Adult Population: High Income Countries

Regression	1	2
Constant	3.8*** (<.0001)	5.0
log (percentage of overweight adults in the population)	3.5*** (<.0005)	3.5*** (<.0001)
log (median age)		-0.3
Sample size	52	52
Adjusted R-squared	0.2	0.2
F-statistic	13.8	6.8

Table 3. COVID-19 Mortality and Proportion of the Overweight in Adult Population: Upper Middle Income Countries

Regression	1	2
Constant	2.9*** (<.0001)	5.4
log (percentage of overweight adults in the population)	2.2** (0.03)	2.4** (0.03)
log (median age)		-0.7
Sample size	42	42
Adjusted R-squared	0.1	0.1
F-statistic	4.8	2.5

Table 4. COVID-19 Mortality and Proportion of the Overweight in Adult Population: Lower Middle and Low Income Countries

Regression	1	2
Constant	2.9*** (<.0001)	1.1
log (percentage of overweight adults in the population)	2.3*** (<.0001)	2.1*** (0.001)
log (median age)		0.5
Sample size	60	60
Adjusted R-squared	0.3	0.3
F-statistic	23.6	11.7

Notes: Dependent variable is log of COVID-19 Mortality.

*** indicates that a regression coefficient is statistically significant at 1% level and

** indicates that a regression coefficient is statistically significant at 5% level; *p*-values in parenthesis.

Table 5. COVID-19 Mortality and Proportion of the Overweight in Adult Population:
Robustness

Regression	1	2	3	4	5	6	7	8	9	10	11	12
log (percentage of overweight adults in the population)	2.571***	2.391***	2.468***	2.431***	2.449***	2.417***	2.463***	2.369***	2.488***	2.528***	2.534***	2.567***
Income group dummy (1 = high income; 2 = upper middle income; 3 = lower middle income; 4 = low income)		-0.098	-0.169	-0.063	-0.083	-0.077	-0.128	0.017	-0.033	-0.039	0.004	-0.005
log (median age)			-0.374		-0.096		-0.507		-2.291	-75.828	-1.875	-71.269
log (percentage of female in the population)				-0.656	-0.606			-1.406	-4.087	-68.287	-1.888	-62.642
log (percentage of elderly in the population)						-0.001	0.122	0.170	1.049	0.865	11.316	10.188
log (median age)*log (percentage of female in the population)										18.844		17.773
log (percentage of elderly in the population)*log (percentage of female in the population)											-2.648	-2.402
Constant	3.231***	3.298***	4.765*	5.801	5.984	3.261***	4.864	8.171	24.771*	275.699	14.969	252.539
Sample size	154	154	154	153	153	153	153	153	153	153	153	153
Adjusted R-squared	0.370	0.367	0.364	0.364	0.360	0.363	0.359	0.361	0.365	0.368	0.365	0.368
F-statistic	90.84	45.40	30.22	29.96	22.33	29.82	22.29	22.44	18.44	15.76	15.58	13.65

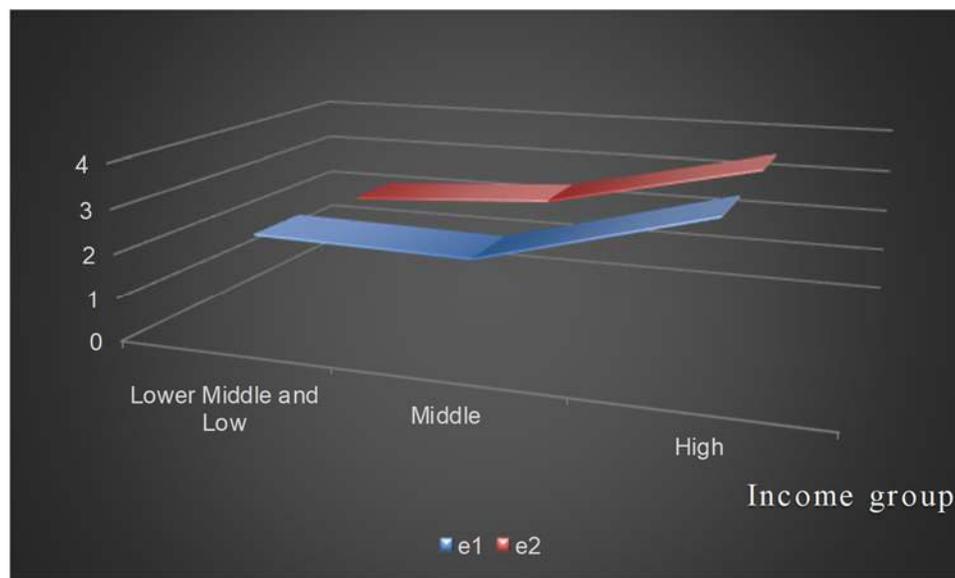
Notes: Dependent variable is log of COVID-19 Mortality.

- *** indicates that a regression coefficient is statistically significant at 1% level;
- ** indicates that a regression coefficient is statistically significant at 5% level; and
- * indicates that a regression coefficient is statistically significant at 10% level.

Table 5 confirms that the positive and significant partial correlation between COVID-19 Mortality and the proportion of the overweight in adult populations remains robust to reasonable alterations in the conditioning information set, such as, inclusion of the proportion of elderly, proportion of females, and/or a dummy variable for income groups among potential regressors, as well as interaction terms. Such a sensitivity check, of course, lends credibility to our findings to the extent that the sign and significance of the coefficient of our variable of interest are not fragile.

Figure 6. Elasticity of COVID-19 Mortality

(with respect to the proportion of overweight in the population of a country, by income group)



Estimated elasticities (e_i , where $i = 1,2$ refers to a column number corresponding to regression results reported on the tables 2 – 4) of COVID-19 mortality, with respect to the proportion of the overweight in adult populations residing in countries that belong to different income groups, are plotted in figure 6. Limits of confidence intervals around the point estimates of elasticities range between 0.2 and 5.4 and are consistently higher for the sub-sample of countries that fall in a higher income group: every percentage point

increment in the proportion of overweight in the adult population, on an average, contributes to an additional 3.5 percentage points to COVID-19 mortality in high income countries.

4. Conclusion

In sum, the positive association between COVID-19 mortality and the proportion of the overweight in a country's adult population is alarming. The current pandemic has, on an average, been more fatal for adult populations residing in parts of the world characterized by excess body weight. At the same time, the food industry has been profiting from the sale of food and beverages which are often ultra-processed, high in salt, sugar, and saturated fat to an extent that can lead to an accumulation of excess body weight exacerbating the fatal consequences of COVID-19. As the World Health Organization underscores, companies should reduce the fat, sugar, and salt content of processed food and beverages and ensure that healthy and nutritious choices are available and affordable to all consumers. On the contrary, some firms in the food industry have taken the liberty of using the pandemic as a platform for marketing in ways that are all but conducive to restraining body weight. For instance, Krispy Kreme's coronavirus updates (<https://www.krispykreme.co.uk/coronavirus>) include serving "half a million 'smiles', in the form of donations" of "glazed doughnuts (via contactless drops) to hospitals, charities, food banks, police stations, carers and other critical key worker groups." But for some scattered instances (e.g. taxes on sweetened beverages in the United Kingdom), a comprehensive regulation of the food industry is conspicuous in its absence while public policy is far from being aligned with public health priorities. Our observed association,

between COVID-19 mortality and the share of the overweight in nearly 5.5 billion adults residing across 154 countries that host more than 7.5 billion people around the globe, serves as a caution against putting more lives at stake: in hindsight, with a seven figure death toll from the current pandemic alone, our findings call for immediate and effective regulations (e.g. restrictions on “serving” the market for food and beverages with items, the intake of which can result in the accumulation of excess body weight) that are long overdue.

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Figures

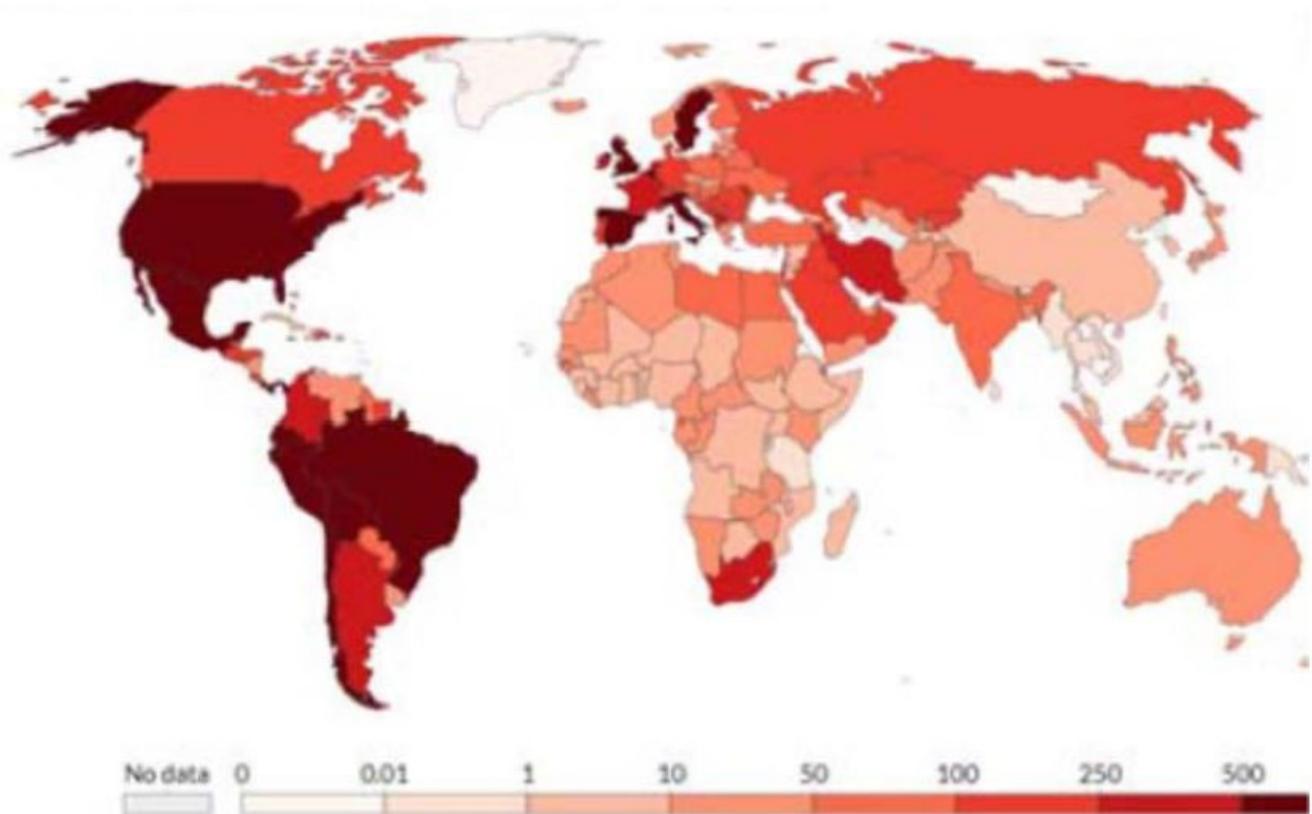


Figure 1

Global Distribution of COVID-19 Deaths Per Million People Source: European Centre for Disease Prevention and Control Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

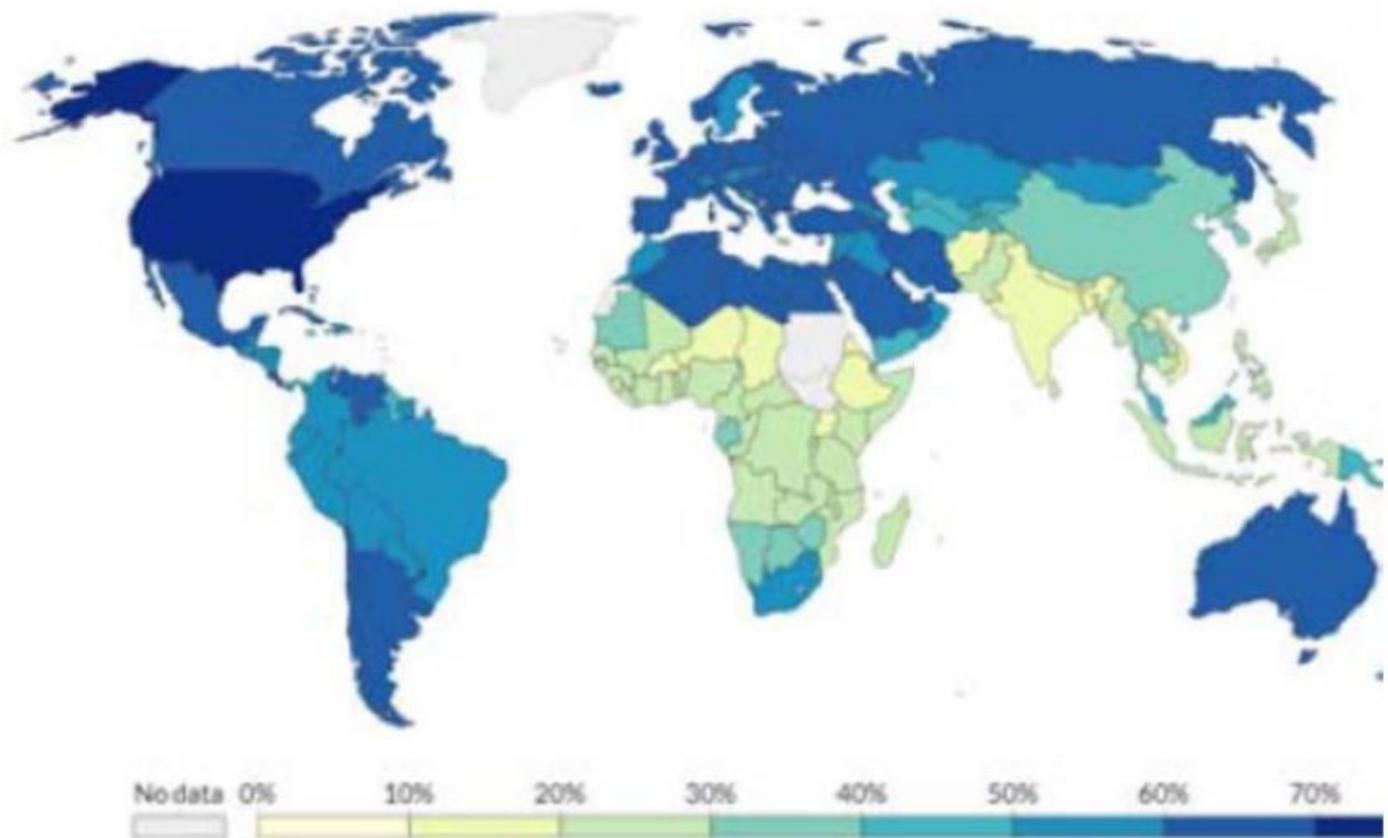


Figure 2

Global Distribution of the Overweight Adult Population Source: Global Health Observatory, World Health Organization Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

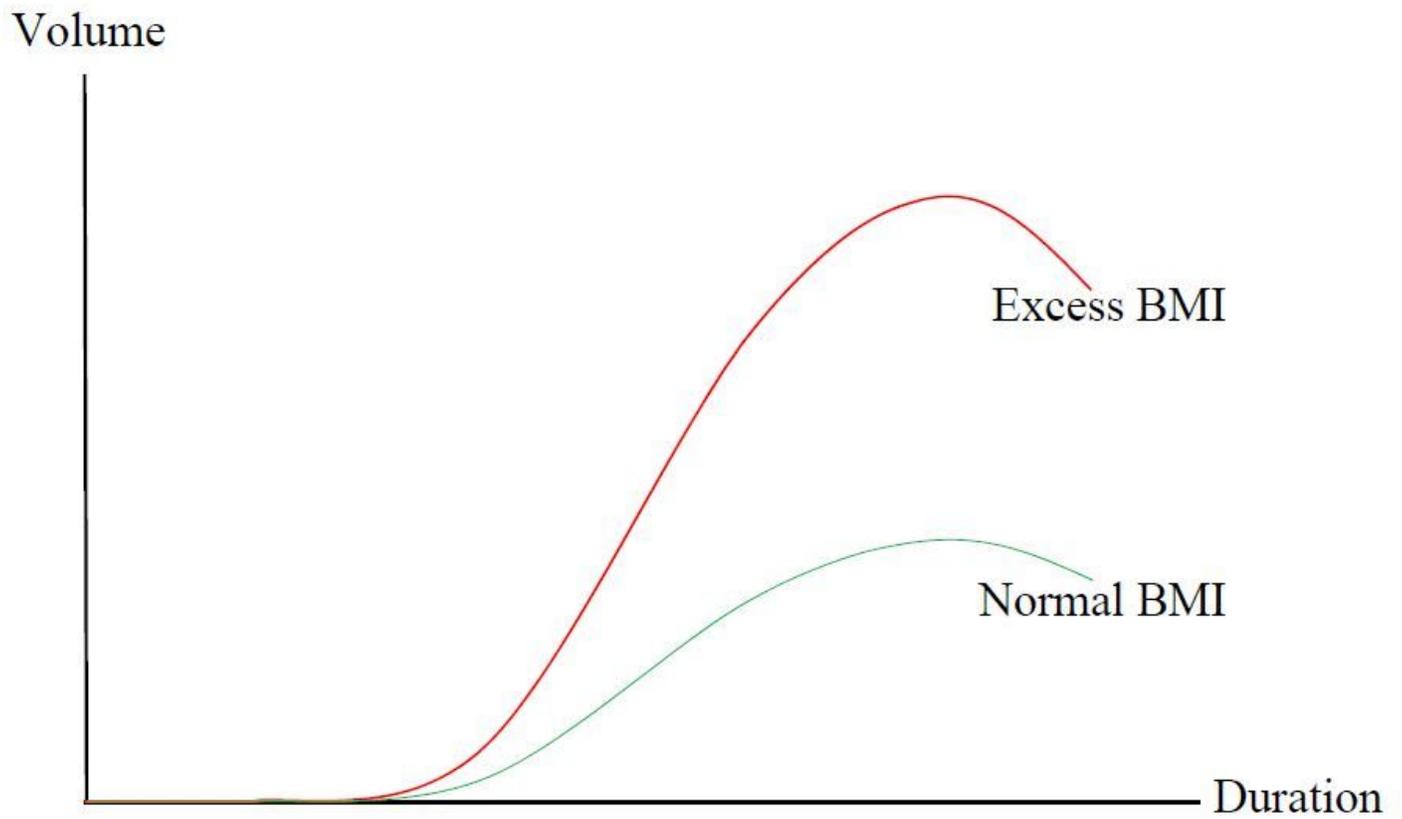


Figure 3

Volume and Duration of Viral Shedding: Excess vs. Normal BMI Source: Authors' adaptation of Honce and Stacey (2019)

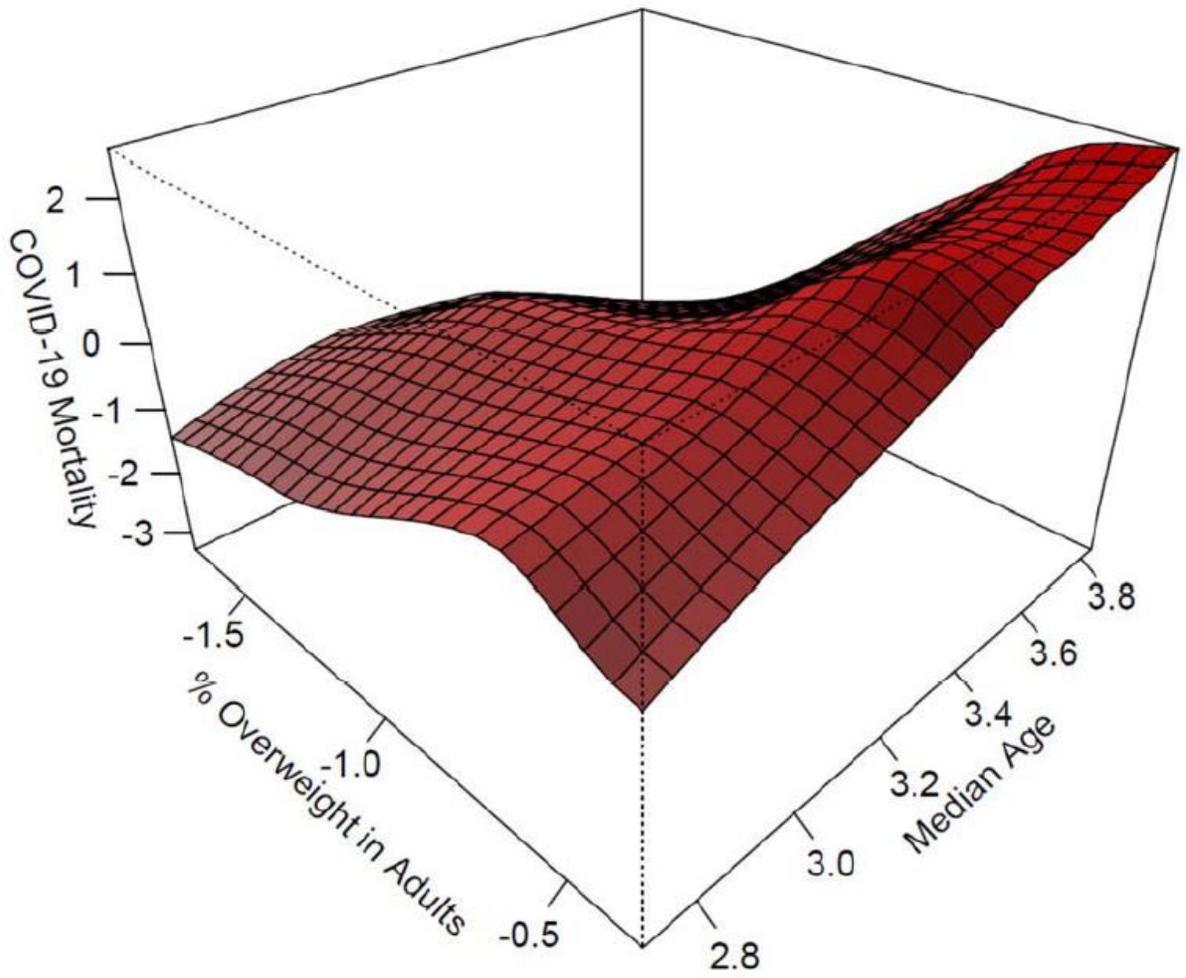


Figure 4

COVID-19 Mortality with Weight and Age

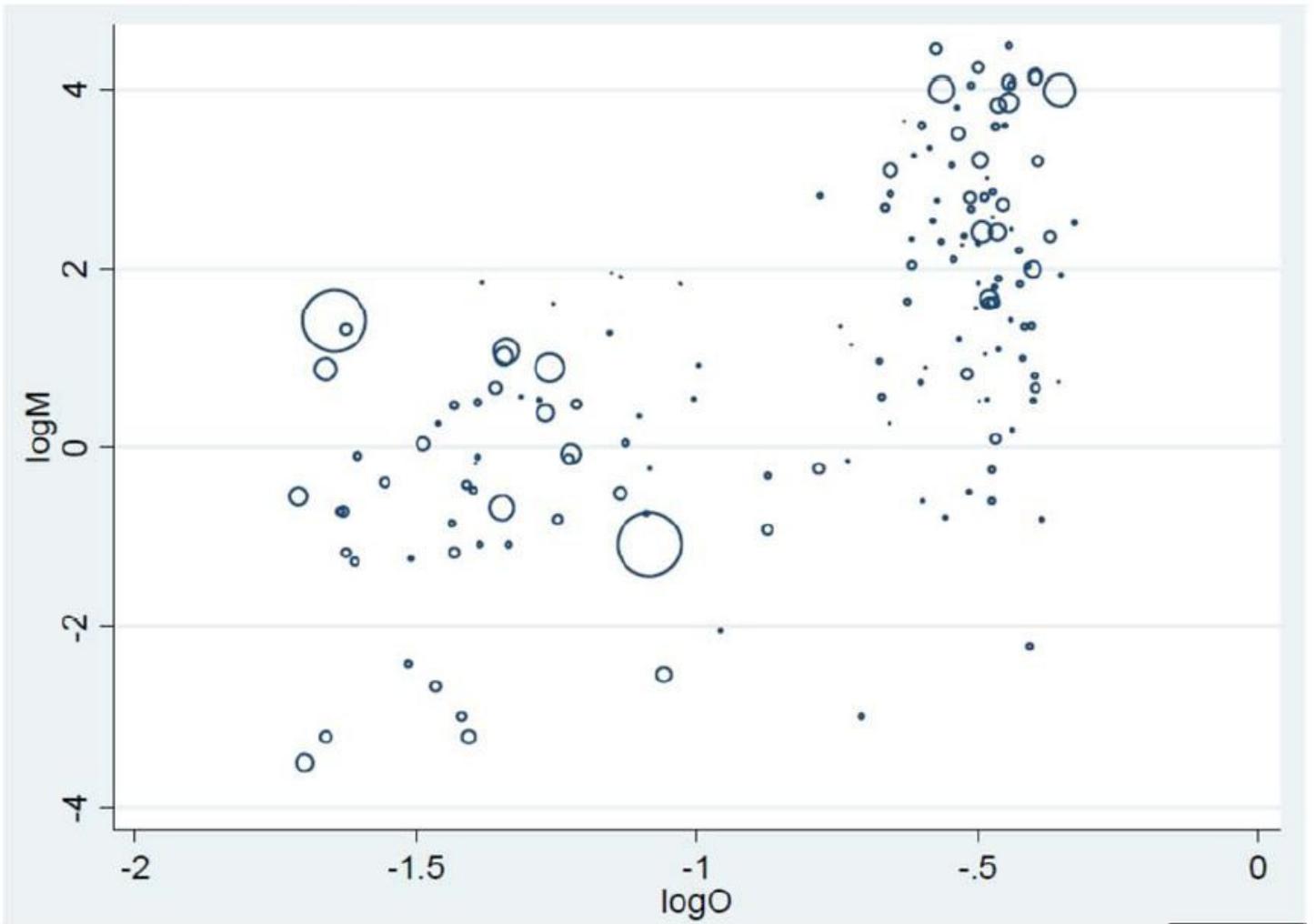


Figure 5

COVID-19 Mortality and Proportion of the Overweight in Adult Populations (154 countries hosting more than 7.5 billion people) Note: Each circle, with radius proportional to population size, represents a country

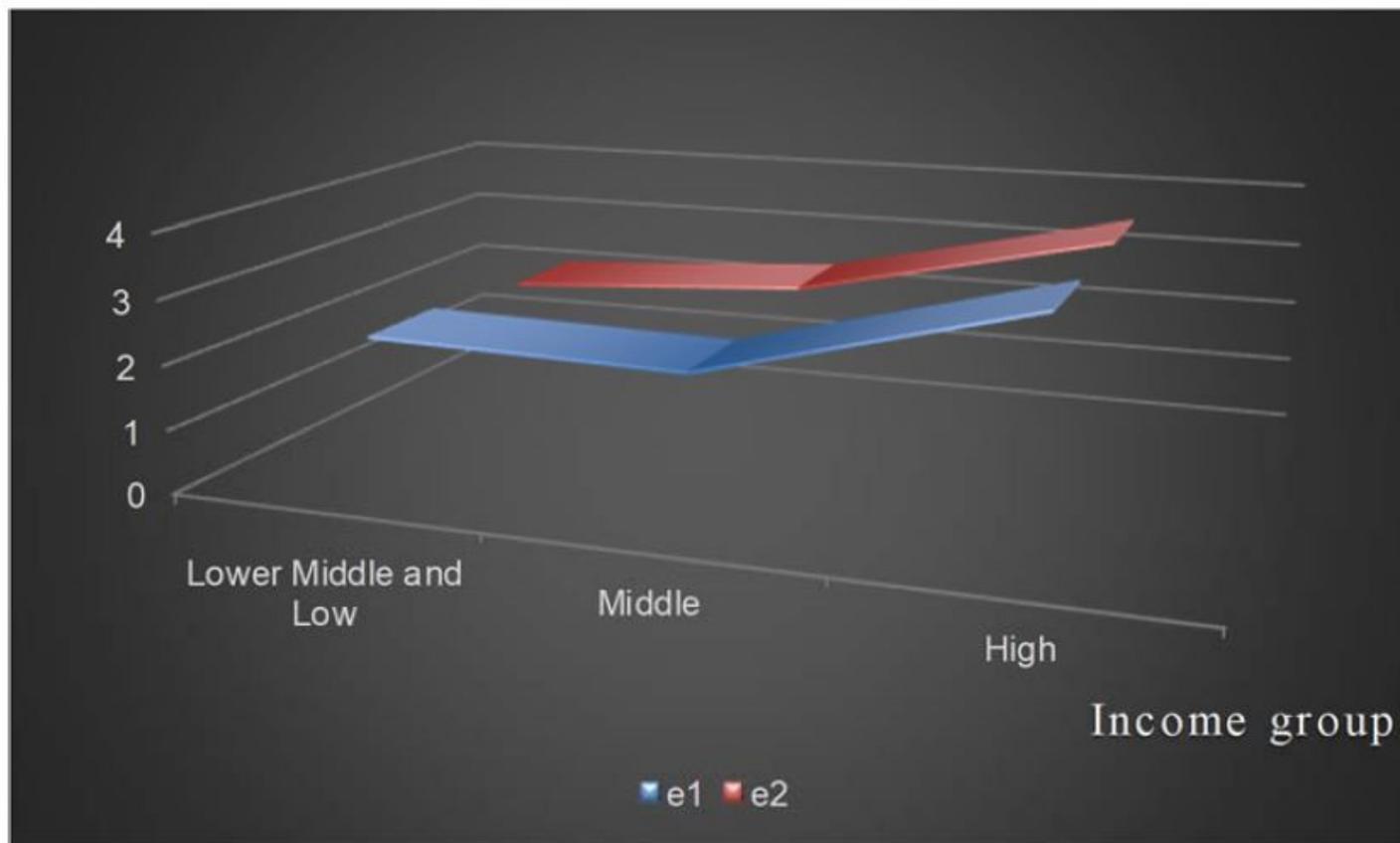


Figure 6

Elasticity of COVID-19 Mortality (with respect to the proportion of overweight in the population of a country, by income group)

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [AppendixABC11272020.pdf](#)