Exploring the impact of cultural variability on COVID-19-related mortality: A meta-analytic approach

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Research Article

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Abstract

Deaths associated with COVID-19 shows a high degree of heterogeneity across different populations. An assessment of the global variability in COVID-19-attributable deaths is essential for predicting the health and economic impact of future outbreaks in different settings. Moreover, a comprehensive understanding of population-level predictors is also crucial for devising better-targeted and more appropriate emergency preparedness measures. While, demographic, economic and health-system capacity have featured prominently in recent work, cultural and behavioural characteristics have largely been overlooked. However, cultural differences likely shape both the public policy response and individuals' behavioural responses to the crisis in ways that can impact infection dynamics and key health outcomes. To address this gap, we used meta-analytic methods to explore the global variability of COVID-19-attributed deaths during the first-wave of the pandemic and identified cultural/behavioural attributes (e.g., individualism, uncertainty avoidance) as independent predictors of COVID-19 fatalities after adjusting for important demographic, political, economic and health-system-related predictors.

Introduction

The case fatality and mortality rates associated with COVID–19, a disease caused by the severe acute respiratory syndrome coronavirus–2 (SARS-CoV–2) shows a high degree of heterogeneity across different countries and populations. Based on available patient-level data, risk of severe illness and death are typically highest among older adults (>65 years), as well as immunocompromised individuals, and those with comorbid conditions.[1] Moreover, COVID–19-attrributed mortality also appears to rise rapidly as the surge in the number of severe cases requiring specialised care exceed existing health system capacity. [1,2] In particular, health system constraints in terms of the number of healthcare workers, hospital beds and the availability of personal protective equipment, as well as specialised medical devices remain a global concern in the fight against COVID–19.

To mitigate the sudden surge in the number of COVID–19 cases, in the early weeks of March 2020, many countries have implemented large-scale social distancing measures to varying degrees, with the aim of reducing the transmission of SARS-CoV–2.[3,4] During this time, which comprises the initial wave of the pandemic, countries have also expanded testing for SARS-CoV–2 in combination with contact tracing and isolation to varying degrees. With many countries reporting a reduction in incident cases and deaths, in mid-May 2020, discussion around deconfinement has become more salient, followed by a gradual relaxation of confinement in early June.

In summary, the exceptional global phenomenon of the COVID–19 crisis has led to a situation where societies that vary considerably—in terms of social and cultural values as well as economic and demographic characteristics—found themselves having to deal with a common public health emergency simultaneously, with a variable degree of success in mitigating fatalities.

An accurate understanding of the global variability in COVID–19 mortality is vital for projecting the burden of future outbreaks in different settings and for developing better-targeted and more appropriate emergency preparedness measures. While public health capacity, demographic differences and socioeconomic development are certainly important factors that can account for such disparities, cultural characteristics (i.e., a set of common values and norms) should not be overlooked.

Culture is an important factor in understanding the development of social policies.[5] Specifically, culture has been shown to affect the health behaviour of individuals as well as healthcare practices and outcomes.[6] Moreover, in the context of the COVID–19 pandemic, socio-psychological cultural traits have been proposed to influence policy approaches of different governments, as well as community engagement with public health recommendations.[7,8] Yet, societies' cultural characteristics have so far, to our knowledge, been largely absent from empirical studies that have explored COVID–19-related outcomes.

In this study, we address this scholarly gap by exploring the observed variation in the crude case fatality and the mortality risk which has been attributed to SARS-CoV–2 during the initial phase of the pandemic (April-June); specifically examining the extent to which certain cultural attributes can explain these disparities alongside other key factors (e.g., demographics, health system capacity, timing of the epidemic) at a population-level.

Results

Country characteristics

The analysis included 49 countries (representing a total of 5,654,050 detected cases and 370,928 deaths attributed to COVID–19 over an average follow-up time from diagnosis of initial case of 108 days (range: 66–187)). Countries were selected based on the size and significance of the epidemics during the initial months of the pandemic and based on surveillance capacity. Together, this data represents 82% of the confirmed cases of COVID–19 and 93% of the COVID–19-attributed deaths worldwide.

The key characteristics of countries are displayed in *Table 1.* The analysis included 31 (63%) countries from the European region, 7 (14%) from the Americas, 7 (14%) from Western Pacific, 2 (4%) from South-East Asia, and 2 (4%) from the African and Eastern Mediterranean regions. The average per capita GDP was USD $35,410 (range: $2,010-$116,640), the proportion of the population aged above 65 years was 16% (range: 5–28%). In terms of health system capacity, on average, for every 1,000 individuals, there were 4.6 hospital beds (range: 0.5–13), 3 doctors (range: 0.4–5) and 8 nurses (range: 1–18). With respect to COVID–19 related factors, there were a total of 78,594,612 tests performed for SARS-CoV–2 translating to an average testing coverage of 46,737 tests per 1 million population (range: 1,394-182,000).

Pooled estimates of COVID–19 deaths

Pooled outcomes based on random-effects meta-analyses are presented in *Table 2.* In brief, over the timeframe of the analysis, the pooled crude CFR changed from 2.59% (95%CI: 2.00–3.35, PI: 0.48–1.81) in April 5th, to 3.97% (95%CI: 3.02–5.21, PI: 0.56–23.28) in June 5th. Over the same period, the pooled COVID–19-attributed mortality risk per 1,000 changed from 0.008 (95%CI: 0.004–0.014, PI: 0.0001-0.2944) to 0.05 (95%CI: 0.032–0.087, PI: 0.0014–0.6985). Pooled estimates from the final follow-up date are illustrated using Forrest plots (*Figure 1).*

Population-level predictors of COVID–19 deaths

The substantial variability in COVID–19 mortality during the first wave of the COVID–19 pandemic was further explored using random effects meta-regression analyses (*Table 3 and Table 4)* using two different model specification approaches: a theory driven a priori model and an exploratory model developed using automated variable selection methods.[9] In the *a priori* model (Model 1) we explored the effects of predetermined set of predictors including underlying demographics, health system capacity, the epidemic timeline, and key cultural and political characteristics that may play a role in infectious disease dynamics, emergency preparedness and crisis management capacity of different societies. The exploratory model (Model 2) used a bootstrapping variable selection method in the model specification process to identify potentially relevant covariates from a larger set of predictors described in *Table 1.*

Based on the *a priori* model (*Table 3,* Model 1), after adjusting for these covariates, we found that countries with a larger proportion of individuals over the age of 65 (OR:1.06) and a greater number of days past the index death (OR:1.02) had higher crude CFR, indicating an increase in fatalities with time and with an older demographic profile. In contrast, indicators of health system strength such as the number of hospital beds (OR:0.85) as well as the extent of COVID–19 testing (OR:0.99) displayed a significant negative association with crude CFR. With respect to cultural characteristic, we found that countries that demonstrate a tendency towards individualism, as opposed to collectivism on the Hofstede dimensions, presented with a significantly higher CFR (OR:1.02). Similarly, societies that report a greater discomfort with uncertainty also displayed significantly higher crude CFR (OR:1.01).

When we applied a bootstrap variable selection method to select model variables from a larger set of potential covariates (*Table 3,* Model 2). Variables selected using the bootstrap method matched closely with the theory driven variables (*Table 3,* Model 1). However, the bootstrap method (Model 2) excluded three variables (GDP per capita, healthcare workers per 1,000 population and polity) and included two additional cultural variables (indulgence vs. restraint and long-term vs. short-term orientation) as relevant covariates. In this model, a cultural tendency for long-term (vs. short-term) normative orientation was also a significant positive predictor of crude CFR (OR:1.02), along with individualism (OR: 1.03) and uncertainty avoidance (OR: 1.02). The relationship between potentially relevant cultural attributes with case fatalities are additionally illustrated in *Figure 2.* Covariates included in Model 1 and Model 2 accounted for 55% and 56% of the total observed variability in the crude CFR respectively and resulted in similar model fit.

As with CFR, the mortality risk (*Table 4)* also demonstrated similar associations with selected predictors; however, with the theory-driven *a priori* model specification approach (*Table 4,* Model 1) only four covariates reached statistical significance in this case: the number of hospital beds (OR:0.77), GDP per capita (OR:1.04), the extent of individualism (vs. collectivism) (OR:1.03) and uncertainty avoidance (OR:1.03). With the statistical model specification approach (*Table 4,* Model 2), variables selected using the bootstrap variable selection method closely resembled Model 1. However, the bootstrap method excluded polity as a relevant predictor and included two additional cultural variables: indulgence vs. restraint and power distance index as covariates. In this model, a cultural tendency towards power distance was identified as a significant positive predictor of mortality risk (OR:1.03); in addition to individualism (OR: 1.05) and uncertainty avoidance (OR: 1.04). The relationship between potentially relevant cultural attributes with mortality are additionally illustrated in *Figure 3.* With respect to the mortality risk, covariates included in Model 1 and Model 2 accounted for 36% and 50% of the total observed variability in mortality risk respectively. In terms of model selection criteria Model 2 displayed a better model fit.

The impact of including specific countries in the analysis was explored through a sensitivity analysis. In brief, the findings were in general robust for both the outcomes after the removal of outliers such as Belgium, China, USA, Singapore, and Iceland from the analyses (*Supplemental Tables 1 and 2).*. When key cultural characteristics were re-evaluated in Model 1, individualism displayed a significant relationship with both outcomes in all sensitivity analysis performed (OR: 1.01–1.04); whereas uncertainty avoidance displayed a significant relationship in most analyses (OR: 1.01–1.04) with the exception of two cases: the removal of either Singapore or USA from the analysis resulted in a loss in the significant relationship between case fatality and uncertainty avoidance. As for the bootstrap variable selection (Model 2), the sensitivity analyses consistently identified at least two cultural attributes as important predictors of both outcomes except for one case: upon the removal of Belgium from the analysis, no cultural attribute was identified as an important predictor of the case fatality outcome. In bootstrap variable selection models, uncertainty avoidance (OR: 1.02–1.06; n = 8/10) was most frequently identified as a significant predictor, followed by individualism (OR: 1.02–1.06 n = 6/10), and long-term avoidance (OR: 1.01–1.04; n = 5/10).

Discussion

It has been suggested that cultural factors can define the pre-existing (or, baseline) social and behavioural characteristics of societies and help to modulate both the public policy response and individuals' behavioural responses to the crisis in ways that impact infection transmission dynamics and key health outcomes.[7,8,10] Indeed, numerous studies have shown that cultural factors can influence infectious disease dynamics, vaccination rates, infection prevention and control practices, and health outcomes. [6,11–13] For instance, it has been demonstrated that cultural attributes can predict almost half of the variance in Methicillin-resistant *Staphylococcus aureus* infections among European countries.[11]

However, no study has explored the impact of cultural/behavioural attributes in the context of the 2020 COVID–19 pandemic. To address this gap, we used meta-analytic methods to explore the global variability of COVID–19 attributed deaths during the first wave of the pandemic using two metrics (crude CFR and the mortality risk) and evaluated the role of demographic, cultural/behavioural, political economic and health-system-related predictors. We focused on mortality rather than the infection rate as this is the most crucial and most reliable metric of the pandemic's impact given the absence of widespread surveillance and testing in most settings.

With respect to case fatalities (or, the risk of death among confirmed cases of infection), we found that health system resources constraints had the largest impact on case fatalities followed by demographics. A one unit increase in the number of hospital beds per 1,000 individuals led to a ~15–20% reduction in the odds of a fatal outcome among cases; while a unit increase in the proportion of the population over 65 years resulted in a ~6% increase in the odds of fatal outcome. Moreover, the findings highlight that cultural distinctions also play a small but significant role in accounting for the severity of the COVID–19 crisis. We found that a one-unit increase in individualism (vs. collectivism) was associated with ~2–3% increase in the odds of fatal outcome among infected individuals. We also found that a one-unit increase in uncertainty avoidance (i.e., a society's discomfort with and resistance to unfamiliar phenomenon) was associated with ~1–2% increase in the odds of fatal outcome.

Similar trends were apparent when we evaluated the effects of these covariates on mortality risk (or, the risk of death among the general population). In this case, a one unit increase in the number of hospital beds per 1,000 individuals led to a ~23–26% reduction in the odds of a COVID–19-attributed death; while a unit increase in the proportion of the population over 65 years resulted in a ~11–13% increase in mortality. Cultural/behavioral characteristics also had a significant impact: a one-unit increase along the individualism dimension was associated with ~3–5% increase, while a one-unit increase in the uncertainty avoidance dimension was associated with ~3–4% increase in the odds of a COVID–19-attributed mortality among the population.

In total, demographic, economic, and cultural/behavioural factors could explain approximately half the variability in case fatalities and mortality risk during the initial wave of the pandemic. In terms of cultural characteristics, our analysis found that having a national culture that is more individualistic (vs. collectivist) and a cultural tendency toward uncertainty avoidance were both consistently associated with higher fatalities for both outcomes in all models assessed. Our exploratory analysis also found that a tendency towards long-term orientation vs. short-term normative orientation was also associated with a 2% increase in the odds of case fatality, whereas a greater degree of power distance index was associated with a 3% increase in the odds of a COVID–19 mortality.

In terms of individualism, in general, many European and Anglo-American democracies tend strongly towards individualism, whereas Asian nations display more collectivist attitudes.[14,15] Individualism has often been equated with neo-liberal socioeconomic policies that tend to undermine social welfare and lead to weak collective protections.[16] As well, individualist attitudes may more broadly lead to social behaviour that focuses on the individual rather than the collective well-being. For instance, in previous investigations, collectivist societies have been shown to be more effective in reducing the transmission of pathogens during outbreaks vs. individualistic ones.[13,17] Similarly, individuals from more individualistic nations on the Hofstede dimensions have been shown to have lower vaccination intentions.[12] However, a communication of the concept of herd immunity was shown to be able to improve vaccination intentions particularly in societies that lack a collectivistic baseline stance.[12]

As for uncertainty avoidance, Hofstede describes this dimension as a measure of a nation’s ability to adapt and cope with ambiguity.[18] This indicates the degree of discomfort with unstructured, unknown and unexpected situations[11,18] Societies with high uncertainty avoidance tend to be more resistant to change and therefore, paradoxically, more risk-tolerant.[11] Typically, this characteristics is more common in countries with high degree of bureaucracy.[11] For instance, Southern and Eastern European countries display greater uncertainty avoidance, whereas Northern European countries tend to rank lower in this attribute. [18] Past research has highlighted a negative relationship between uncertainty avoidance with both prosocial behaviour (e.g., volunteerism) and rapport building with patients.[19–21] Therefore, higher degrees of individualism and uncertainty avoidance could lead to weaker social responses and attention given to vulnerable groups; two factors that can worsen a health crisis.

Moreover, other potentially important cultural factors identified in the current analysis were long-term orientation and power distance, which displayed significantly higher case fatality and mortality risk respectively. Typically, East Asian and European nations tend towards long-term orientation, whereas African countries, Islamic nations, South American nations, and Anglo-American democracies tend towards short-term orientation.[22,23] In general, societies with long-term normative orientation tend to be more adaptive, less ideological, and future-focused, whereas those with short-term orientation tend to focus on past and present, respect tradition, norms and social obligations.[18,23] A greater focus on the present may therefore lead to stricter immediate emergency measures, which may play a role in more quickly reacting to a crisis in nations with short-term orientation. In terms of power distance, this index measures the level of hierarchy within a society and is an indicator of the extent of deference given by less powerful members in society towards authority figures such as governmental officers.[2218] However, societies that rank higher on the power distance index also tend to have greater centralisation of decision-making, lower accountability, as well as a large degree of income inequity.[18] High power distance societies tend to therefore have less inclusive and participative decision-making bureaucratic procedures.[24] Typically, Eastern European and Asian nations rank higher on the power distance index, while Western nations rank lower.[22] In societies with lower degree of power distance, a decentralisation of power may enable more efficient decision-making during a crisis.

In summary, this study makes important contributions to the current scholarship by: 1) examining data from the initial phase of the pandemic, prior to initiation of broader deconfinement; 2) focusing on a collection of countries with important outbreaks during this period, representing an overwhelming majority (~82%) of reported infections world-wide; 3) exploring the variability in COVID−19 fatalities across nations taking into account important demographic, social, economic, and cultural factors; 4) evaluating the robustness of findings and sensitivity to country selection and 5) lastly, this is the first study to our knowledge to show the extent to which culture attributes can impact key health outcomes during the COVID–19 pandemic. The results suggest that in such public health crises (i.e., with limited therapeutic options), baseline cultural and behavioural factors may play an important role in influencing outcomes.[12]

However, the study also has limitations. The first limitation pertains to the accuracy of the estimated outcomes. The purpose of this study is not to generate a precise estimate of the CFR or mortality rate, which has been previously attempted by others using a variety of statistical approaches.[25–28] Rather, the intent is to explore the observed variation in fatalities. Therefore, we only estimate the crude CFR. With this metric, the denominator includes unresolved (or, active) cases resulting in a time-lag bias that likely underestimates the true CFR, particularly in the earlier instances of the outbreak. Nonetheless, the estimated CFRs in this study are more likely to be an overestimate owing to the relatively greater influence of ascertainment bias (i.e., the under-detection of mild and asymptomatic cases resulting from undertesting). Indeed, we find that crude CFR is significantly lower with greater testing coverage of the population, suggesting that expanded testing should reduce CFR estimates by identifying more mild infections. Further, a higher testing coverage could also reflect a better capacity for contact tracing and isolation, which may reduce onward transmission particularly among high-risk groups. A second limitation is related to residual variability resulting from the inconsistency in recording COVID–19-attributable deaths across nations. Further, we have also not evaluated the potential impact of divergent medical management practices; however, as no known effective treatment or vaccine for SARS-CoV–2 is available during this period demographic factors, comorbidities and health system resource capacity are the behavioural responsiveness of societies are more plausible explanations for the variability in deaths at the current time. Finally, the study tends to focus on high- and middle-income nations given the larger epidemic size and data availability in these settings at this time, making it difficult to generalize findings to low-income settings.

Conclusions

Taken together, these results indicate that an assessment of underlying cultural and demographic characteristics along with health system constraints should contribute to better-suited and more effective public health and emergency preparedness measures. Specifically, our findings highlight that a society's cultural and behavioural attributes are also important factors that can independently impact outcomes during a public health crisis. This suggests that policies devised during such a crisis should consider the cultural context of societies and should bear in mind these differences when evaluating the transferability and implementation of divergent and seemingly successful policy approaches from one context to another.

Methods

Country selection and data sources

We explored the variation in COVID–19-attributable deaths in a subset of 49 countries with adequate health information and system capacity and/or prominent SARS-CoV–2 epidemics during the first wave of the pandemic (i.e., April-June 2020).[29] Together these countries account to ~82% of confirmed cases and ~93% of deaths attributed to COVID–19 during this time period. We collected data on the extent of SARS-CoV–2 testing, the number of confirmed cases, the number of COVID–19-attributed deaths, the time of first confirmed case and first death at various time points during the initial phase of the pandemic using publicly available datasets.[30,31] We obtained data on demographics, health system, and economic indicators using country-level data (2018) from the World bank,[32] World Health Organization,[33] and the OECD databases.[34] Finally we collected data on cultural characteristics of countries using the Hofstede (2010) model, a well-accepted and frequently used method for evaluating behavioural variation between countries.[11,18,35] The model is comprised of six cultural dimensions, (preference for individualism vs. collectivism, the degree of discomfort with uncertainty, preference for long-term vs. short-term normative orientation, preference for indulgence vs. restraint, and masculinity vs. femininity), which conceptualizes and measures independent preferences for these cultural constructs to describe the cultural characteristics of each country.[18,35] Political characteristic was collected using the polity data series, a widely used dataset that indicated the level of democracy, anocracy and autocracy.[36] Specifically, we use the Combined Polity Score for 2018, the most recent year for which data on the political characteristics (i.e., regime type) of countries were available.

Outcomes

We estimated crude case fatality rates (CFR) defined as the probability of death among all confirmed cases and mortality risk defined as the number of COVID–19-attributed deaths per 1,000 population. These metrics measure related but different attributes of COVID–19 deaths. Mortality risk is affected by the underlying size of the population, and size of the local epidemic. High mortality therefore could arise from a wider spread of the infection among the general population and/or a more vulnerable demographic composition. The CFR measures the lethality of the disease among infected patients and may indicate an inability to prevent infections among vulnerable risk groups within a society (e.g., long-term care homes).

Meta-analysis

We used random-effects meta-analysis to pool crude case fatality and mortality rate estimates reported by countries at specific time points during the initial phase of the pandemic (April-June). All statistical analyses were performed using R version 3.6.3 with RStudio (R Core Team, 2020). A random-effect model was chosen to account for high degree of variability across estimates derived from heterogenous settings, populations, and contexts. Meta-analyses were performed with “metafor” package using logit transformation to stabilise the variance of proportions. [37,38] Confidence and Prediction intervals were generated for all pooled estimate to reflect the uncertainty and the distribution of expected range of true estimates in similar set of observations.[39]

Meta-regression analysis

Random-effects meta-regression model was used to explore heterogeneity across observed estimates, using two model specification approaches: a theory-driven *a priori* variable selection approach and an exploratory statistical model specification using bootstrap variable selection approach.[9] The *a priori* model was developed to adjust for predetermined and theory-driven predictors of COVID–19 attributable case fatality and mortality such as underlying demographics (i.e., age distribution), indicators of health system capacity (i.e., numbers of doctors, nurses and hospital beds per 1,000 population, the extent of SARS-CoV–2 testing coverage), economic indicators (i.e., gross domestic product (GDP) per capita in 2018), a political indicator (i.e., the Polity score) and pertinent cultural dimensions as defined by Hofstede et al., while also controlling for the timing of the outbreak (i.e., days since first death on record).[40] To avoid model overfit we focused on only the two cultural/behavioural dimensions that most frequently explain variation in crisis management and/or public health practice (e.g., individualism and uncertainty avoidance).[11,41–43] Then, a bootstrap variable selection method was used to select potentially important variables from a full regression model including a larger set of demographic and sociocultural predictors as described in *Table 1.* Prior to the regression analysis, missing data on predictors were imputed using multiple imputation methods. Pseudo R-squared values were used to quantify the proportion of observed variability explained by covariates included in the models. Akaike and Bayesian information criterion were estimated to compare across models.

Sensitivity analysis

In a sensitivity analysis outlier were removed the evaluate the robustness of findings and how these can impact model specification. In the sensitivity analyses, models were refitted after omitting China, Belgium, USA, Iceland and Singapore.

Declarations

Author Contributions: A. Erman collected and analysed the data and drafted the manuscript. M. Medeiros contributed to the analysis and interpretation of the results and the drafting of the manuscript. All authors contributed in the revision of the manuscript and gave final approval for the version to be published.

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Data availability: All the data were collected from publicly available sources and will be made available by the corresponding author on request.

References

1. Onder, , Rezza, G. & Brusaferro, S. Case-Fatality Rate and Characteristics of Patients Dying in Relation to COVID-19 in Italy. *JAMA* **25**, (2020).
2. Armocida, B., Formenti, B., Ussai, S., Palestra, F. & Missoni, E. The Italian health system and the COVID-19 challenge. *Public Heal.* **5**, e253 (2020).
3. Koo, J. R. *et al.* Interventions to mitigate early spread of SARS-CoV-2 in Singapore: a modelling *Lancet. Infect. Dis.* **20**, 678–688 (2020).
4. Mahase, E. Covid-19: UK starts social distancing after new model points to 260 000 potential deaths. *BMJ* **368**, m1089 (2020).
5. Baldock, J. Culture: The Missing Variable in Understanding Social Policy? *Policy Adm.* **33**, 458–473 (1999).
6. Borg, M. A. Prolonged perioperative surgical prophylaxis within European hospitals: an exercise in uncertainty avoidance? *Antimicrob. Chemother.* **69**, 1142–1144 (2014).
7. Ruhi, U. A Socio-Psychological Perspective on Flattening the COVID-19 Curve: Implications for Public Health Program Delivery in Canada. *Heal. Policy* **April**, (2020).
8. Bavel, J. J. Van *et al.* Using social and behavioural science to support COVID-19 pandemic response. *Hum. Behav.* **4**, 460–471 (2020).
9. Austin, P. C. & Tu, J. V. Bootstrap Methods for Developing Predictive Models. *Stat.* **58**, 131–137 (2004).
10. West, , Michie, S., Rubin, G. J. & Amlôt, R. Applying principles of behaviour change to reduce SARS-CoV-2 transmission. *Nat. Hum. Behav.* **4**, 451–459 (2020).
11. Borg, A. Cultural determinants of infection control behaviour: understanding drivers and implementing effective change. *J. Hosp. Infect.* **86**, 161–168 (2014).
12. Betsch, , Böhm, R., Korn, L. & Holtmann, C. On the benefits of explaining herd immunity in vaccine advocacy. *Nat. Hum. Behav.* **1**, 0056 (2017).
13. Fincher, C. L., Thornhill, R., Murray, D. R. & Schaller, M. Pathogen prevalence predicts human cross-cultural variability in individualism/collectivism. *R. Soc. B Biol. Sci.* **275**, 1279–1285 (2008).
14. Triandis, H. C. *Individualism and Collectivism*. *Individualism and Collectivism* (Routledge, 2018). doi:10.4324/9780429499845

15. Kitayama, S., Park, H., Sevincer, A. T., Karasawa, M. & Uskul, A. K. A cultural task analysis of implicit independence: Comparing North America, Western Europe, and East Asia. *Pers. Soc. Psychol.* **97**, 236– 255 (2009).
16. James Marshall and Michael Peters. *Individualism and Community: Education and Social Policy in the Postmodern Condition*. (Routledge, 2002).
17. Morand, & Walther, B. A. Individualistic values are related to an increase in the outbreaks of infectious diseases and zoonotic diseases. *Sci. Rep.* **8**, 3866 (2018).
18. Hofstede, G. Dimensionalizing Cultures: The Hofstede Model in Context. *Online Readings Psychol. Cult.* **2**, (2011).
19. Meeuwesen, L., van den Brink-Muinen, A. & Hofstede, G. Can dimensions of national culture predict cross- national differences in medical communication? *Patient Educ. Couns.* **75**, 58–66 (2009).
20. Smith, P. B. To Lend Helping Hands: In-Group Favoritism, Uncertainty Avoidance, and the National Frequency of Pro-Social Behaviors. *Cross. Cult. Psychol.* **46**, 759–771 (2015).
21. Stojcic, , Kewen, L. & Xiaopeng, R. Does uncertainty avoidance keep charity away? comparative research between charitable behavior and 79 national cultures. *Cult. Brain* **4**, 1–20 (2016).
22. Hofstede, G., Hofstede, G. J. & Minkov, M. *Cultures and organizations: software of the mind : international cooperation and its importance for survival*. (Mcgraw-Hill, 2010).
23. Hofstede, G. & Minkov, M. Long- versus short-term orientation: new perspectives. *Asia Pacific Bus. Rev.* **16**, 493–504 (2010).
24. Khatri, N. Consequences of Power Distance Orientation in Organisations. *J. Bus. Perspect.* **13**, 1–9 (2009).
25. Basu, A. Estimating The Infection Fatality Rate Among Symptomatic COVID-19 Cases In The United *Health Aff.* **0**, 10.1377/hlthaff (2020).
26. Verity, R. *et al.* Estimates of the severity of coronavirus disease 2019: a model-based analysis. *Infect. Dis.* (2020). doi:10.1016/S1473-3099(20)30243-7
27. Wu, J. T. *et al.* Estimating clinical severity of COVID-19 from the transmission dynamics in Wuhan, *Nat. Med.* **26**, 506–510 (2020).
28. Ruan, S. Likelihood of survival of coronavirus disease 2019. *Lancet Infect. Dis.* **20**, 630–631 (2020).
29. *Beyond Containment: Health systems responses to Covid-19 in the OECD*. (2020).
30. World Health Organization (WHO). Coronavirus disease 2019 (COVID-19) situation reports. Available at: https://wwwho.int/emergencies/diseases/novel-coronavirus-2019/situation-reports.
31. Dong, E., Du, H. & Gardner, L. An interactive web-based dashboard to track COVID-19 in real time. *Infect. Dis.* **20**, 533–534 (2020).
32. World Bank. The World Bank Data. Available at: https://data.worldbank.org/.
33. World Health Organization (WHO). Global Health Observatory data Available at: https://apps.who.int/gho/data/node.home.

34. The Organisation for Economic Co-operation and Development Data. Available at: https://data.oecd.org/.
35. Hofstede, G. Country Comparison - Hofstede Insights. *Hofstede Insights* (2010).
36. Marshall, M. G. & Gurr, T. R. Polity 5: Political regime characteristics and transitions, 1800–2018. (2020). Available at: https://wwsystemicpeace.org/polityproject.html.
37. Schwarzer, G., Chemaitelly, H., Abu-Raddad, L. J. & Rücker, G. Seriously misleading results using inverse of Freeman-Tukey double arcsine transformation in meta-analysis of single proportions. *Synth. Methods* **10**, 476–483 (2019).
38. Barendregt, J. J., Doi, S. A., Lee, Y. Y., Norman, R. E. & Vos, T. Meta-analysis of prevalence. *Epidemiol. Community Health* **67**, 974–978 (2013).
39. IntHout, J., Ioannidis, J. P. A., Rovers, M. M. & Goeman, J. J. Plea for routinely presenting prediction intervals in meta-analysis. *BMJ Open* **6**, e010247 (2016).
40. Thompson, S. G. & Higgins, J. P. T. How should meta-regression analyses be undertaken and interpreted? *Stat. Med.* **21**, 1559–73 (2002).
41. Masood, , Aggarwal, A. & Reidpath, D. D. Effect of national culture on BMI: a multilevel analysis of 53 countries. *BMC Public Health* **19**, 1212 (2019).
42. Deschepper, R. *et al.* Are cultural dimensions relevant for explaining cross-national differences in antibiotic use in Europe? *BMC Health Serv. Res.* **8**, 123 (2008).
43. Verma, A., Griffin, A., Dacre, J. & Elder, A. Exploring cultural and linguistic influences on clinical communication skills: a qualitative study of International Medical Graduates. *BMC Med. Educ.* **16**, 162 (2016).

Tables

Table 1: Characteristics of countries included in the meta-analysis

Country characteristics	N	Mean (SD)	Min	Max
GDP per capita ($US, 2018)	49	35,410 (25,253)	2,010	116,640
Population density (pop per km^2)	49	286 (1,125)	3.2	7,953
Urban population (%)	49	76 (14)	34	100
Demographics and health				
Life expectancy at birth (years)	49	79 (4.3)	63.0	84.0
Proportion over 65 years (%)	49	16 (5.4)	5.3	28.0
Proportion over 80 years (%)	49	4.1 (1.9)	0.7	8.4
Prevalence of smoking (%)	49	24 (8.3)	9.0	43.0
Prevalence of overweight (% of adults)	49	56 (11.0)	20.0	68.0
Health system capacity				
Hospital beds (n. per 1000 pop)	49	4.6 (3.0)	0.5	13.0
Healthcare workers (n. per 1000 pop)	49	11.0 (5.0)	1.9	22.0
Doctors (n. per 1000 pop)	49	3.0 (1.1)	0.4	5.4
Nurses (n. per 1000 pop)	49	8.4 (4.3)	0.9	18.0
Out-of-pocket health expenditure (%)	49	23.0 (12.0)	7.8	65.0
Pandemic-specific data*				
Number of confirmed cases	49	115,389 (287,446)	1,085	1,897,380
Number of deaths	49	7,570 (17,839)	10	109,132
Testing coverage (n. test per 1 million pop)	49	46,737 (38,221)	1,394	182,444
Time since first case (days)	49	108 (21)	66	187
Time since first death (days)	49	83 (14)	59	146
Cultural dimensions**				
Individualism vs. collectivism	49	53 (23)	13	91
Uncertainty avoidance	49	66 (23)	8	112
Indulgence vs. restraint	49	49 (20)	13	97
Long-term vs. short-term normative orientation	49	52 (22)	13	100
Masculinity vs. femininity	49	48 (23)	5	110
Power distance index	49	54 (23)	11	104

Political dimensions***				
Polity (democracy vs authoritarianism)	49	8.0 (4.2)	-7.0	10.0

Table 1. Characteristics of countries included in the meta-analysis. *Pandemic-specific data is collected at the last follow up date (June 5th). **Cultural dimensions: higher values reflect a stronger attachment for one cultural dimension relative to its complement (e.g., a higher value on individualism vs. collectivism dimension indicates a stronger preference for individualism relative to collectivism). ***Polity is a measure of regime type in each country ranging from democracy to authoritarianism.

Table 2: Pooled estimates of fatalities

Pandemic timeline	Days since 1st case (mean, range)	[A] Crude case fatality risk (%)	[B] Mortality risk (per 1,000 population)
		Mean (95%CI, PI)	Mean (95%CI, PI)
05-April-20	47 (5-126)	2.59 (95%CI: 2.00-3.35, PI: 0.48-12.81)	0.008 (95%CI: 0.004-0.014, PI: 0.0001-0.2944)
15-April-20	56 (14-135)	3.24 (95%CI: 2.48-4.21, PI: 0.54-17.14)	0.017 (95%CI: 0.010- 0.029, PI: 0.0004-0.4252)
30-April-20	72 (30-151)	3.79 (95%CI: 2.90-4.95, PI: 0.56-21.51)	0.031 (95%CI: 0.019-0.053, PI: 0.0007-0.5838)
20-May-20	92 (50-171)	4.00 (95%CI: 3.05-5.22, PI: 0.57-23.80)	0.044 (95%CI: 0.026-0.073, PI: 0.0011-0.6593)
05-June-20	108 (66-187)	3.97 (95%CI: 3.02-5.21, PI: 0.56-23.28)	0.054 (95%CI: 0.032-0.087, PI: 0.0014-0.6985)

Table 2. Random-effects meta-analysis of (A) the crude case fatality risk and (B) mortality risk during initial phase (April 5th to June 5th) of the 2020 COVID-19 pandemic in 49 countries. Outcomes were logit transformation to stabilise the variance of proportions prior to meta-analysis. Abbreviations: CI: confidence interval; PI: prediction interval.

Table 3: Random-effects meta-regression of crude case fatality risk

MODEL 1: a priori model					MODEL 2: bootstrap variable selection model			
	Crude case fatality risk (%)				Crude case fatality risk (%)			
Covariates	β	SE	P-value	OR	β	SE	P-value	OR
Intercept	*-6.8189*	*0.8803*	-	-	*-7.8081*	*1.9591*	-	-
GDP per capita ($1,000 USD, 2018)	-0.0037	0.0083	*0.656*	*1.00*	-	-	-	-
Life expectancy (years)	-	-	-	-	-0.0114	0.0295	*0.700*	*0.99*
Proportion over 65 years (%)	0.0625	0.0292	***0.032***	***1.06***	-	-	-	-
Time since 100 cases (days)	-	-	-	-	0.0308	0.0115	***0.008***	***1.03***
Time since 1st death (days)	0.0244	0.0086	***0.004***	***1.02***	-	-	-	-
Testing coverage (n. tests per 100,000 pop)	-0.0085	0.0038	***0.024***	***0.99***	-0.0081	0.0033	***0.013***	***0.99***
Health system strength								
Healthcare workers (n. per 1,000 pop)	0.0079	0.0388	*0.839*	*1.01*	-	-	-	-
Hospital beds (n. per 1,000 pop)	-0.1603	0.0390	***<.0001***	***0.85***	-0.2185	0.0455	***<.0001***	***0.80***
Cultural characteristics								
Individualism vs. collectivism	0.0171	0.0065	***0.008***	***1.02***	0.0270	0.0053	***<.0001***	***1.03***
Uncertainty avoidance	0.0128	0.0052	***0.015***	***1.01***	0.0229	0.0050	***<.0001***	***1.02***
Indulgence vs. restraint	-	-	-	-	0.0058	0.0067	*0.390*	*1.01*
Long-term vs. short-term orientation	-	-	-	-	0.0191	0.0070	***0.007***	***1.02***
Power distance	-	-	-	-	-	-	-	-
Masculinity vs. femininity	-	-	-	-	-	-	-	-
Political characteristics								

Polity (democracy vs authoritarianism)	0.0040	0.0314	*0.900*	*1.02*	-	-	-	-
		pseudo-R^2: 54.86%				pseudo R^2: 55.52%		
	AIC: 104.77 BIC: 123.07				AIC: 104.22 BIC: 121.11			

Table 3. Random-effects meta-regression analysis of the crude case fatality risk at the last follow-up date (June 5th) for 49 countries. Dependent variables were logit transformation to stabilize the variance of proportions. Missing data was using multiple imputation methods prior to regression analysis. Random-effects meta-regression was used to adjust for important predefines predictors of COVID-19 attributable case fatality and mortality including economic indicators (i.e., gross domestic product (GDP) per capita in 2018), demographics (i.e., age distribution), the extent of SARS-CoV-2 testing coverage, differential timing of the outbreak (i.e., days since first death on record), indicators of health system capacity (i.e., numbers of healthcare workers and hospital beds per 1,000 population) and pertinent cultural dimensions for each nation as defined by Hofstede et al. The odds ratios (OR) represents the odds of a fatal outcome upon exposure to a risk factor relative to no exposure. For example, an OR of 1.06 indicates that a one unit increase the proportion of the population over 65 years, we expect to see an 6% increase in the odds of fatal outcome among infected individuals. Pseudo-R-squared value represent the proportion of heterogeneity explained by predictors included in the model. AIC: Akaike information criterion; BIC: Bayesian information criterion.

Table 4: Random-effects meta-regression of mortality risk

MODEL 1: a priori model					MODEL 2: bootstrap variable selection model			
	Mortality risk (per 1,000 population)				Mortality risk (per 1,000 population)			
Covariates	**β**	**SE**	**P-value**	**OR**	**β**	**SE**	**P-value**	**OR**
Intercept	*-6.6841*	*1.9185*	*-*	*-*	*-15.7650*	*2.7181*	*-*	*-*
GDP per capita ($1,000 USD, 2018)	0.0355	0.0182	***0.050***	***1.04***	0.0447	0.0154	***0.004***	***1.05***
Life expectancy (years)	-	-	-	-	-	-	-	-
Proportion over 65 years (%)	0.1029	0.0638	*0.107*	*1.11*	0.1118	0.0537	***0.037***	***1.12***
Time since 100 cases (days)	-	-	-	-	0.1251	0.0447	***0.005***	***1.13***
Time since 1st death (days)	0.0025	0.0187	*0.895*	*1.00*	-0.0697	0.0321	***0.030***	***0.93***
Testing coverage (n. tests per 100,000 pop)	-0.0023	0.0081	*0.776*	*1.00*	-	-	-	-
Health system strength								
Healthcare workers (n. per 1,000 pop)	-0.0815	0.0847	*0.336*	*0.92*	-0.1401	0.0753	*0.063*	*0.87*
Hospital beds (n. per 1,000 pop)	-0.2611	0.0856	***0.002***	***0.77***	-0.3060	0.0826	***<.0001***	***0.74***
Cultural characteristics								
Individualism vs. collectivism	0.0322	0.0142	***0.023***	***1.03***	0.0461	0.0133	***0.001***	***1.05***
Uncertainty avoidance	0.0303	0.0115	***0.009***	***1.03***	0.0392	0.0111	***<.0001***	***1.04***
Indulgence vs. restraint	-	-	-	-	0.0197	0.0124	*0.112*	*1.02*
Long-term vs. short-term orientation	-	-	-	-	-	-	-	-
Power distance	-	-	-	-	0.0283	0.0126	***0.0252***	***1.03***
Masculinity vs. femininity	-	-	-	-	-	-	-	-
Political								

characteristics								
Polity (democracy vs authoritarianism)	-0.0960	0.0689	*0.163*	*1.03*	-	-	-	-
		pseudo R^2: 36.37%				pseudo R^2: 49.90%		
	AIC: 165.20 BIC: 183.49				AIC: 154.48 BIC: 174.14			

Table 4. Random-effects meta-regression analysis of the mortality risk at the last follow-up date (June 5th) for 49 countries. Dependent variables were logit transformation to stabilize the variance of proportions. Missing data was using multiple imputation methods prior to regression analysis. Random-effects meta-regression was used to adjust for important predefines predictors of COVID-19 attributable case fatality and mortality including economic indicators (i.e., gross domestic product (GDP) per capita in 2018), demographics (i.e., age distribution), the extent of SARS-CoV-2 testing coverage, differential timing of the outbreak (i.e., days since first death on record), indicators of health system capacity (i.e., numbers of healthcare workers and hospital beds per 1,000 population) and pertinent cultural dimensions for each nation as defined by Hofstede et al. The odds ratios (OR) represents the odds of a fatal outcome upon exposure to a risk factor relative to no exposure. For example, an OR of 0.77 indicates that a one unit increase the number of hospital beds per 1,000 people, we expect to see an 23% decrease in the odds of mortality risk. Pseudo-R-squared value represent the proportion of heterogeneity explained by predictors included in the model. AIC: Akaike information criterion; BIC: Bayesian information criterion.

Figures

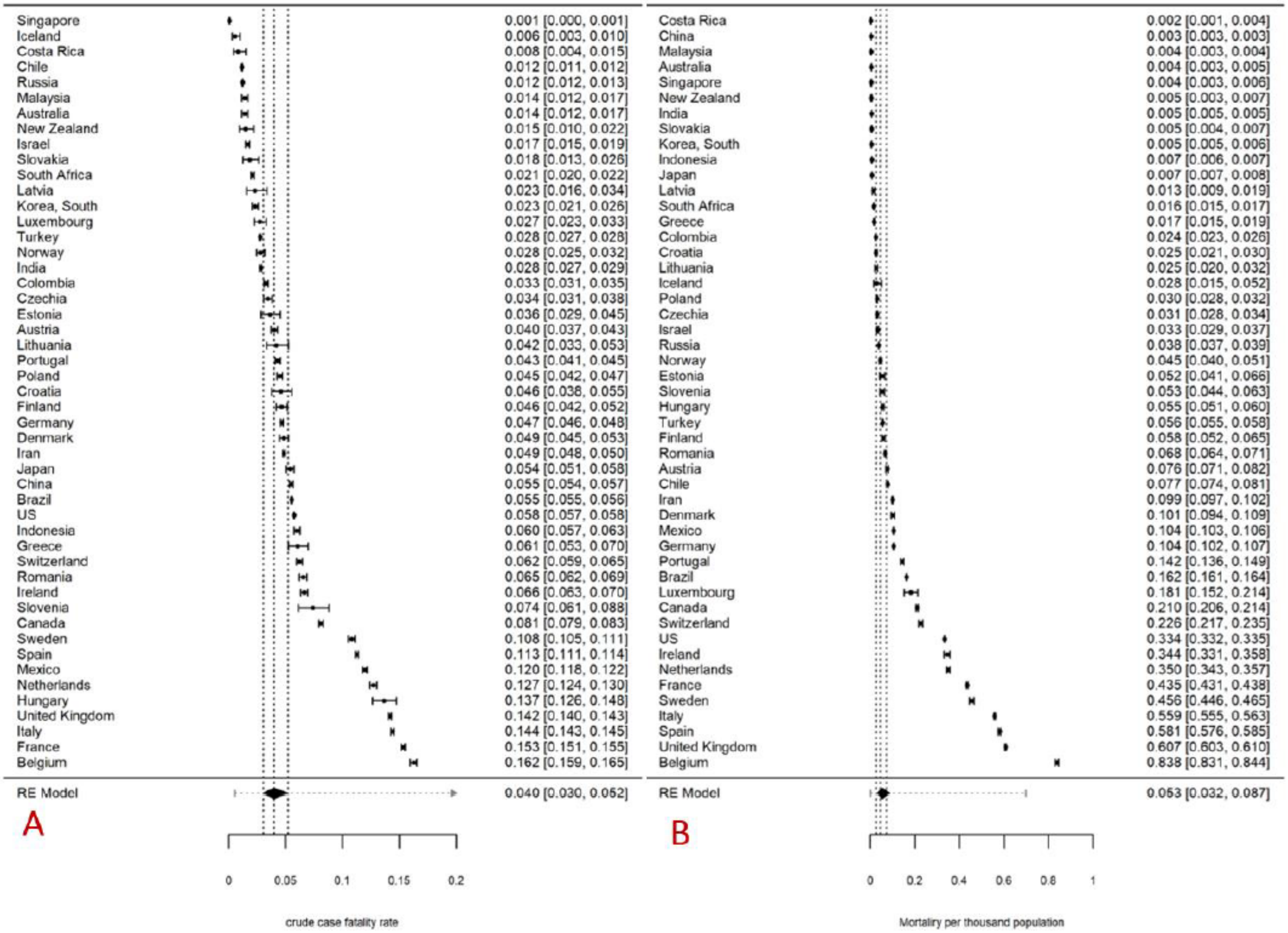

Figure 1

Forrest plot showing pooled mortality outcomes. Figure showing forest plot of pooled (a) crude case fatality risk, and (b) mortality per 1,000 population attributable to COVID-19. A random-effects meta-analysis was used to pool estimates across countries using data from the final follow-up point (June 05, 2020).

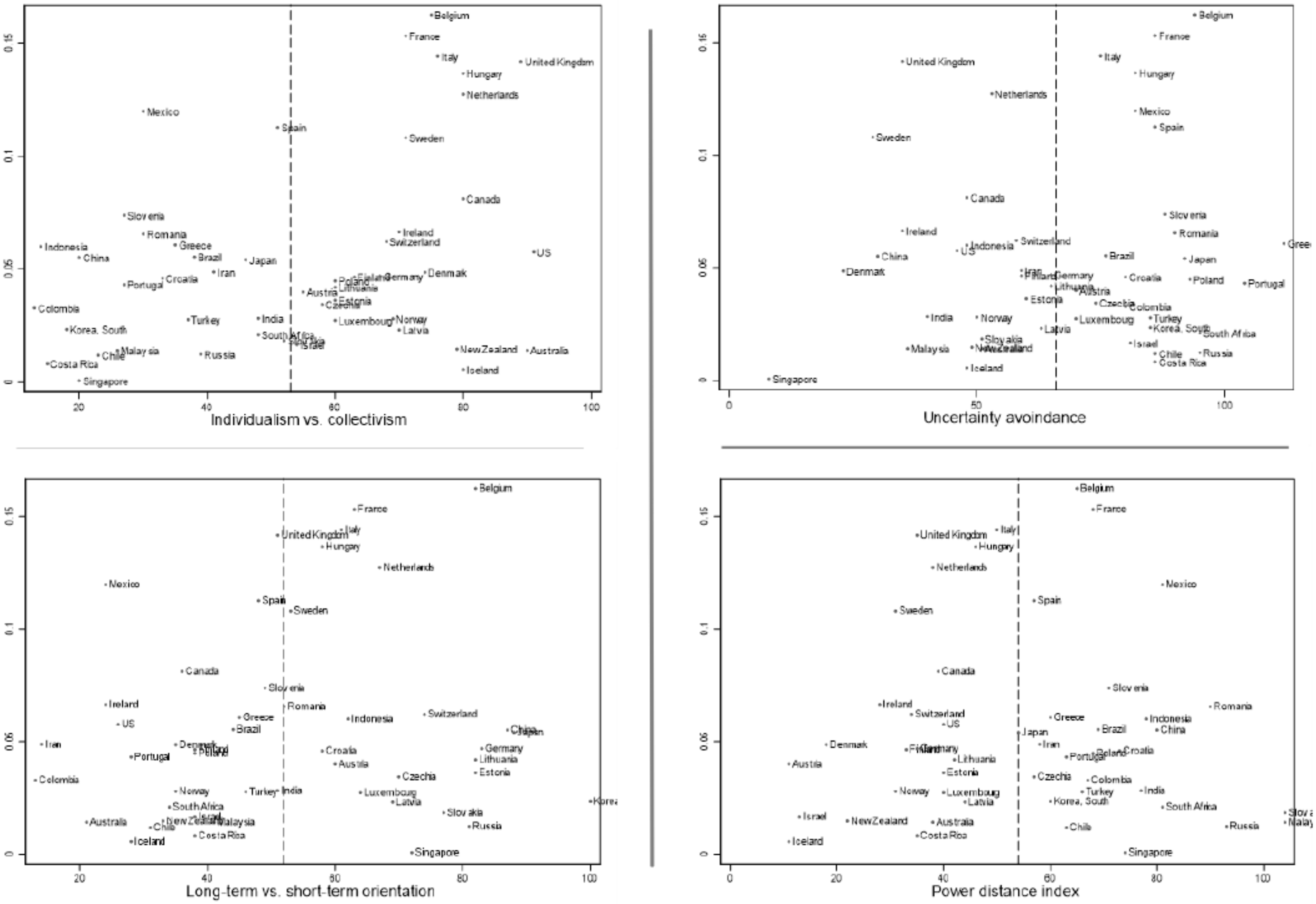

Figure 2

catterplot of relevant cultural dimensions with case fatality risk. Scatterplot of potentially relevant cultural dimensions as identified by exploratory-regression analyses (i.e. individualism, uncertainty avoidance, long-term-orientation vs. short-term and power distance index) versus crude case fatality risk (%) of COVID-19 for 49 countries included in the analysis using data from the final follow-up point. With respect to cultural dimensions, higher values indicate a higher degree of individualism (vs. collectivism), a higher level of uncertainty avoidance (vs. comfort with uncertainty) a higher degree of power distance (hierarchy) within society, and a higher preference for long-term orientation (vs. short term). Dashed line indicates the mean value for each cultural dimension across countries included in the analysis.

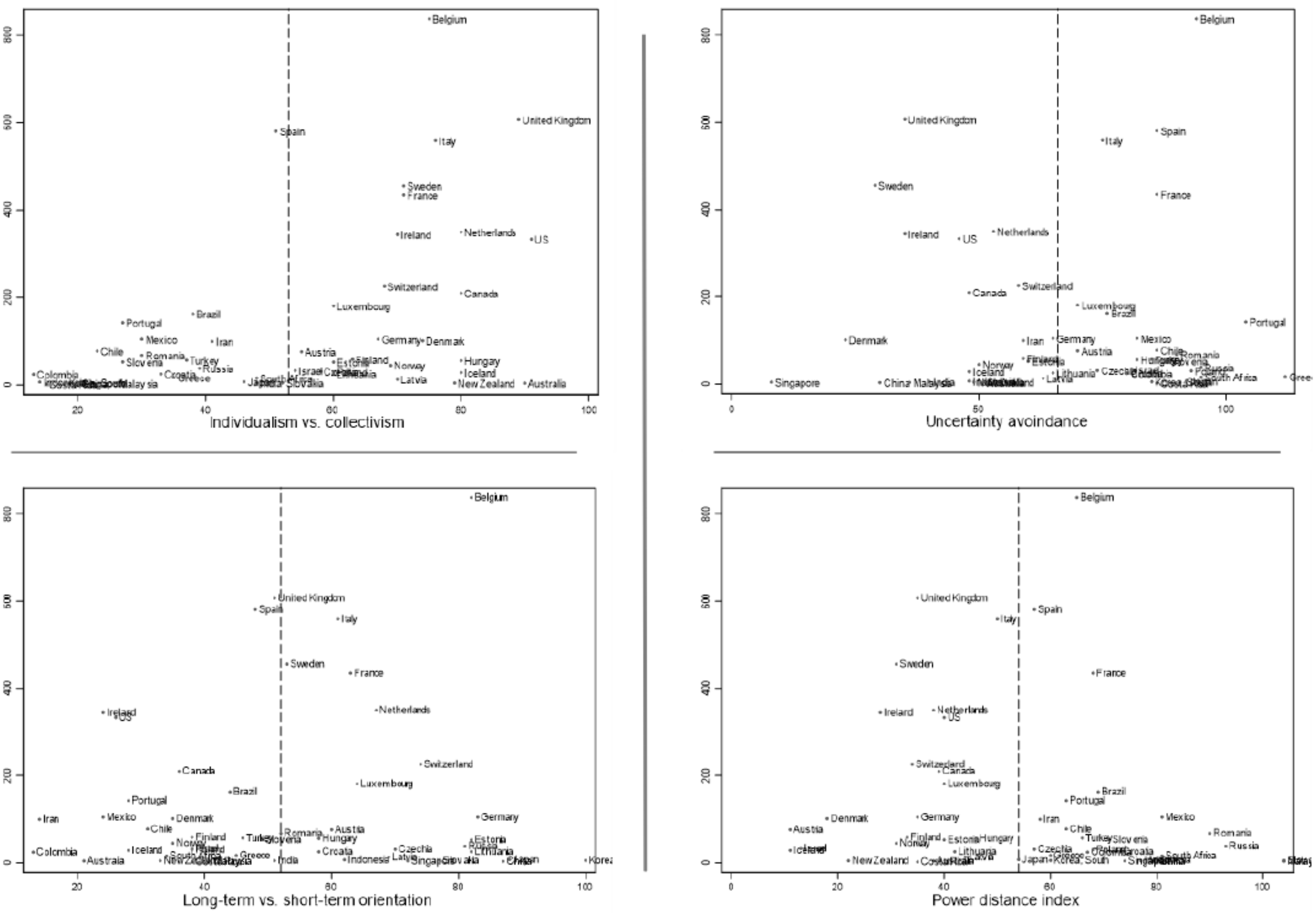

Figure 3

Scatterplot of relevant cultural dimensions with mortality risk. Scatterplot of potentially relevant cultural dimensions as identified by exploratory-regression analyses (i.e. individualism, uncertainty avoidance, long-term-orientation vs. short-term and power distance index) versus mortality per 1,000,000 population attributable to COVID-19 for 49 countries included in the analysis using data from the final follow-up point. With respect to cultural dimensions, higher values indicate a higher degree of individualism (vs. collectivism), a higher level of uncertainty avoidance (vs. comfort with uncertainty), a higher degree of power distance (hierarchy) within society, and a higher preference for long-term orientation (vs. short term). Dashed line indicates the mean value for each cultural dimension across countries included in the analysis.

Supplementary Files

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

- SupplementaryMaterial.docx