The Association of Country-Level Factors with Outcomes of COVID-19: Analysis of the pandemic after one million cases

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Abstract

Background: Coronavirus infectious disease 2019 (COVID-19) is an ongoing global pandemic. Without a vaccine or an effective treatment in the near horizon, only public health measures have been effective in potentially reducing its impact. Due to the wide disparity in current response from individual countries, studying factors associated with public health measures may inform ongoing efforts. Therefore, this study aims to analyze the contributing factors across the globe with specific measures of the disease.

Methods: This is a cross-sectional study that used publicly available data of COVID-19 cases as of April 6, 2020. We analyzed country public information on demographic and socioeconomic indicators published in different sources. The association between country-level variables and the incidence rate, the recovery rate, severity of the cases, and mortality rate were evaluated using regression techniques.

Results: Multiple factors were found to be significantly associated with COVID-19 outcomes. The number of tests per million, GDP per capita, a country population size of 2020, country median age, and life expectancy are associated with the incidence rate of COVID19. The yearly net change population, migrants, and tourism are associated with the recovery rate of COVID-19. The number of tests per million and male life expectancy are associated with the critical cases rate of COVID-19. Finally, the GDP per capita, land area (Km2), life expectancy, and tourism are associated with the mortality rate of COVID-19.

Conclusion: Overall, higher GDP per capita, median age, and a higher number of lab tests were found to be associated with more incidents of COVID-19 cases, which indicates a better and maintained system for detection, reporting, and management of the pandemic. This study suggests that investing in better screening and testing may reveal more cases that can be managed and controlled; while limiting travelers would further support the pandemic control.

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Background

Infectious diseases are among the leading threats to global health. Currently, the coronavirus infectious disease 2019 (COVID-19) outbreak is a global pandemic [1]. According to the World Health Organization (WHO), the first recognized case was reported in Wuhan, China, on December 31, 2019 [2]. By April 6, 2020, there have been more than 200 affected countries and territories, and more than one million confirmed cases and more than 70,000 deaths [3]. The economic burden caused by COVID-19 is staggering on China and the globe. It is estimated that China has lost up to $62 billion in the first quarter of 2020, while the world is expected to lose over $280 billion [4]. Unfortunately, these numbers are increasing with raising concerns from the international community about the disparity in the incidence rate, recovery rate, severity of the disease, and mortality rate of the COVID-19 pandemic.

Even though the current SARS-CoV-2 virus is not as lethal as MERS-CoV, its devastating impact on global health and economy is incomparable [5]. Major world events have been canceled, and more will be if no significant progress is made in finding a vaccine or an effective treatment [6, 7]. One of the reasons for its major global impact is the rapid spread across the globe [8]. Moreover, there is a wide disparity in incidence and mortality rates across affected countries. While China was able to relatively control the spread, health systems in countries like Spain and Italy are on the verge of collapse due to failure to control this pandemic [9]. Even the United States, with its major and advanced healthcare and public health system, is struggling with states like New York deploying new graduates of medical school to keep up with the influx of patients [10].

Currently, public health interventions are the only means to face the disease [11]. Various factors may contribute to the efficiency of public health control measures used to deal with COVID-19 [12, 13]. These may include factors that pertain to individual countries such as demographics of socioeconomic characteristics. For example, Germany has a low mortality rate compared to that of Italy and Spain, which raises questions of differences between these countries in COVID-19 outcomes

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[14]. To inform efforts organized to reduce the impact of this pandemic, learning about these factors can guide the international community to invest further to improve current and future pandemic preparedness and response. Therefore, this study aims to analyze country-level factors that may contribute to the outcomes of COVID-19.

Methods

This is a cross-sectional study in which we utilized publicly available data of COVID-19 cases for each country and territory. We combined these data with countries' publicly available information about demographics and socioeconomic indicators published in different sources. Overall, we included 211 countries and territories. We excluded countries with less than 100 cases reported by April 6, 2020. Statistical models were built to identify factors associated with each outcome variable, including the incidence rate, recovery rate, rate of critical cases, and mortality rate.

Study variables

Outcome variables:

The incidence rate of COVID-19 was obtained using country reported cases and country population size from the Worldometer website [3]. The Worldometer specifies the source of each country data, which are based on official media venues, and has been used in previous publications [15]. The incidence rate per 1000 was calculated using the equation: (total cases/ population size) *1000.

The COVID-19 mortality rate was calculated using the country reported deaths of COVID-19 and divided by the population size [3]. Thus, mortality rate per 1000= (total deaths / population size) * 1000. The rate of critical cases rate was calculated using country reported critical cases divided by the total confirmed cases [3]. The recovery rate was calculated using reported cases that recovered divided by the population size [3].

Explanatory variables:

The demographic and socioeconomic indicators analyzed in this study include population size, urban population rate, median age, fertility rate, population density, land area, life expectancy, gross domestic product (GDP), tourism indicator, and the 2019 Global Health Security Index (GHS). The GHS index is a comprehensive assessment of the global health security capabilities of 195 countries,

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where a score of 100 points is the highest [16]. The index is focused on the capabilities of countries to predict, prepare for, prevent, and respond to infectious disease outbreaks as well as the health system, commitment to improving, and vulnerability to biological risk.

The explanatory variables were collected from various sources and included population size (2020), yearly population change (%), net population change, population density (P/Km²), land area (Km²), migrants (net), fertility rate, median age, life expectancy for each gender and overall, the urban population in percentage, and world share in the population. These variables were based on the latest United Nations Population Division estimates [17]. The country-level factors, including the published number of COVID-19 tests per million for each country, the 2017 gross domestic product (GDP), GDP growth, GDP per capita, and share of World GDP, were based on the World Bank and the United Nations data [18]. Moreover, we included the 2018 international tourism indicator for each country. The 2018 international tourism indicator is based on the total number of travelers who travel into a country other than their country of residence obtained from the World Bank data [19].

Statistical Analysis

All analyses were conducted using SAS 9.4 (SAS Institute Inc., Cary, NC, USA). The analyses performed include the incidence rate, recovery rate, rate of critical cases, and mortality rate. For the incidence rate and mortality rate, we applied the log-transformation to approximate the normal distribution. For the rate of critical cases and recovery rate, we applied the logit transformation to obtain the appropriate distributions of the linear regression.

For all explanatory variables in the model, we standardized variables with mean=0 and standard deviation=1. This was done to address the multicollinearity in the models. Next, we constructed a stepwise linear regression model for each outcome variable to build the final model and estimate the coefficient of each explanatory variable. In all models, we excluded countries with less than 100 cases of COVID-19 to omit outliers. Thus, the sample sizes for incidence rate, recovery rate, rate of critical cases, and mortality rate are 93, 96, 90, and 94 counties, respectively. The level of significance was declared at alpha (α) = 0.05. Because the study used publicly available information a country level without individual identifiers, it was exempt from IRB review.

Results

Incidence rate

The analysis included one million cases of COVID-19. Results of the stepwise multiple linear regression indicated that there was a significant collective association between the number of tests per million, GDP per capita, country population size of 2020, country median age, life expectancy, and incidence rate of COVID19, $F_{(5,87)}=41.14$, $p=<.0001$, $R^2= 0.7028$). The individual predictors were examined further and indicated that the number of tests per million ($t=2.48$, $p=0.0149$), GDP per Capita ($t=2.69$, $p=0.0085$), country population size of 2020 ($t=-2.24$, $p=0.0279$), country median age ($t=2.66$, $p=0.0092$), and life expectancy ($t=3.01$, $p=0.0035$) were significant predictors of COVID-19 incidence rate in the model. The results suggested that the population size of 2020 was associated negatively with incidence rate, while the number of tests per million, GDP per Capita, country median age, and life expectancy had positive associations with incidence.

Further, we applied a simple linear regression of the log incidence rate with a standard score of GDP per capita for countries with more than 1000 cases (Figure 1). Similarly, we applied simple linear regression models of the log incidence rate with the standard score of county median age and life expectancy. Figure 2 and figure 3 depict these relationships, respectively.

Recovery rate

Results of the stepwise multiple linear regression indicated that there was a significant collective association between the yearly net change population, migrants, tourism (the number of travelers), and the recovery rate of COVID-19 ($F_{(3,92)}=6.39$ $p=0.0006$, $R^2= 0.1724$)). The individual predictors were examined further and indicated that the yearly net change of population ($t=3.14$, $p=0.0023$), migrants (net) ($t=-2.06$, $p=0.0422$), and the number of travelers ($t=3.47$, $p=0.0008$) were significant predictors of COVID-19 recovery rate in the model. Thus, we found that the migrants (net) is associated negatively with the recovery rate of COVID-19, while the yearly net change of population and tourism have positive associations.

Rate of critical cases

Results of the stepwise multiple linear regression indicated that there was a significant collective

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association between the number of tests per million, male life expectancy, and critical cases rate of COVID-19 ($F_{(2,87)}=9.43$, p=0.0002, R^2= 0.1782)). The individual predictors were examined further and indicated that the number of tests per million (t=-3.66, p=0.0004), male life expectancy, and (t=3.65, p=0.0005) were significant predictors of COVID-19 critical cases rate in the model. The results suggest that the number of tests per million is associated negatively with critical cases rate, while male life expectancy has positive associations. A simple linear regression was applied for the logit transformation of critical cases rate and the standardized sore of the number of tests per 1 million, which shows the negative correlation (Figure 4).

Mortality rate

Results of the stepwise multiple linear regression indicated that there was a significant collective association between the GDP per capita, land area (Km^2), life expectancy, tourism by the number of travelers and mortality rate of COVID-19 ($F_{(4,89)}=13.41$, p=<.0001, R^2= 0.3761)). The individual predictors were examined further and indicated that the GDP per capita (t=1.87, p=0.0648), land area (Km^2) (t=-2.07, p=0.0417), life expectancy (t=2.46, p=0.0157), and tourism by the number of travelers (t=2.96, p=0.0039), were significant predictors of COVID-19 mortality in the model. The results suggest that the land area (Km^2) is associated negatively with mortality, while the GDP per Capita, life expectancy, and tourism have positive associations. As shown in figure 5 and figure 6, we applied a simple linear regression of the logit of mortality rate with the standard score of life expectancy and the total number of travelers to show the positive relationship.

Discussion

Our study found GDP per capita, number of incoming travelers, life expectancy, median age, and number of laboratory COVID-19 tests to have a direct impact on COVID-19 outcomes on a country level. Surprisingly, the GHS index score was not associated with any of the measured COVID-19 pandemic outcomes. The GHS index was developed and used to rank countries based on their abilities for pandemic preparedness and response; however, our results demonstrate that the GHS index score failed to predict a country's ability for better response to outbreaks COVID-19 in particular. This

failure might be due to the unprecedented magnitude of the current pandemic, the exceptional measures taken by some countries such as China (including city lockdown and business closure), the variety of responses to the pandemic by different affected countries, or at least the inaccurate measures that the GHS was built on. Noteworthy to mention that GHS was built on six categories: prevention, detection and reporting, rapid response, health system, compliance with international norms, and risk environment [14]. Therefore, responses to the COVID-19 pandemic should be used as a framework to optimize the tools used by the GHS index scoring system.

The number of incoming travelers to a given country was associated with the COVID-19 mortality rate and recovery rate. These findings may support the travel ban that has been imposed by many countries as a public health measure for mitigating the risk of COVID-19 pandemic. This is consistent with previous literature suggesting that closing borders is associated with a reduction of pandemic spread [20–23]. However, closing borders or restricting travel was not advised by the World Health Organization in several news reports during the COVID-19 pandemic [24, 25]. This recommendation came despite the confirmation of COVID-19 human-to-human transmission that has been reported in several countries [24]. Therefore, countries that rely on tourism or expect to receive a large number of travelers would need to invest in public health services to protect and prepare for infectious diseases that may cross their borders and affect their population, healthcare systems, and tourism industry.

The number of laboratory tests of COVID-19 cases was associated with a higher incidence rate and negatively with the critical case rate. It has been suggested that, due to limited resources, low and middle-income countries have performed a smaller number of tests and reported fewer cases compared to high-income countries [26, 27]. As a result, this might explain the under-reported number of cases in these countries. Early detection of cases could lead to early isolation and management of cases and could prevent the pandemic spread into vulnerable populations. This also indicates an underreported number of cases in countries with a low number of tests where testing is only performed on cases presented into healthcare facilities.

The recovery rate was found to be inversely associated with migration. Despite findings in previous

studies that suggested migrants have better physical health and outcomes [28, 29].

Other factors could also impact positively on the spread of COVID-19, such as the median age that was associated with a higher incidence rate. Life expectancy was associated with mortality rate, which might explain the observation of Germany's lower mortality rate as compared to that of Italy or Spain [30]; and male life expectancy, in particular, was associated with higher critical cases rate.

The current measures to curb the spread of COVID-19 are mainly public health countermeasures as the medical (vaccine or therapeutic) interventions would take months to years to be available for use. The impact of intense gathering versus social distancing on COVID-19 spread was not analyzed here, but it has to be considered in assessing the effects of public health measures. The country score in implementing the WHO International Health Regulations ((IHR) 2005), which is signed by 195 countries to prepare for pandemics, should also be analyzed in future studies to gauge the status of pandemic preparedness, especially as tested by COVID-19 pandemic. Pandemic preparedness is included in the G20 Summit agenda since the 2018 Summit; therefore, G20 countries and WHO are encouraged to revisit the IHR (2005) in order to assess the real utility of these regulations.

This study is the first to examine a wide variety of country-level factors. Nonetheless, it has some limitations as it was based on publicly accessible information and data that cannot be verified. Some potential confounders were not taken into account; for example, biological factors that may contribute to the spread of COVID-19. These factors include possible genetic variations in some of the SARS-CoV-2 isolates or the expression level of ACE2 (the cellular receptor for the virus) in certain populations based on the rate of chronic diseases, smoking, diet, or other population-based health conditions [31].

Conclusion

GOVID-19 pandemic has revealed challenges to the public health systems in which we found that countries' demographic and socioeconomic indicators associated with the COVID-19 outcomes. Countries should invest and maintain the public health system for detection, reporting, and responding to a pandemic. Some of the public health response plans should depend on a country demographic that includes a better screening and testing system that may detect more infectious

disease outbreaks that allow for early management and control.

Abbreviations

COVID-19 Coronavirus infectious disease 2019
WHO World Health Organization (WHO)
SARS-CoV-2 Severe acute respiratory syndrome coronavirus 2
MERS-CoV Middle East respiratory syndrome coronavirus
GDP Gross domestic product
GHS Global Health Security
IHR International Health Regulations
G20 Group of Twenty
ACE2 Angiotensin-converting enzyme 2

Declarations

Ethics approval and consent to participate:

Because the study used publicly available information at a country level without individual identifiers,

it was exempt from IRB review.

Availability of data and material:

The the study used publicly available with provided soures for each variable.

Funding source:

No funding was needed or granted.

Conflict of interest:

The authors declare no conflict of interest.

Authors' contributions:

O.A., N.A. and S.A. conceived of the presented idea. O.A. wrote the manuscript with support from N.A.

and S.A., O.A. and S.A. research methodology and data analysis.

All authors provided critical feedback and helped shape the research, analysis and the final

manuscript.

References

1. Zhou G, Chen S, Chen Z. Back to the spring of Wuhan: facts and hope of COVID-19

    outbreak. Front Med. 2020.

2. Coronavirus. 2020. https://www.who.int/emergencies/diseases/novel-coronavirus-

    2019.

3. Coronavirus Update (Live): 1,286,294 Cases and 70,446 Deaths from COVID-19 Virus Outbreak - Worldometer. 2020. https://www.worldometers.info/coronavirus/.

4. Ayittey FK, Ayittey MK, Chiwero NB, Kamasah JS, Dzuvor C. Economic impacts of Wuhan 2019-nCoV on China and the world. Journal of Medical Virology. 2020;92:473–5. doi:10.1002/jmv.25706.

5. COVID-19 in the Shadows of MERS-CoV in the Kingdom of Saudi Arabia. J Epidemiol Glob Health. 2020;10:1–3.

6. Gautret P, Al-Tawfiq JA, Hoang VT. COVID 19: Will the 2020 Hajj pilgrimage and Tokyo Olympic Games be cancelled? Travel Med Infect Dis. 2020;:101622.

7. Gallego V, Nishiura H, Sah R, Rodriguez-Morales AJ. The COVID-19 outbreak and implications for the Tokyo 2020 Summer Olympic Games. Travel Medicine and Infectious Disease. 2020.

8. Tuite AR, Bogoch II, Sherbo R, Watts A, Fisman D, Khan K. Estimation of Coronavirus Disease 2019 (COVID-19) Burden and Potential for International Dissemination of Infection From Iran. Ann Intern Med. 2020. doi:10.7326/M20-0696.

9. Remuzzi A, Remuzzi G. COVID-19 and Italy: what next? Lancet. 2020.

10. YOUNG S, EISENBERG A. New York's health care workforce braces for influx of retirees, inexperienced staffers. Politico PRO. 2020. https://politi.co/3dxHzha. Accessed 15 Apr 2020.

11. Hartley DM, Perencevich EN. Public Health Interventions for COVID-19. JAMA. 2020. doi:10.1001/jama.2020.5910.

12. Chinazzi M, Davis JT, Ajelli M, Gioannini C, Litvinova M, Merler S, et al. The effect of travel restrictions on the spread of the 2019 novel coronavirus (COVID-19) outbreak. Science. 2020. doi:10.1126/science.aba9757.

13. Wells CR, Sah P, Moghadas SM, Pandey A, Shoukat A, Wang Y, et al. Impact of

international travel and border control measures on the global spread of the novel 2019 coronavirus outbreak. Proc Natl Acad Sci. 2020;:202002616.

14. Could Germany become Europe's first country to flatten the curve? 2020. https://www.independent.co.uk/news/world/europe/coronavirus-germany-cases-death-toll-italy-spain-bavaria-lockdown-a9424591.html. Accessed 27 Mar 2020.

15. Meo SA, Al-Khlaiwi T, Usmani AM, Meo AS, Klonoff DC, Hoang TD. Biological and Epidemiological Trends in the Prevalence and Mortality due to Outbreaks of Novel Coronavirus COVID-19. J King Saud Univ Sci. 2020. doi:10.1016/j.jksus.2020.04.004.

16. The Global Health Security Index. GHS Index. 2020. https://www.ghsindex.org/.

17. Population by Country (2020) - Worldometer. 2020. https://www.worldometers.info/world-population/population-by-country/.

18. GDP by Country - Worldometer. 2020. https://www.worldometers.info/gdp/gdp-by-country/.

19. International tourism, number of arrivals | Data. 2020. https://data.worldbank.org/indicator/ST.INT.ARVL.

20. Hilyard KM, Freimuth Prof. VS, Donald director M, Supriya K, Sandra CQ. The vagaries of public support for government actions in case of a pandemic. Health Aff. 2010;29:2294–301. doi:10.1377/hlthaff.2010.0474.

21. Paek HJ, Hilyard K, Freimuth VS, Barge JK, Mindlin M. Public support for government actions during a flu pandemic: lessons learned from a statewide survey. Health promotion practice. 2008;9 4 Suppl. doi:10.1177/1524839908322114.

22. Kraemer MUG, Yang C-H, Gutierrez B, Wu C-H, Klein B, Pigott DM, et al. The effect of human mobility and control measures on the COVID-19 epidemic in China. Science (80-). 2020;:eabb4218.

23. Tsai FJ, Tipayamongkholgul M. Are countries' self-reported assessments of their

capacity for infectious disease control reliable? Associations among countries' self-reported international health regulation 2005 capacity assessments and infectious disease control outcomes. BMC Public Health. 2020;20:282. doi:10.1186/s12889-020-8359-8.

24.   World Health Organization (WHO). Updated WHO recommendations for international traffic in relation to COVID-19 outbreak (24-Jan). COVID-19 Travel Advice. 2020. https://www.who.int/news-room/articles-detail/updated-who-advice-for-international-traffic-in-relation-to-the-outbreak-of-the-novel-coronavirus-2019-ncov-24-jan. Accessed 8 Apr 2020.

25.   World Health Organization (WHO). Updated WHO recommendations for international traffic in relation to COVID-19 outbreak (29 Feb). COVID-19 Travel Advice. 2020. https://www.who.int/news-room/articles-detail/updated-who-recommendations-for-international-traffic-in-relation-to-covid-19-outbreak. Accessed 8 Apr 2020.

26.   Maxmen A. How poorer countries are scrambling to prevent a coronavirus disaster. Nature. 2020. doi:10.1038/d41586-020-00983-9.

27.   Jenny Lei Ravelo. A look at COVID-19 testing and why country-wide is impossible right now. 2020. https://www.devex.com/news/a-look-at-covid-19-testing-and-why-country-wide-is-impossible-right-now-96842. Accessed 8 Apr 2020.

28.   Wingate MS, Alexander GR. The healthy migrant theory: variations in pregnancy outcomes among US-born migrants. Soc Sci Med. 2006;62:491–8. http://files/414/S0277953605002972.html.

29.   Chen J. Internal migration and health: re-examining the healthy migrant phenomenon in China. Soc Sci Med. 2011;72:1294–301. http://files/416/S0277953611001031.html.

30.   Coronavirus Age, Sex, Demographics (COVID-19) - Worldometer. 2020. https://www.worldometers.info/coronavirus/coronavirus-age-sex-demographics/.

31.   Cao Y, Li L, Feng Z, Wan S, Huang P, Sun X, et al. Comparative genetic analysis of

the novel coronavirus (2019-nCoV/SARS-CoV-2) receptor ACE2 in different
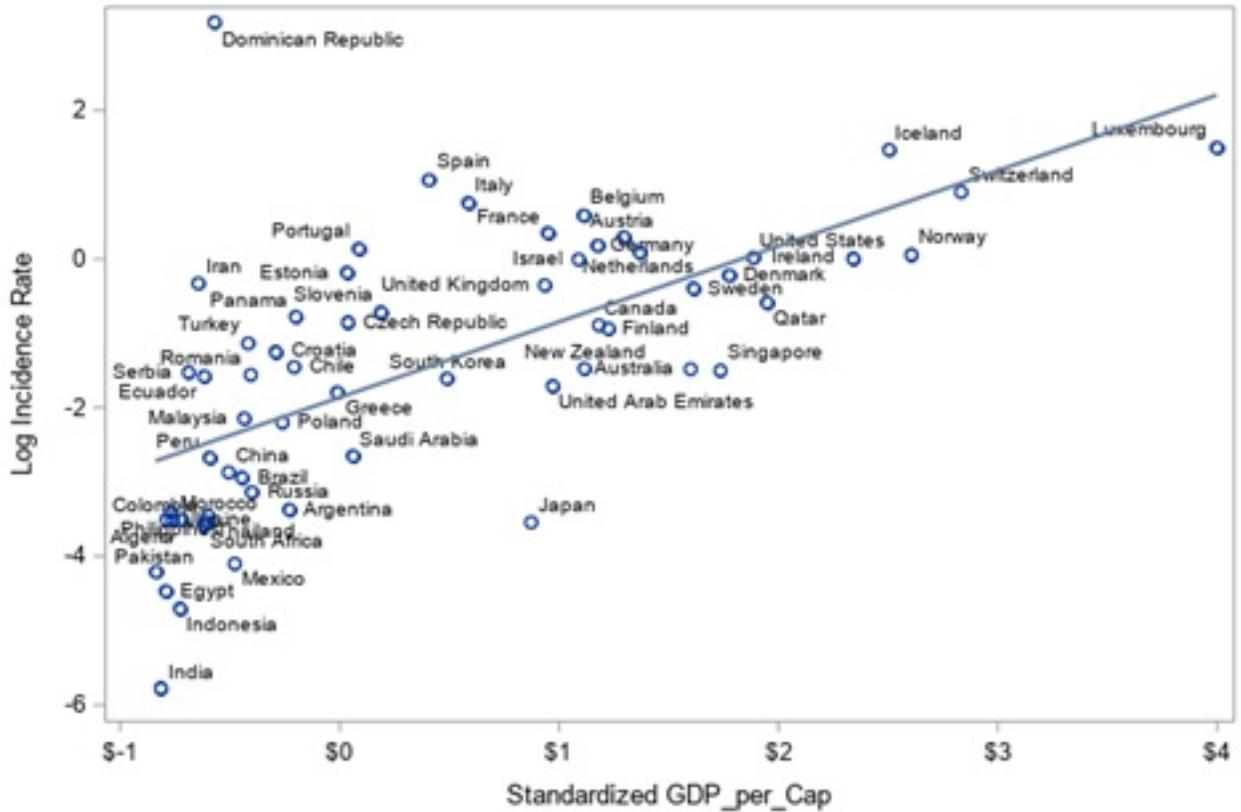
populations. Cell Discovery. 2020;6:1–4.

Figures

Figure 1

A linear relationship between the log transformation of the incidence rate and the standard

score of GDP per Capita. Including 60 countries with more than 1000 cases reported
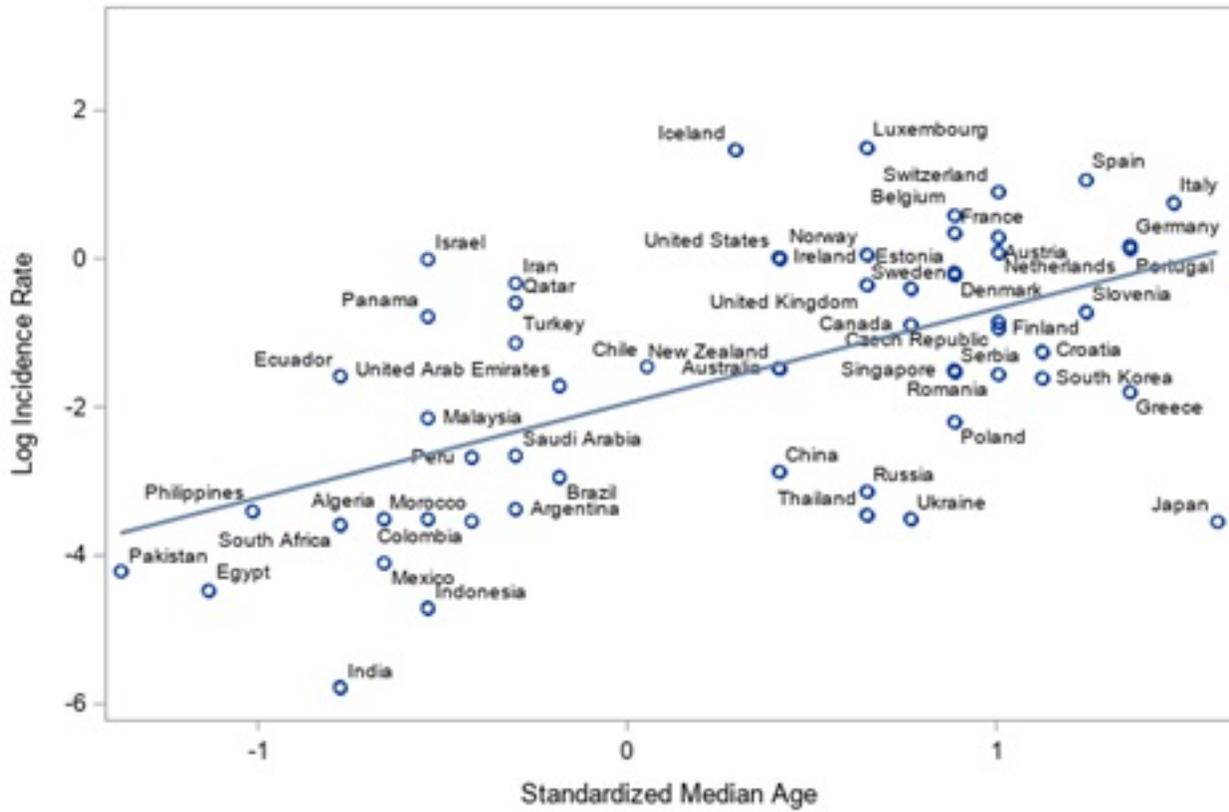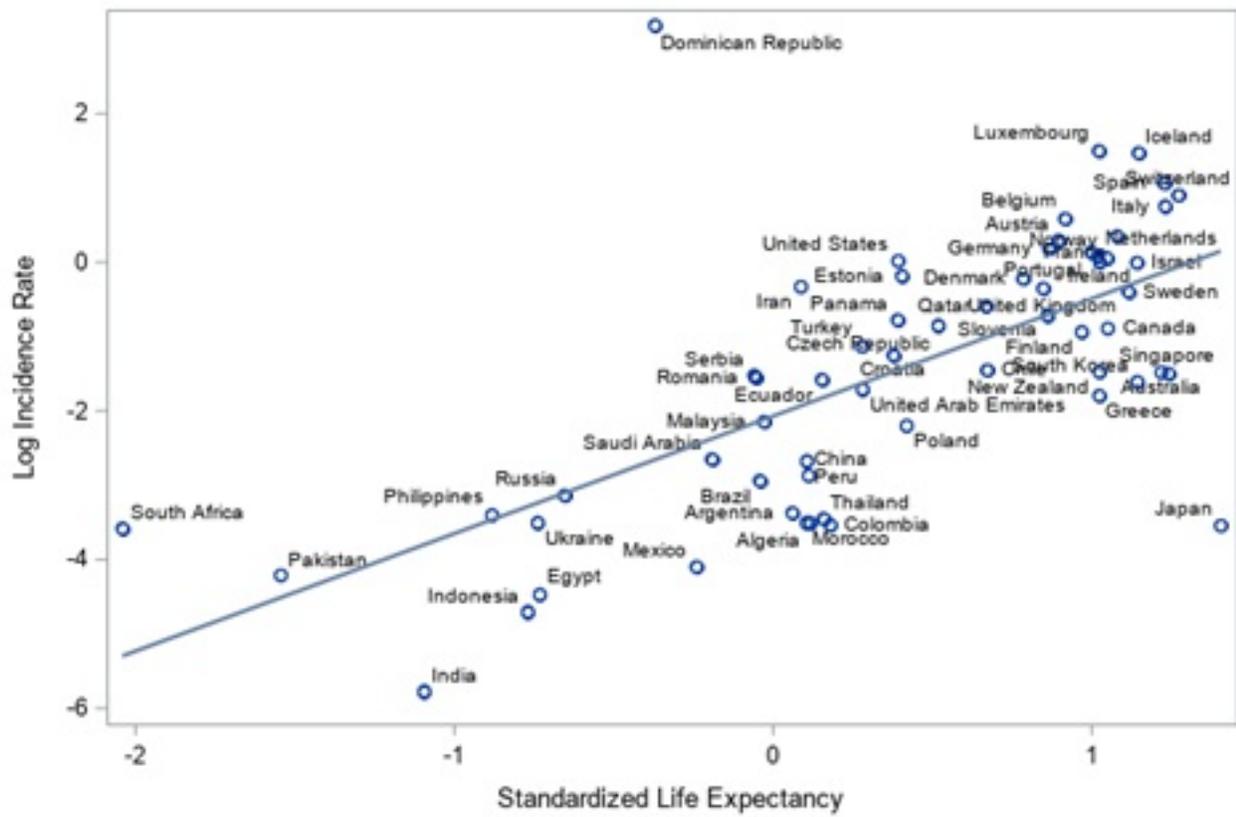
$(R2=0.41)$.

Figure 2

. A linear relationship between the log transformation of the incidence rate and the standard

score of median age. Including 59 countries with more than 1000 cases reported (R2=0.33).

Figure 3

A linear relationship between the log transformation of the incidence rate and the standard

score of life expectancy. Including 60 countries with more than 1000 cases reported
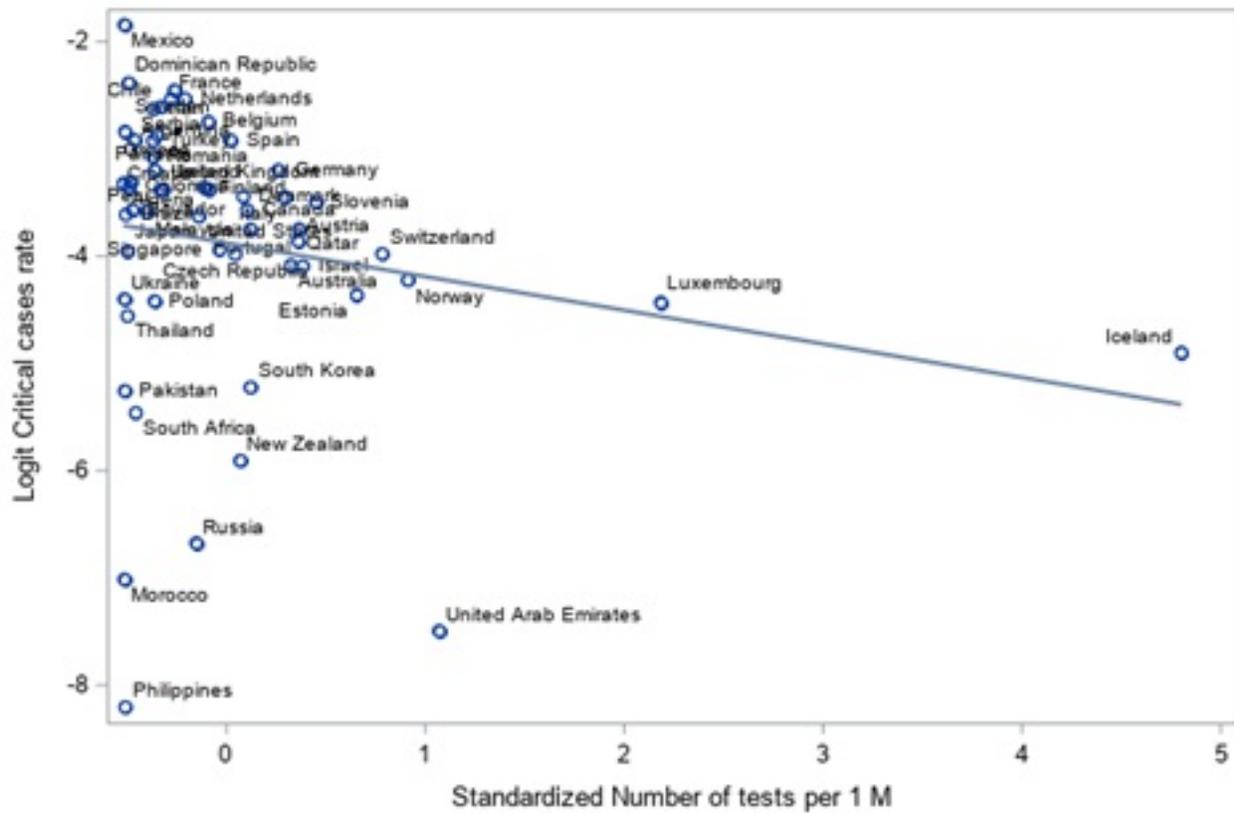
(R2=0.43).

Figure 4

A linear relationship between the logit transformation of critical cases rate and the standard score of the number of tests per 1 million. Including 55 countries with more than 1000 cases reported (R2= 0.042).
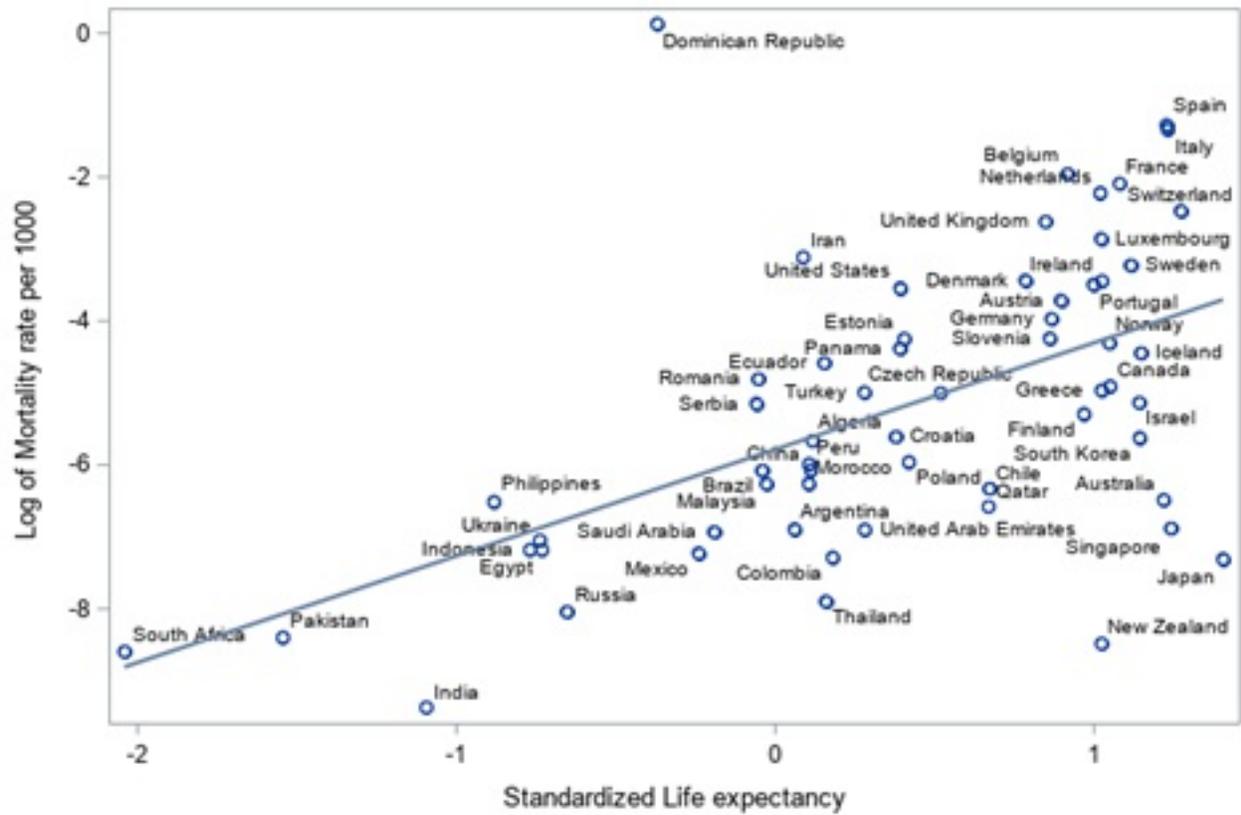
Figure 5

A linear relationship between the log transformation of mortality rate and the standard score of life expectancy. Including 60 countries with more than 1000 cases reported (R^2= 0.30).
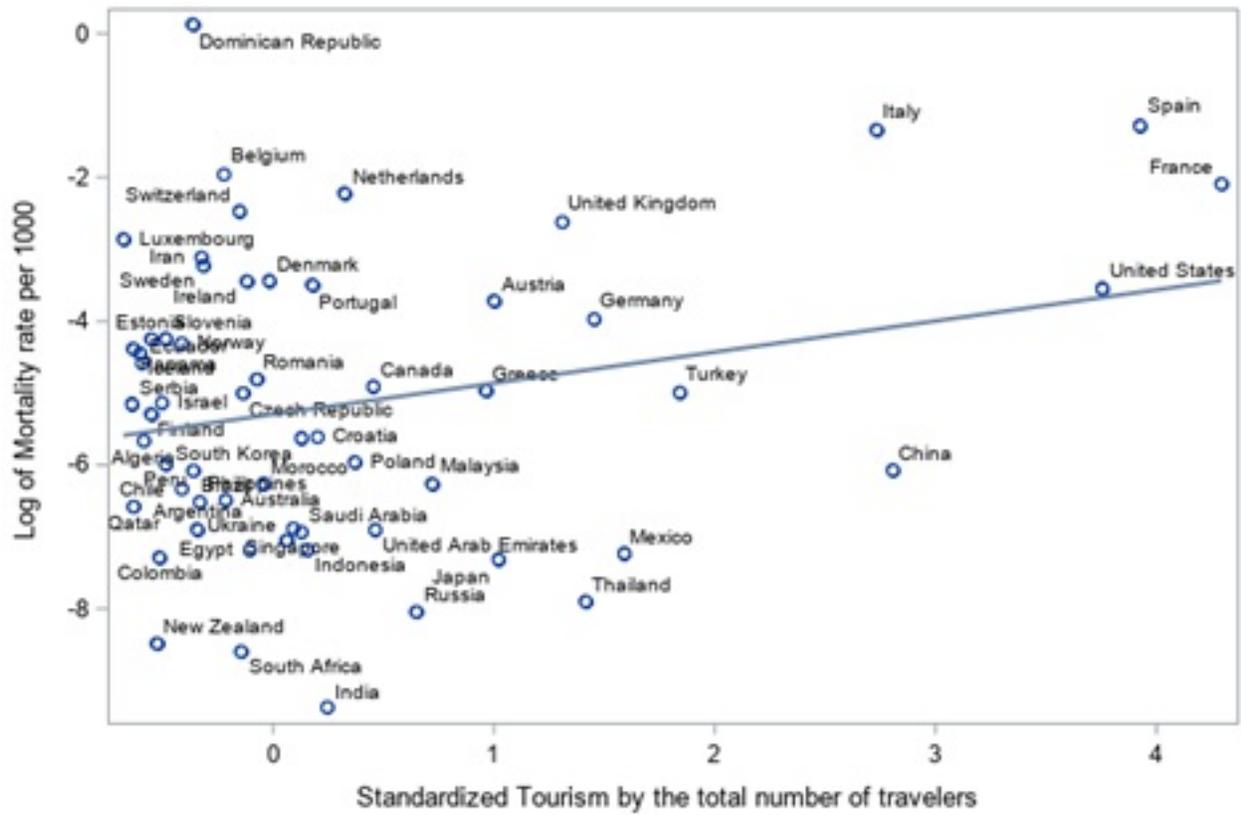
Figure 6

A linear relationship between the log transformation of mortality rate and the standard

score of the total number of travelers, including 60 countries with more than 1000 cases

reported (R2= 0.06).