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ORIGINAL RESEARCH

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# An assessment of the relationship between national rates of Covid-19 incidence and mortality as reported to an international comparison database: An ecological study

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## Abstract

**Background and Aims:** Making a judgment only based on formal national reports can be misleading. We aimed to assess the relationship between countries' development indicators and reported coronavirus disease 2019 (Covid-19)-related incidences and death.

**Methods:** Covid-19 related incidence and death cases were extracted from the updated Humanitarian Data Exchange Website on October 8, 2021. Univariable and multivariable negative binomial regression were utilized to investigate the relationship between development indicator and incidence and mortality from Covid-19 by calculating the Incidence rate ratio (IRR), mortality rate ratio (MRR), and fatality risk ratio (FRR).

**Results:** Very high human development index (HDI) compared with low HDI (IRR:3.56; MRR:9.04), the proportion of physicians (IRR:1.20; MRR:1.16), besides extreme poverty (IRR:1.01; MRR:1.01) were independently correlated with the mortality and incidence rate of Covid-19. Very high HDI and population density were inversely correlated with the fatality risk (FRRs of 0.54 and 0.99). The cross-continental comparison shows Europe and the North Americas, had significantly higher incidence and mortality rates with IRR of 3.56 and 1.84 as well as MRRs of 6.65 and 3.62, respectively. Also, they inversely correlated with the fatality (FRR:0.84 and 0.91, respectively).

**Conclusion:** A positive correlation between the fatality rate ratio based on countries' development indicators and the reverse for the incidence and mortality rate was found. Developed countries with sensitive healthcare systems can diagnose infected cases as soon as possible. Also, the mortality rate of Covid-19 will be accurately registered and reported. Due to more access to diagnostic tests, patients are diagnosed at the initial stages and will have a better opportunity to receive treatment. This leads to higher reports of incidence/and/or mortality rates and lower fatality of COVID-19. In conclusion, more Covid-19 incidence and mortality cases in

developed countries can result from a more comprehensive care system and a more accurate recording procedure.

KEYWORDS
Covid-19, fatality rate, incidence rate, mortality rate, World Development Indicators

## 1 | INTRODUCTION

In December 2019, the third most crucial coronavirus in the 21st century (SARS-COV-2: severe acute respiratory syndrome) was identified as the cause of SARS spread in Wuhan, China's Hubei province. SARS-COV-2 abruptly spread Worldwide, turning it into a Covid-19 pandemic on March 11, 2020. Therefore, the coronavirus pandemic (COVID-19) 2019 spread worldwide, and millions of people were either infected or killed. Countries have adopted various strategies to combat this pandemic based on their domestic capacities.[1] Some of these countries utilized national quarantine policies, which were extended differently during the day. Others used the social distance approach, leaving house inhibition and international journey prohibition, particularly to infected destinations.[2] Meanwhile, studying pandemic situations indicates distinct differences in the rate of pandemic spread and mortality rate. It seems social development inequality has been influential enough on countries' capacities to react to Covid-19.[3] The experiences of various healthcare systems in different countries represent that access to resources is merged with the capability to react to the crisis, including the ability to observe crisis for making a decision, the ability to cure those who need medical care, and the ability to develop products and services compatible to the changing conditions in the healthcare system or beyond that.[3,4] Previous studies show that regional development indicators such as education, occupation, income, accessibility to general healthcare infrastructures, and general health have directly influenced the consequences of social health.[4,5] Some researchers also believe that the Covid-19 pandemic can be measured against macro variables like population, human development factors, and other social development indices across the world. For instance, a study conducted in 14 Asian regions showed a positive relationship between Covid-19 approved cases, and the death toll and human development index (HDI) recognized.[6] In Brazil's inner cities, approved cases increased by 1.32 and 0.54, with a 10% increase in GINI and HDI in which the death toll also went up by 0.6% and 1.42%. Ecological studies asserted a positive correlation between Covid-19 and HDI across the world.[7] As a result, social development factors provide a better healthcare infrastructure that highly influences citizens' health in every country regardless of that country's wealth status in the world bank.[6] Overall, due to the availability of universal Covid-19 data and social development factors, ecological studies and their related factors can investigate different countries' status in the corona pandemic. Making a judgment about the conditions related to the Covid-19 pandemic and drawing a comparison of different countries only based on the formal reports of incidence and mortality can be baffling.[8] Therefore, this study has been devised to assess the relationship between countries' development indicators and reported Covid-19 related incidence and death.

## 2 | MATERIALS AND METHODS

### 2.1 | Study design and data sources

This was an ecological study. To study the influence of countries' development indicators on Covid-19 incidence cases and the international mortality rate, this study used the updated data on the Humanitarian Data Exchange Website (https://data.humdata.org/dataset/total-covid-19-tests-performed-by-country/resource/f16895fd-8e3d-4dce-a47a-69beb72b5328) on October 8, 2021 (dates covered by the data). Selected global indices to show countries' development levels included HDI (Very high (HDI:1.00–0.80)/high (0HDI: 0.79–0.70)/middle (HDI: 0.69–0.55)/low (HDI: 0.54–0.35), gross domestic product (GDP) per capita (per capita in US dollars), health expenditure (% of GDP), physicians per 1000 people, hospital beds per 1000 people, extreme poverty, life expectancy, and Covid-19 tests per 1000 people. The data was related to 191 countries which were compared into six groups (Africa/Asia/Europe/North America/Ocean/South America). Other potential risk factors for Covid-19 mortality include the population over 65 years of age, the proportion of diabetes, the proportion of obese adults, and the population for every single country (Supplementary).

### 2.2 | Statistical analysis

The Spearman correlation coefficient was used to assess the bivariate correlation between variables. Univariable and multivariable negative binomial regression also was used to investigate the association between the outcome variables of interest (death and incident cases) and the explanatory variables. For each country, person-year (PY) was calculated based on the multiplication of the population by years from the start date. PY of exposure was included as an offset variable. We regressed single-covariate on the death or case count; then, statistically significant variables at $p = 0.5$ were included in the multivariable model. 0.5 cutoff have chosen because of the small sample size of the ecologic studies for increasing statistical power. Finally, backward selection with a statistically significant level of 0.1

was run. Incidence rate ratio (IRR) (total cases divided by the mean population), mortality rate ratio (MRR) (total deaths divided by the mean population), and fatality risk ratio (FRR) (total deaths divided by the total cases) were calculated with STATA software version 16.0 (Stata Corp).

### 2.3 | Ethics statements

This study was approved by the Ethics Committee of the Kurdistan University of Medical Sciences under the ethics code No. IR.MUK.-REC.1400.240. Also, we confirm that all the experiment protocol for involving human data was carried out in accordance with relevant guidelines and regulations.

## 3 | RESULTS

The status of studied indexes, comparing countries' development in Table 1, indicates the pandemic incidence means of 7594.36 (IQR: 458.10–8052.46) in 100,000 people, the mortality rate means of 133.92 people in every 100,000 people (IQR: 9.14–143.05), and fatality rate means of 1.5% (IQR: 1%–3%). In addition, the lowest and highest HDI index has been 0.29 and 0.96. The lowest and highest GDP per capita has been 274 and 19052 American dollars, respectively. There have been reports of healthcare expenditure mean (IQR: 4.40–7.95) at 3.5%, the number of physicians per 1000 people was between 0.38 and 3.07, and there were 1.3–3.86 hospital beds for every 1000 individuals. Other information related to the population upper 65 years, the number of recognition tests, the amount of extreme poverty, life expectancy, diabetes spread, and obesity are represented in Table 1.

Table 2 indicates the mutual correlation between different variables in the present study. As is shown in this table, a positive correlational relationship can be observed between incidence and other variables (for instance, Diabetes, GDP per capita, life expectancy, and the like), except for extreme poverty ($r = -0.66$), fatality rate ($r = -0.16$). An intriguing point is that extreme poverty is negatively correlated with all the variables in the present research but the fatality rate; nor does it have any significant correlation with population. There was also a positive correlation between mortality rate and other variables, although it's negatively correlated with tests per case and extreme poverty ($p < 0.05$). The fatality rate had a negative correlation with most variables despite having a positive correlation with healthcare expenditure and extreme poverty ($p < 0.05$).

Table 3 displays the detrimental factors in both crude and modified models of the incidence rate ratio, mortality rate ratio, and fatality risk ratio consequences. In the crude model, most variables have been statistically meaningful in every mentioned consequence ($p < 0.05$). Amongst variables under investigation, the amount of incidence and mortality rate ratio among areas with very high HDI compared to areas with very high HDI was 29 ($p < 0.001$, 95% confidence interval [CI]: 19.92–41.63) and 19 ($p < 0.001$, 95% CI:

**TABLE 1** Summary of sociodemographic characteristics, health measures, and exposures.

| | Minimum | P25 | P50 | P75 | IQR | Maximum | *N* |
|---|---|---|---|---|---|---|---|
| Incidence[a] | 6.68 | 458.10 | 3667.20 | 8052.46 | 7594.36 | 21,965.42 | 191 |
| Mortality rate[a] | 0.31 | 9.14 | 48.72 | 143.05 | 133.92 | 598.43 | 191 |
| Fatality rate[b] | 0.001 | 0.01 | 0.02 | 0.03 | 0.015 | 0.19 | 191 |
| HDI | 0.29 | 0.60 | 0.76 | 0.85 | 0.25 | 0.96 | 189 |
| GDP per capital | 274.01 | 1968.79 | 5888.00 | 20,110.32 | 18,141.53 | 190,512.70 | 177 |
| Healthcare expenditure | 1.60 | 4.40 | 6.26 | 7.95 | 3.55 | 17.55 | 182 |
| Physicians per 1000 people | 0.01 | 0.38 | 1.59 | 3.07 | 2.69 | 8.42 | 166 |
| Hospital beds per 1000 people | 0.10 | 1.30 | 2.40 | 3.86 | 2.56 | 13.80 | 165 |
| Population over age 65 years | 1.14 | 3.40 | 6.34 | 14.31 | 10.91 | 27.05 | 178 |
| COVID-19 tests per 1000 people | 3.30 | 132.65 | 457.94 | 1186.82 | 1054.17 | 13,583.37 | 130 |
| Extreme poverty | 0.10 | 0.55 | 2.20 | 21.95 | 21.40 | 77.60 | 120 |
| life expectancy | 54.24 | 67.20 | 74.48 | 78.54 | 11.34 | 86.75 | 184 |
| Diabetes | 0.99 | 5.29 | 7.11 | 10.08 | 4.79 | 30.53 | 186 |
| Obesity | 0.02 | 0.09 | 0.20 | 0.25 | 0.16 | 0.56 | 181 |
| Population (000) | 33.701 | 2159.067 | 9119.005 | 30,500 | 28,300 | 1,440,000 | 191 |

Abbreviations: COVID-19, coronavirus disease 2019; GDP, gross domestic product; HDI, human development index; IQR, interquartile range.
[a]Per 100,000.
[b]Proportion (between 0 and 1).

**TABLE 2** Bivariate Spearman correlation coefficient for all variables.

| | Incidence | Mortality rate | Fatality rate | Diabetes | HDI | GDP per capital | Healthcare expenditure | Physicians per people | Hospital beds per people | Population over age 65 years | Total test | Tests per case | Population | Extreme poverty | life expectancy |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Incidence | 1 | | | | | | | | | | | | | | |
| Mortality rate | 0.88[a] | 1 | | | | | | | | | | | | | |
| Fatality rate | −0.16[c] | 0.27[a] | 1 | | | | | | | | | | | | |
| Diabetes | 0.24[b] | 0.17[c] | −0.17[c] | 1 | | | | | | | | | | | |
| HDI | 0.69[a] | 0.56[a] | −0.23[b] | 0.24[b] | 1 | | | | | | | | | | |
| GDP per capital | 0.68[a] | 0.49[a] | −0.35[a] | 0.28[b] | 0.95[a] | 1 | | | | | | | | | |
| Healthcare expenditure | 0.38[a] | 0.42[a] | 0.10[c] | −0.08 | 0.42[a] | 0.34[a] | 1 | | | | | | | | |
| Physicians per 1000 people | 0.71[a] | 0.60[a] | −0.19[c] | 0.21[c] | 0.86[a] | 0.79[a] | 0.44[a] | 1 | | | | | | | |
| Hospital beds per 1000 people | 0.53[a] | 0.45[a] | −0.16[c] | 0.05 | 0.69[a] | 0.61[a] | 0.31[a] | 0.75[a] | 1 | | | | | | |
| Population over age 65 years | 0.61[a] | 0.61[a] | −0.02 | 0.14 | 0.81[a] | 0.73[a] | 0.52[a] | 0.78[a] | 0.70[a] | 1 | | | | | |
| Total tests per 1000 people | 0.69[a] | 0.43[a] | −0.3[b] | 0.17 | 0.80[a] | 0.78[a] | 0.42[a] | 0.71[a] | 0.52[a] | 0.61[a] | 1 | | | | |
| Tests per case | 0.02 | −0.12 | −0.13 | −0.07 | 0.31[c] | 0.32[a] | 0.06[a] | 0.17 | 0.095 | 0.08 | 0.40[a] | 1 | | | |
| Population (000) | 0.19[b] | 0.06 | −0.19[c] | 0.21[c] | 0.18[c] | 0.18[c] | −0.02 | 0.12 | 0.08 | 0.14 | 0.04 | −0.04 | 1 | | |
| Extreme poverty | −0.66[a] | −0.53[a] | 0.19[c] | −0.39[a] | −0.85[a] | −0.81[a] | −0.29[b] | −0.79[a] | −0.66[a] | −0.77[a] | −0.71[a] | −0.16[c] | −0.001 | 1 | |
| life expectancy | 0.65[a] | 0.53[a] | −0.20[b] | 0.27[b] | 0.92[a] | 0.87[a] | 0.43[a] | 0.80[a] | 0.56[a] | 0.78[a] | 0.71[a] | 0.28[a] | 0.27[a] | −0.80[a] | 1 |

[a]$p < 0.001$; [b]$p < 0.01$; [c]$p < 0.05$.

12.66–28.92) times more in respect; whereas, the fatality rate ratio was 50% ($p < 0.001$, 95% CI: 0.39–0.69) lower among areas with very high HDI. The comparison conducted between countries asserts that the amount of incidence and mortality rate ratio in Europe (IRR = 6.1, MRR = 6.6), South America (IRR = 4.5, MRR = 8.7), and North America (IRR = 3.1, MRR = 3.6) have been higher compared to Africa, however, the fatality risk ratio was statistically meaningful more than 50% ($p < 0.001$, 95%. CI: 0.22–0.96) for Ocean. Similarly, along with the increase of physicians, the number of incidence and mortality rate ratio ascends to 1.62 ($p < 0.001$, 95% CI:1.43–1.83) and 1.5 ($p < 0.001$, 95% CI: 1.31–1.71) while the fatality risk ratio descends to %48 ($p < 0.001$, 95% CI: 0.86–0.97) by the increase of HDI. Likewise, regarding the number of hospital beds, the number of recognition tests, besides the number of days passed from the initial days of Covid-19 breakout, there has been a positive correlation between the rate of incidence and mortality rate ratio in contrast to the negative correlation with the fatality risk ratio ($p < 0.05$). Furthermore, there has been a positive correlation between the proportion of health care cost from GDP, the number of recognition tests per identified individual, and the extreme national rates in addition to the extreme amount of incidence and mortality rate ratio ($p < 0.05$);. However, there was no meaningful correlation with the fatality risk ratio ($p > 0.05$).

In the modified level, which used a backward approach still the fatality risk ratio for countries with high HDI was reported less. This figure for Ocean (FRR = 0.51) and Asia (FRR = 0.70) was reported 30% and %50 less than Africa ($p < 0.05$). With the increase of higher than 65 years of age population, the fatality risk ratio increased to 3% (MRR = 1.03), while the crude model displayed a contrary correlation. Besides, with the increase of population density, the fatality risk ratio decreases significantly ($p < 0.05$). Regarding the incidence and mortality rate, majority of the variables function similarly to the crude models and have a significant correlation with the consequences of incidence and mortality.

## 4 | DISCUSSION

This study used countries' development indexes to predict the consequences of the Covid-19 pandemic incidence, mortality rate, and fatality risk ratio based on national reports. The findings represent that the incidence rate ratio has a positive correlation with the countries' development indices. In countries with higher HDI, incidence and mortality rate were higher to 20 times more than in countries with lower HDI. Comparing the continents further showed that the incidence, and mortality rates ratio in Europe was 4.5 and 8.7 times more than in Africa. Additionally, with the increase in physician numbers, hospital beds, and recognition tests, the incidence and mortality rate significantly increased. Some believe that such differences in incidence and mortality can be due to the demographic pyramid of developed and developing countries to the extent that the rise in the Covid-19 mortality rate is related to the elderly, and most developing countries have the highest old population compared to other developed countries.[9] Studies have shown that countries with higher developing healthcare indices like the United States, UK, Spain, Italy, and South Korea have had higher recognition of incidence and mortality rates compared to developing countries due to access to healthcare services, data clarity, and higher amount of Covid-19 rapid recognition tests.[10,11] However, up to 75% of Covid-19 cases have not been reported in developing countries due to the lack or absence of recognition tests.[12] Even the analysis of "excess deaths" estimates for every country in the world indicates that the total mortality rate of this pandemic is probably more than what has been reported. For example, in India, economist estimates show that up to the beginning of May 2021, compared to the 20,000 official deaths, probably 2.3 million people have lost their lives due to Covid-19.[13] Therefore, it seems that the official statistics in those many countries with little capacity for testing have removed those victims whose corona recognition test was not positive. In some African and Asian countries, the death certificate is issued only for a small proportion of the population.[14] Besides, in these countries, there is a probability that hospitals and registry (notary) organizations don't issue death certificates for days or weeks to delay putting out the data intentionally. Finally, the pandemic has aggravated the situation of treating other diseases for doctors in more deprived areas who lack physicians. Many people have surrendered going to the hospital, which may indirectly increase the mortality rate from other diseases and decrease the mortality rate report of COVID-19. In some large parts of Africa and Asia, where some countries issue death certificates to only a small portion of the population.[13,15] The results of estimates indicate that the proportion of excess deaths for OECD countries has been 1.17 according to formal reports while estimating excess deaths for South Saharan countries has been 14 times more than official reports during this pandemic.[14] Then, countries that enjoy higher development indexes have better surveillance systems to recognize the incidence rate with much more accuracy and consequently report more mortality rates. In countries with lower development indexes, the capability of recognizing cases seems absent, or death reports seem inaccurate due to some unreported reasons.

The findings of the current study illustrate a positive correlation between fatality rate ratio based on countries' development indicators which were utterly different from findings related to the incidence and mortality. The fatality rate ratio in countries with higher HDI was less than countries with lower HDI to 50%. Cross-continental comparison indicates that the fatality rate ratio in Ocean is 50% less than in Africa. Furthermore, the fatality rate ratio significantly decreased by increasing the number of physicians, hospital beds, and recognition tests. It seems that in countries that appropriate surveillance and healthcare systems, mortality cases in the reported accounts are less than in other countries. However, the experience of the healthcare system shows that patients in those countries which do not profit from a suitable surveillance and healthcare system visit hospitals at a time when it is probably too late to receive treatment, for which the mortality rate has intensified.[16] Due to the low healthcare quality, hospitals cannot provide exemplary healthcare services for patients in these countries.[17]

**TABLE 3** Univariable and multivariable negative binomial regression model for incidence rate, mortality rate, and fatality rate of covid 19.

| | Incidence rate | | | | Mortality rate | | | | Fatality rate | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Model 1 | | Model 2 | | Model 1 | | Model 2 | | Model 1 | | Model 2 | |
| | IRR (95% CI) | *p*-Value | OR (95% CI) | *p*-Value | IRR (95% CI) | *p*-Value | OR (95% CI) | *p*-Value | IRR (95% CI) | *p*-Value | OR (95% CI) | *p*-Value |
| Diabetes | 1.04 (0.98–1.10) | 0.147 | 1.06 (1.00–1.11) | **0.020** | 1.02 (0.95–1.09) | 0.497 | 1.08 (1.01–1.16) | **0.038** | 0.98 (0.96–1.01) | 0.290 | | |
| Obesity | | | | | | | | | | | | |
| 20.2%> | 1.00 | | | | 1.00 | | 1.00 | | 1.00 | | | |
| 20.2%≤ | 2.91 (2.08–4.78) | **<0.001** | 39.68 (5.43–289) | **<0.001** | 2.52 (1.76–3.60) | **<0.001** | 1.24 (1.75–11.15) | **0.002** | 0.80 (0.65–0.99) | **0.038** | | |
| HDI | | | | | | | | | | | | |
| 0.25–0.54 | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| 0.55–0.69 | 5.96 (3.89–9.14) | **<0.001** | 3.46 (1.84–6.50) | **<0.001** | 5.12 (3.16–8.26) | **<0.001** | 4.42 (1.75–11.15) | **0.002** | 0.67 (0.49–0.94) | **0.019** | 1.07 (0.67–1.72) | 0.768 |
| 0.70–0.79 | 19.15 (12.98–28.25) | **<0.001** | 7.82 (3.61–16.95) | **<0.001** | 18.32 (11.82–28.38) | **<0.001** | 11.77 (3.86–35.88) | **<0.001** | 0.84 (0.62–1.13) | 0.251 | 1.29 (0.79–2.09) | 0.306 |
| 0.80–1.00 | 28.79 (19.92–41.63) | **<0.001** | 3.56 (1.97–6.42) | **<0.001** | 19.14 (12.66–28.92) | **<0.001** | 9.04 (2.66–30.78) | **<0.001** | 0.52 (0.39–0.69) | **<0.001** | 0.54 (0.40–0.72) | **<0.001** |
| Healthcare expenditure | 1.15 (1.06–1.24) | **<0.001** | | | 1.24 (1.14–1.36) | **<0.001** | | | 0.99 (0.94–1.03) | 0.619 | | |
| Physicians per 1000 people | 1.62 (1.43–1.83) | **<0.001** | 1.20 (1.05–1.37) | **0.007** | 1.50 (1.31–1.71) | **<0.001** | 1.16 (1.00–1.33) | **0.048** | 0.92 (0.86–0.97) | **0.005** | | |
| Hospital beds per 1000 people | 1.21 (1.10–1.35) | **<0.001** | | | 1.19 (1.08– 1.31) | **0.001** | | | 0.93 (0.89–0.97) | **0.002** | | |
| Population over age 65 years | 1.09 (1.06–1.12) | **<0.001** | 0.96 (0.91–1.02) | 0.185 | 1.12 (1.08–1.15) | **<0.001** | | | 0.98 (0.96–0.99) | **0.047** | 1.03 (1.00–1.05) | **0.013** |
| Total tests per 1000 people | 1.00 (1.00–1.01) | **0.007** | | | 1.01 (1.00–1.01) | 0.529 | | | 0.99 (0.98–0.99) | **<0.001** | 0.99 (0.98–0.99) | **0.039** |
| Tests per case | 0.99 (0.98–0.99) | **<0.001** | 0.99 (0.98–0.99) | **0.008** | 0.99 (0.99–1.00) | **<0.001** | 0.99 (0.98–0.99) | **<0.001** | 1.00 (0.99–1.00) | 0.844 | | |
| Population density | 1.00 (0.99–1.00) | 0.759 | | | 1.01 (1.00–1.01) | 0.501 | | | 0.99 (0.99–1.00) | **0.035** | 0.99 (0.98–0.99) | **<0.001** |
| Extreme poverty | 0.95 (0.94–0.96) | **<0.001** | 1.01 (0.99–1.02) | **0.051** | 0.94 (0.94–0.95) | **<0.001** | 1.01 (0.99–1.03) | 0.107 | 0.99 (0.99–1.00) | 0.974 | | |
| Number of days from start date | 1.02 (1.01–1.03) | **<0.001** | | | 1.02 (1.00–1.03) | **0.007** | | | 0.99 (0.98–0.99) | **0.035** | | |
| Contains | | | | | | | | | | | | |
| Africa | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| Asia | 2.77 (1.81–4.25) | **<0.001** | 1.97 (1.27–3.08) | **0.003** | 1.86 (1.22– 2.83) | **0.004** | 0.74 (0.38–1.49) | 0.399 | 0.89 (0.68–1.17) | 0.428 | 0.70 (0.54–0.91) | **0.008** |
| Europe | 6.09 (3.94–9.41) | **<0.001** | 3.56 (1.97–6.42) | **<0.001** | 6.64 (4.32–10.18) | **<0.001** | 2.86 (1.82–4.541) | **<0.001** | 0.81 (0.61–1.07) | 0.133 | 0.84 (0.47–1.49) | 0.555 |
| North America | 3.12 (1.83–5.33) | **<0.001** | 1.84 (1.10–3.08) | **0.02** | 3.62 (2.14–6.11) | **<0.001** | 1.55 (0.86–2.76) | 0.141 | 0.95 (0.67–1.34) | 0.791 | 0.91 (0.57–1.46) | 0.694 |

TABLE 3 (Continued)

| | Incidence rate | | | | Mortality rate | | | | Fatality rate | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Model 1 | | Model 2 | | Model 1 | | Model 2 | | Model 1 | | Model 2 | |
| | IRR (95% CI) | *p*-Value | OR (95% CI) | *p*-Value | IRR (95% CI) | *p*-Value | OR (95% CI) | *p*-Value | IRR (95% CI) | *p*-Value | OR (95% CI) | *p*-Value |
| Ocean | 0.85 (0.31–2.33) | 0.759 | 0.61 (0.24–1.56) | 0.304 | 0.82 (0.27–2.43) | 0.715 | 0.38 (0.14–1.01) | 0.054 | 0.47 (0.22–0.95) | **0.037** | 0.51 (0.27–0.96) | **0.037** |
| South America | 4.50 (2.27–8.93) | **<0.001** | 2.68 (1.66–4.35) | **<0.001** | 8.73 (4.45–17.09) | **<0.001** | 4.03 (2.30–7.06) | **<0.001** | 1.50 (0.97–2.33) | 0.066 | 1.70 (1.14–2.54) | **0.009** |

Abbreviations: CI, confidence interval; COVID-19, coronavirus disease 2019; HDI, human development index; IRR, incidence rate ratio; OR, odds ratio.

Model 1: Crude model.

Model 2: The backward elimination met the backward elimination method to remove inefficient variables from the model to obtain the most parsimonious model.

## 5 | CONCLUSION

Despite the study's limitations, including the considerable differences in countries' reporting systems, and the fact that this study has used ecologic data for which the findings might be influenced by its ecologic nature, this study has been conducted thoroughly for the first time. In this study, we found a positive correlation between the fatality rate ratio based on countries' development indicators, however, it was reversed for the incidence and mortality rate. The fatality rate ratio in countries with higher HDI was significantly less and decreased by increasing the number of physicians, hospital beds, and recognition tests. Generally, it asserts that developed countries recognize incidence cases with more sensitivity due to benefiting from a better healthcare system. Accordingly, Covid-19 mortality will be accurately reported and recorded. This leads to reporting more incidence and mortality rates compared to other countries. In addition, more access to recognition tests helps patients be diagnosed with the disease at earlier stages; therefore, they will have a better chance to receive health care, leading to lower Covid-19 fatality rates in such countries. In countries with lower development indicators, in addition to less sensitivity in recognizing incidence individuals, there is also a more fragile system to report and record Covid-19 cases. As a result, more Covid-19 incidence and mortality cases in developed countries can be the result of more comprehensive health care and more accurate recording systems; which is why making a judgment about the Covid-19 pandemic and making a comparison across countries only based on the official reports of incidence and mortality can be baffling.

### AUTHOR CONTRIBUTIONS

**Azad Shokri**: Conceptualization; data curation; investigation; methodology; project administration; resources; supervision; writing—original draft; writing—review & editing. **Hassan Mahmoodi**: Data curation; methodology; writing—original draft; writing—review & editing. **Bakhtiar Piroozi**: Investigation; methodology; writing—original draft; writing—review & editing. **Yousef Moradi**: Methodology; writing—original draft; writing—review & editing. **Ghobad Moradi**: Conceptualization; methodology; project administration; writing—original draft; writing—review & editing. **Farhad Moradpour**: Methodology; project administration; writing—original draft; writing—review & editing. **Ali Ebrazeh**: Project administration; writing—original draft; writing—review & editing. **Parisa Daftarifard**: Writing—original draft; writing—review & editing.

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## CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict or interest.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author (Farhad Moradpour) upon reasonable request.

## ETHICS STATEMENT

This study was approved by the Ethics Committee of the Kurdistan University of Medical Sciences under the ethics code No. IR.MUK.-REC.1400.240. Also, we confirm that all the experiment protocol for involving human data was carried out in accordance with relevant guidelines and regulations.

## TRANSPARENCY STATEMENT

The lead author Ghobad Moradi, Farhad Moradpour affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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