Demography, inequalities and Global Health Security Index as correlates of COVID-19 morbidity and mortality

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Abstract

Background: During a pandemic, the occurrence of infections and case fatality rates are expected to vary from one country to another due to several variables such as poverty, existing comorbidities, population density, access to health care, availability and quality of health system resources, and environmental factors.

Objectives: Our aim is to investigate the relationship between various demographic and socioeconomic factors and reported COVID-19 morbidity and mortality indicators in different countries. Also, to determine the position of the countries relative to each other in terms of three indicators including COVID-19 cases, deaths and tests.

Methods: Canonical correlation analysis is used to investigate the intercorrelations between independent variables and the COVID-19 cases and deaths for 92 countries. Countries' performances are measured by MULTIMOORA.

Results: Human Development Index, smoking habits, percentage of elderly population and test frequency are the most significant variables associated with COVID-19 morbidity and mortality according to our study findings. Singapore, New Zealand and Australia are the best performed countries.

Conclusions: Several significant and unexpected associations exist between socioeconomic factors and the COVID-19 cases and deaths. Singapore, New Zealand and Australia are surrounded by water, have been more successful in the pandemic process compared to other countries.
INTRODUCTION

The pandemic risk has risen in the 21st century because of increased global travel and integration, urbanization, changes in land use, and greater exploitation of the natural environment. Past experiences show that pandemics have serious effects on the global economy and create social chaos besides loss of lives.

The COVID-19 pandemic has started as the infections of Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) in Wuhan, China in December 2019 and followed by occurrences of new cases in Thailand, Japan and the Republic of Korea in January. WHO declared the outbreak of COVID-19 as a pandemic on 11 March 2020.

The rapid spread of the new infection causing high levels of morbidity and mortality in every country has overwhelmed health systems and caused the inevitable economic downturn. Governments have tried to keep mortality as low as possible and also manage the economic consequences of voluntary/mandated quarantine, lockdowns, closure of educational institutes or places of work, and isolation of households, towns, or cities. According to an OECD economic evaluation report, the COVID-19 outbreak has already brought major economic disruption and GDP is expected to decrease by 2.4% in 2020.

During a pandemic, the proportion of infected individuals and case fatality rates vary significantly from country to country. Study findings indicate that poverty, inequality, and social determinants of health create conditions for the transmission of infectious diseases and the discrepancy in health system capacity, political security, and socioeconomic risk can further contribute to unequal burdens of morbidity and mortality. Stojkoski et al. (2020) state the importance of the socioeconomic determinants for developing policies aimed at preventing future health crises. Khan et al. (2020) show that amount of health expenditure is positively associated with case fatalities. Liu et al. (2020) indicate that elderly patients with COVID-19 are more likely to progress to severe disease. Demenech et al. (2020) show an association between the Gini coefficient and COVID-19 incidence and mortality rates. The Gini index determines the distribution of income among individuals or households, runs from zero to one hundred, with zero being complete equality and one hundred being complete inequality.

As it is stated in various studies the case fatality rates are affected by several factors such as poverty, unemployment rates, education level, nutritional status, existing comorbidities, population density, access to health care, quality of health system resources and environmental factors. Income is an indicator of access to economic resources available to purchase health-related goods and services. In previous studies, it is emphasized that deaths during the pandemics are closely related to the income level of countries. Low- and middle-income countries usually suffer from higher mortality rates in a pandemic due to high frequency of malnutrition and existing comorbidities, insufficient health care, lack of access to health care, and higher rates of virus transmission. Education level, which is another measure that reflects social and economic characteristics relevant for health, is a significant predictor of mortality.
rates. Life expectancy is a widely used measure for monitoring the evolution of mortality rate. Human Development Index (HDI) is a composite measure that includes life expectancy, education, and per capita income indicators which are used to rank countries by tiers of human development. The HDI is an indicator for countries’ preparedness to respond effectively and efficiently to a health crisis, provide a convenient window into the impact of COVID-19 on households. That is why we investigate the relationship between COVID-19 morbidity and mortality and countries’ HDI.

Income inequality, frequently measured with the Gini coefficient, is another important variable that is associated with the differences in exposure to the virus, susceptibility to disease, access to health care, and consequently affects mortality rates during the pandemics. On the other hand, the level of preparedness and capacity to manage the pandemics that are summarized by Global Health Security (GHS) Index can help to understand different dynamics in different countries. GHS Index was developed after the outbreak of Ebola in 2014, and used to evaluate the countries’ capacity to manage the pandemics. In our study, both measures are used as independent study variables.

In the early stages of the pandemic, several studies indicated that COVID-19 morbidity and mortality rates are significantly associated with older age, high number of comorbidities, diabetes and smoking. Population density, which is related to physical distancing and the transmission of the disease, seems to be another significant factor during pandemics. Based on the evidences from available literature these variables are included in this study.

All this evidence reflects the complex nature and multivariate dynamics of the pandemic. It is important to determine which variables are related to the better management of the pandemics and to be prepared for the next pandemics. Although several studies have investigated the relationship between COVID-19 and demographic, social and economic factors, studies discussing different variable combinations are still needed to determine interaction of the factors related to COVID-19. This research contributes to the literature for determining the probable predictors of varying COVID-19 morbidity and mortality rates in different countries. We compare data of 92 countries to determine key factors associated with increased cases and mortality rate of COVID-19. These data include country-specific socioeconomic factors, the health status of society, and the country’s capability to prevent and mitigate pandemics. Furthermore, countries were ranked in terms of three indicators including COVID-19 cases, deaths, and tests and, their performances were evaluated. Countries are grouped as the countries with best conditions, less favourable, and the least favourable conditions according to their performance.

Therefore our aim in this study is to explore the complex relationship between ‘COVID-19 indicators’ (COVID-19 cases and deaths) and a group of ‘independent variables’ including demography, diabetes prevalence, probability of dying between ages 30 and 70, percentage of smoking, GINI index, HDI and Global Health Security Index (GHSI) in 92 countries. Moreover, to rank the countries according to their performances measured by MULTIMOORA method.

2 | METHODS

We conducted this descriptive study to investigate how various demographic and socioeconomic factors are associated with reported COVID-19 morbidity and mortality in different countries. We collected all data from various international open sources such as, Our World in Data, GHSI web site, World Bank, Human Development Data Center. Our study included the countries (n = 92) that have reported complete data regarding the study variables. We collected the latest available data (18th of December 2020) of all the variables for 92 countries.

Dependent and independent variables of the study are as follow:

- **Dependent variables:**
  - **Cases:** Confirmed cases of COVID-19 per million population
  - **Deaths:** Confirmed deaths from COVID-19 per million population

- **Independent variables:**
• GHSI (Global Health Security Index)\textsuperscript{23}: The GHSI calculated from 6 categories, 34 indicators, and 85 sub-indicators to assess a country’s capability to prevent and mitigate epidemics and the pandemics.

• GINI (GINI coefficient)\textsuperscript{29}: A measure of statistical dispersion intended to represent the income or wealth distribution of a nation's residents and is the most commonly used measurement of inequality.

• Male smokers (%)\textsuperscript{28}: Percentage of male population who smoke.

• Elderly population (%)\textsuperscript{28}: Percentage of people aged 65 or over.

• Diabetes prevalence\textsuperscript{28}: Diabetes prevalence (as % of population aged 20 to 79) in 2017

• Probability of dying between ages 30 and 70\textsuperscript{26} (as % from any of cardiovascular disease, cancer, diabetes, or chronic respiratory diseases),

• Population density\textsuperscript{28}: Number of people divided by land area, measured in square kilometres.

• Tests per case\textsuperscript{28}: Tests conducted per new confirmed case of COVID-19.

• HDI (Human Development Index)\textsuperscript{31}: This composite index is a measure for three dimensions of human development that include life expectancy, education and per capita income.\textsuperscript{18}

Logarithmic, ln and square root transformations are used for some variables and multivariate normality assumption is provided for the research variables. We found that missing values are random, and replaced them with the mean values of each variable (Table 1). We performed Pearson’s correlation analysis and the canonical correlation analysis (CCA) to investigate the intercorrelation between independent variables and the COVID-19 cases and deaths.

### 2.1 Canonical correlation analysis

CCA is used to investigate the intercorrelation between independent variables and the COVID-19 cases and deaths. CCA aims to find a linear relationship between sets of multiple dependent and independent variables. It develops a weighted average of the variables from the first set and correlates with a weighted average of the variables from the second set. The weighted averages of the original variables are called canonical variates. A pair of canonical variates is also named as a canonical root. It finds the linear combination of independent variables, (X₁, X₂, etc.), and the linear combination of dependent variables (Y₁, Y₂, etc.), which maximizes the correlation. Each canonical function is con-

### TABLE 1 Independent variables and correlations with COVID-19 indicators

| Independent variables                  | Transform | Missing (n) | Correlation to dependent variables | Cases | Deaths |
|----------------------------------------|-----------|-------------|-----------------------------------|-------|--------|
| GHSI                                   | -         | -           |                                   | 0.240*| 0.341**|
| GINI coefficient                       | Ln        | 10          |                                   | -0.351**| -0.275**|
| Male smokers                           | Square root | 6           |                                   | 0.601**| 0.589**|
| Elderly population                     | Square root | -           |                                   | 0.498**| 0.519**|
| Diabetes prevalence                    | Ln        | -           |                                   | 0.275**| 0.201  |
| Probability of dying from chronic diseases | -         | -           |                                   | -0.355**| -0.280**|
| Tests per case                         | Ln        | -           |                                   | -0.364**| -0.550**|
| Population density                     | Ln        | -           |                                   | 0.092  | -0.106 |
| HDI                                    | -         | -           |                                   | 0.653**| 0.567**|
| Cases                                  | Square root | -           |                                   | 0.845* |        |
| Deaths                                 | Ln        | -           |                                   | 0.845* | -      |

Abbreviations: GHSI, Global Health Security Index; HDI, Human Development Index.

*\( p < 0.05 \); **\( p < 0.01 \).
structured from the correlation between two canonical variates, one variate from the dependent variables and one from the independent variables. The number of canonical correlations equals the number of variables in the small set. $V_1$ is the linear combination of the $y$ variables. Let $W_1$ be a linear combination of the $X$ variables. Let $C_1$ be the correlation between $W_1$ and $V_1$:

$$W_1 = a_{11}X_1 + a_{12}X_2 + ... + a_{1p}X_p$$

$$V_1 = b_{11}y_1 + b_{12}y_2 + ... + b_{1q}y_q$$

(1) (2)

The objective of canonical correlation is to estimate $a_{11}, a_{12}, ... a_{1p}$ and $b_{11}, b_{12}, ... b_{1q}$ such that $C_1$ is maximized.

Equations (1) and (2) are canonical equations, $W_1$ and $V_1$ are the canonical variates and $C_1$ is the canonical correlation. This procedure is continued until the $m$th set of canonical roots. In summary, the objective of canonical correlation is to identify the $m$ sets of canonical variates, $(W_1, V_1), (W_2, V_2), ... (W_m, V_m)$ such that the corresponding canonical correlations $C_1, C_2, ..., C_m$ are maximum and $\text{Corr}(V_j, V_k) = 0$, for all $j \neq k$, $\text{Corr}(W_j, W_k) = 0$, for all $j \neq k$ and $\text{Corr}(W_j, V_k) = 0$, for all $j \neq k$. CCA is an optimization problem with certain constraints. Redundancy analysis is used to fit the overall model. Redundancy index ($R_d$) indicates that measure of the variance of a variable explained by other variables in a given canonical correlation. It can be calculated for both dependent and independent variables. A redundancy index for the dependent variables demonstrates the amount of variance from dependent variables explained by the independent variables. It is calculated as:

$$R_d = (\text{average loading})^2 (\text{canonical correlation})^2$$

If the index close to one shows that independent variable’s variance being shared with the dependent variable, vice versa.

In CCA, there are three statistics available to determine the relative importance of variables in the study: standardized canonical coefficients, canonical loadings, and canonical cross-loadings. Canonical coefficients ($R_c$) are interpreted like regression coefficients. The squared canonical correlation coefficients ($R_c^2$) indicate the proportion of variance common to the two groups of indicators. Canonical loading is the correlation between each variable and its canonical variate. Canonical cross-loadings are correlations between each variable and opposite canonical variate. To decide which variables are most important in a given pair of canonical variates, standardized canonical coefficients and/or canonical loadings are used. In most instances, however, the canonical loadings are used to interpret the meanings of canonical variates. Because of the multicollinearity problems, canonical cross-loadings directly measure the relative impact of each variable.

Assumptions of CCA are linearity, multicollinearity (high multiple correlation between dependent or independent set), and multivariate normality. We all checked the assumptions.

The primary aim of this research is to find the relationship between COVID-19 indicators and demographic and socioeconomic indicators using the CCA model (Figure 1). CCA is a multivariate analysis method to study the interrelationships between multiple dependent variables and multiple independent variables. When compared to other multivariate techniques, CCA has fewer rigid restrictions. For this reason, in situations with multiple dependent and independent variables, CCA is the most appropriate and powerful multivariate technique.

### 2.2 Country ranking with MULTIMOORA

After determining the effects of the socioeconomic variables on COVID-19 indicators, we ranked the countries according to these variables to provide broader information about them. MULTIMOORA (Multi-Objective Optimization by Ratio analysis plus Full Multiplicative Form), one of the MCDM (Multi-Criteria Decision-Making) methods, was used to make the rank objectively. MCDM approaches aim to find the best solution from the set of alternatives being evaluated according to objectives (criteria). Brauers and Zavadskas introduced MOORA (Multi-Objective
FIGURE 1 Study variables. GHSI, Global Health Security Index; HDI, Human Development Index.
Optimization by Ratio analysis), which combines ratio and reference point approaches in 2006. In 2010, Brauers and Zavadskas35 extended MOORA by adding a Full Multiplicative Form and applying Dominance Theory36 to obtain a final ranking and call it MULTIMOORA. Thus, MULTIMOORA becomes a robust method for MCDM approaches.37

MOORA method begins with a decision matrix, X, where its elements, xij, denote ith alternative of jth objective (i = 1, 2,...,m and j = 1, 2,..., n). Ratio system is a data normalization method by comparing alternative of criteria to all values of the criteria:

$$x^*_i = \frac{x_{ij}}{\sum^n_{j=1} x^*_{ij}}$$  \hspace{1cm} (3)

where $x^*_i$ denotes ith alternative of jth objective. For optimization, these responses are added in the case of maximization and subtracted in case of minimization:

$$y^*_j = \sum^n_{i=1} x^*_i - \sum^n_{i=g+1} x^*_i$$  \hspace{1cm} (4)

where $g = 1, ... n$ denotes number of objectives to be maximized. An ordinal ranking in a descending order of the $y^*_j$ shows the final preference.

The second part of MOORA is reference point theory is chosen with the Min–Max Metric of Tchebycheff as given by the following formula:

$$\left(\min_{(j)} \left( \max_{(i)} |y^*_j - x^*_i| \right) \right)$$  \hspace{1cm} (5)

This theory starts from the already normalized ratios as defined in the Equation (1).

Full Multiplicative Form method35,36 embodies maximization as well as minimization of purely multiplicative utility function. The overall utility of the i-th alternative can be expressed as a dimensionless number:

$$U_i = \frac{A_i}{B_i}$$  \hspace{1cm} (6)

where $A_i = \prod^n_{j=1} x_{ij}, i = 1,2,...n$ denotes the product of objectives of the i-th alternative to be maximized with g = 1,... m being the number of objectives to be maximized and $B_i = \prod^n_{j=g+1} x_{ij}$ denotes the product of objectives of the i-th alternative to be minimized with m–g being the number of objectives to be minimized.

In MULTIMOORA, we used three COVID-19 indicators to rank the countries performances: COVID-19 cases (minimum the value better the performance of the country), deaths (minimum the value the better the performance of the country), and COVID-19 tests per case (maximum the value better the performance of the country). The decision matrix of the study contains our alternatives (92 countries) and objectives (3 COVID-19 variables). It has 276 elements. The decision matrix was translated into dimensionless ratios according to Equations (3) and (4) for Ratio System. Secondly, Equation (5) used the ratios obtained in Equation (3) to calculate the distances to the Reference Point of MOORA. Thirdly, the Full Multiplicative Form used the decision matrix to rank the countries. Finally, the final classification was made with dominance theory, and MULTIMOORA results were presented in Table 8. On the basis of the multi-criteria analysis, Brauers et al.38 suggested dividing the countries into three groups. It could be called the groups as the best conditions countries (best performance), less favourable countries (medium performance), and the least favourable countries (low performance) for three COVID-19 indicators. The differences of other variables not used in MULTIMOORA according to the countries’ groups were examined by one way analysis of variance (ANOVA).

The calculations were performed using the IBM SPSS 23 for CCA, one way ANOVA. MULTIMOORA is performed by R Studio 1.3.959 version using MCDA package.
RESULTS

Table 1 presents the missing values, suitable transformations and correlation of independent variables with the dependent variables. Because CCA and correlation analysis require assumptions of normal distribution and a linear relationship between the dependent and independent variables, we transformed the data regarding to GINI, male smokers, elderly population, diabetes prevalence, test per case, population density, cases, and deaths indicators by logarithmic and squared root transformation.

One of the CCA assumptions is that the variables in both sets should have a significant level of correlation in themselves. The simple correlation between the indicators of confirmed COVID-19 cases and deaths is significant and high ($r = 0.845; p < 0.001$) as it is seen in Table 1. Table 1 also presents the correlations between COVID-19 indicators and independent variables. There are significant correlations between all independent variables and the COVID-19 indicators with the exception for population density. HDI, percentage of male smokers and elderly population are moderately and positively correlated with the COVID-19 cases (0.653, 0.601, and 0.498, respectively), while number of tests per case, probability of dying from chronic diseases, and GINI coefficient are negatively correlated (−0.364, −0.355, and −0.351, respectively). HDI, percentage of male smokers and the elderly population have significant moderate and positive correlation with the COVID-19 deaths (0.589, 0.567, and 0.510, respectively). COVID-19 deaths have a significant moderate negative correlation with tests per case (−0.550). The correlations between COVID-19 deaths and diabetes prevalence and COVID-19 deaths and population density are not significant.

Table 2 presents the simple linear correlations between the independent variables. There is a strong and significant positive correlation between male smokers prevalence and percentage of the elderly population ($r = 0.845; p < 0.001$), and also between the elderly population and HDI ($r = 0.770; p < 0.001$).

Findings of the Canonical Correlation tests of significance between COVID-19 indicators and independent variables across all detected canonical functions are presented in Table 3. They indicated that the canonical functions are collectively significant ($p < 0.001$); thus, it is possible to say that the two sets of indicators are correlated and dependent each other.

| TABLE 2 Simple Linear Correlation between independent variables |
| --- |
| | GHSI | GINI | Male smokers | Aged 65 older | Diabetes prevalence | Probability of dying from chronic diseases | Tests per case | Population density | HDI |
| GHSI | 1 | - | - | - | - | - | - | - | - |
| GINI | -0.110 | 1 | - | - | - | - | - | - | - |
| Male smokers | 0.401$^b$ | -0.399$^b$ | 1 | - | - | - | - | - | - |
| Aged 65 older | 0.484$^b$ | -0.530$^b$ | 0.845$^b$ | 1 | - | - | - | - | - |
| Diabetes prevalence | -0.133 | -0.098 | -0.079 | -0.017 | 1 | - | - | - | - |
| Probability of dying from chronic diseases | -0.372$^b$ | 0.265$^a$ | -0.307$^b$ | -0.464$^b$ | -0.078 | 1 | - | - | - |
| Tests per case | -0.089 | -0.027 | -0.168 | -0.122 | 0.096 | -0.151 | 1 | - | - |
| Population density | -0.037 | -0.076 | -0.119 | -0.024 | 0.208$^a$ | -0.131 | 0.052 | 1 | - |
| HDI | 0.472$^b$ | -0.523$^b$ | 0.676$^b$ | 0.770$^b$ | 0.344$^b$ | -0.606$^b$ | 0.099 | -0.0139 | 1 |

Abbreviations: GHSI, Global Health Security Index; HDI, Human Development Index.

$^a$Correlation is significant at the 0.05 level (2-tailed).

$^b$Correlation is significant at the 0.01 level (2-tailed).
Table 3 presents the summary statistics of CCA. As it is seen from the Table, 35.1% of canonical roots are covered by internal ‘independent variables’ variation and 100% of canonical roots are covered by ‘COVID-19 Indicators’ variation.

According to Redundancy index ($R_d$), 74.5% of changes in ‘COVID-19 Indicators’ can be predicted by studying changes in ‘independent variables’. Also, 22.8% of changes in ‘independent variables’ can be predicted by changes in ‘COVID-19 Indicators’ (Table 4).

The next step was the estimation of the significance of CCA coefficients. As shown in Table 5, two orthogonal (uncorrelated) functions are resulted from the full CCA process and both functions are found to be significant ($p < 0.001$). The value for the first pairs of variates indicates that 77.8% of the variance between independent variables and COVID-19 Indicators are shared ($R_c = 0.88$) while the second pairs of variates share 35.8% of the variance ($R_c = 0.598$).

Computed values of the canonical loadings and the canonical cross-loadings for our data are presented in Tables 6 and 7 respectively.

As it is seen from Table 7 the cross-loadings of cases and deaths are strongly correlated with the independent variables (0.849 and 0.845 respectively) in the first variate. That means 0.721 of the variance for confirmed COVID-19 cases and 0.714 of the variance for deaths can be predicted by changes in first variate. Among independent variables, HDI (0.641) and percentage of male smokers (0.625) have the highest correlations with the first variate of COVID-19 indicators. Percentage of elderly population (0.536) and tests per case (−0.476) have moderate correlations. All variables have weak correlations with the second variate.

Table 8 presents the rankings of the countries according to MULTIMOORA classified as best performance (holding ranks 1 to 31), medium performance (32–62) and low performance (63–92). As it is seen from the table, Slovenia, Czech Republic, and Croatia have the least favourable conditions while Singapore, New Zealand and Australia have the best. Countries with the best conditions had the lowest rates of male smokers and elderly population and HDI
besides highest values for GINI. No statistically significant differences in diabetes prevalence, population density and probability of dying from chronic diseases are found according to the condition of the countries \((p > 0.05)\).

### 4 | DISCUSSION

In this study, we investigated the association of a group of medical, social and economic variables with COVID-19 morbidity and mortality in 92 countries using CCA. In addition, we calculated countries’ ranks relative to each other with MULTIMOORA method.

According to the summary statistics of CCA, 74.5% of changes in COVID-19 morbidity and mortality which we call ‘COVID-19 Indicators’ can be predicted by ‘Independent variables’. There are significant correlations between the COVID-19 indicators and independent variables except for the population density. Also, the correlation between COVID-19 deaths and diabetes prevalence is not significant.

The value obtained for CCA, \(R_c = 77.8\%\) means a strong correlation between independent variables and COVID-19 indicators. CCA indicated that the number of COVID-19 cases and the deaths are positively correlated \((r = 0.849\) and \(r = 0.845\), respectively). Among the independent variables, HDI and percentage of male smokers have the highest correlations \((0.641; 0.625\), respectively\) and percentage of elderly population and tests per case \((0.536; -0.476\), respectively\) have moderate correlations with COVID-19 indicators. The number of COVID-19 cases and mortality have risen as the HDI value, percentage of male smokers, and the elderly population increased, and have decreased as the number of tests per case decreased.
Income indicators and life expectancy were reported as strong predictors of COVID-19 morbidity and mortality. Some studies have indicated that high COVID-19 morbidity and mortality rates in developed countries are associated with high GDP and life expectancy. On the other hand, Abedi et al. and Goutte, Péran, & Porcher reported that poorer and disadvantaged people are under high risk of COVID-19 mortality. According to these studies, higher rates of COVID-19 mortality in districts with more disability and poverty were associated with working conditions and poverty. However, considering the differences between countries, especially advanced age becomes more important determinant of COVID-19 mortality. Lawal (2021) reported life expectancy as one of the reasons of lower COVID-19 mortality rates in Africa. Countries with high GDP are generally developed countries with advanced health systems, education systems, and high life expectancy. These countries are expected to cope the health problems better. The relationship between education and COVID-19 mortality rates is found to be important in some studies. Abedi et al. (2020) and Gouttea et al. (2020) reported significant relationships between education level and COVID-19 morbidity and mortality rates in different regions of a country with social-economic diversity. Paradoxically, in this study, we found that countries with high HDI have higher number of COVID-19 cases and deaths. Our finding is similar to Chaudhry et al.’s who stated that countries with high per capita GDP have much more COVID-19 cases and deaths. Countries with a high HDI are usually economically developed countries with high proportion of elderly population. The higher probability of morbidity and mortality from COVID-19 in the older populations during the early stages of the pandemic may be the underlying cause of the positive association between HDI and COVID-19 cases and deaths.

Smoking was identified as an important predictor for COVID-19 cases and deaths in many studies. Hamidi et al. reported that countries with a higher percentage of smokers have higher mortality rates from COVID-19. Vardavas and Nikitara explained smoking is most likely associated with the negative progression and adverse outcomes of COVID-19. Cao et al. found that a doubling in the proportion of female smokers is associated with a significant increase in COVID-19 case fatality rates. On the other hand, Cai (2020) stated that the current literature does not support smoking as a predisposing factor in men. According to our study, male smoking is a strong correlate for both
| Countries      | Ratio system | Reference point | Multiplicative form | MultiMoora ranking |
|---------------|--------------|-----------------|---------------------|--------------------|
| Singapore     | 0.2201779432 | 1               | 4.57E+10            | 4                  |
| New Zealand   | 0.1584776685 | 2               | 6.77E+10            | 2                  |
| Australia     | 0.1571128605 | 3               | 3.96E+10            | 5                  |
| Fiji          | 0.0476674574 | 4               | 4.03E+12            | 2                  |
| Vietnam       | 0.0432391605 | 5               | 8.02E+13            | 1                  |
| Cuba          | 0.0057636485 | 6               | 7.27E+09            | 6                  |
| Malawi        | 0.0026446830 | 7               | 2.43E+09            | 12                 |
| Togo          | 0.0013071366 | 9               | 7.40E+09            | 8                  |
| Rwanda        | 0.0010099606 | 10              | 8.45E+09            | 10                 |
| Côte d’Ivoire | 0.0007164367 | 11              | 1.74E+09            | 14                 |
| South Korea   | -0.0001215362| 12              | 2.36E+09            | 13                 |
| Nigeria       | -0.0008022375| 15              | 3.50E+09            | 11                 |
| Uganda        | -0.0008022375| 15              | 1.40E+09            | 15                 |
| Sri Lanka     | -0.0015685244| 18              | 1.01E+09            | 16                 |
| Madagascar    | -0.0010675531| 16              | 8.35E+08            | 17                 |
| Zimbabwe      | -0.0019472322| 19              | 7.40E+08            | 18                 |
| Ghana         | -0.002332458 | 20              | 6.12E+08            | 19                 |
| Ethiopia      | -0.0019472322| 19              | 3.97E+08            | 20                 |
| Senegal       | -0.0022808381| 21              | 3.27E+08            | 21                 |
| Japan         | -0.0026740965| 22              | 3.03E+08            | 22                 |
| Malaysia      | -0.0039716385| 24              | 2.28E+08            | 23                 |
| Kenya         | -0.0039119058| 23              | 1.38E+08            | 24                 |
| Myanmar       | -0.005169182 | 26              | 1.04E+08            | 25                 |
| Pakistan      | -0.0056630707| 25              | 9.93E+07            | 26                 |
| Saudi Arabia  | -0.0131121366| 33              | 7.63E+07            | 27                 |
| United Arab Emirates | -0.0240229745 | 39             | 5.94E+07            | 28                 |
| Philippines   | -0.0103175570| 30              | 4.25E+07            | 29                 |
| Bangladesh    | -0.0069021147| 27              | 4.08E+07            | 30                 |
| Mauritania    | -0.0070282848| 28              | 4.01E+07            | 31                 |
| Finland       | -0.0126501857| 23              | 3.73E+07            | 32                 |
| Norway        | -0.0143163815| 35              | 3.68E+07            | 33                 |
| Iceland       | -0.0240601181| 40              | 3.53E+07            | 34                 |
| India         | -0.0156653310| 36              | 2.83E+07            | 35                 |
| Indonesia     | -0.0082609154| 29              | 1.68E+07            | 36                 |
| Kazakhstan    | -0.0220380556| 37              | 1.65E+07            | 37                 |
| Jamaica       | -0.012003801 | 31              | 1.63E+07            | 38                 |
| Namibia       | -0.0140426731| 34              | 9.35E+06            | 39                 |
| Maldives      | -0.0394296055| 50              | 8.10E+06            | 40                 |

(Continues)
| Countries        | Ratio system | Reference point | Multiplicative form | MultiMoora ranking |
|------------------|--------------|-----------------|--------------------|-------------------|
| El Salvador      | -0.0223336551 | 0.23364076      | 46                 | 6,62E + 06        | 41 |
| Denmark          | -0.0408821533 | 0.23264881      | 24                 | 4,82E + 06        | 42 |
| Belarus          | -0.0338611534 | 0.23336989      | 35                 | 4,55E + 06        | 43 |
| Qatar            | -0.0731068788 | 0.23269541      | 25                 | 4,38E + 06        | 44 |
| Bahrain          | -0.0846927676 | 0.23024954      | 11                 | 3,87E + 06        | 45 |
| Cyprus           | -0.0323795220 | 0.23383295      | 52                 | 3,52E + 06        | 46 |
| Estonia          | -0.0295723389 | 0.23380815      | 52                 | 3,52E + 06        | 47 |
| Ireland          | -0.0517839176 | 0.23205985      | 15                 | 3,43E + 06        | 48 |
| Iraq             | -0.0419602175 | 0.23292780      | 27                 | 3,22E + 06        | 49 |
| Latvia           | -0.0358660876 | 0.23372756      | 36                 | 2,40E + 06        | 50 |
| Guatemala        | -0.0286831569 | 0.23398979      | 73                 | 2,24E + 06        | 51 |
| Morocco          | -0.0288307330 | 0.23398979      | 27                 | 1,68E + 06        | 52 |
| Kuwait           | -0.0627396112 | 0.23318819      | 30                 | 1,70E + 06        | 53 |
| Russia           | -0.0498307929 | 0.23194205      | 13                 | 1,64E + 06        | 54 |
| Israel           | -0.0830300318 | 0.23370276      | 15                 | 1,34E + 06        | 55 |
| Greece           | -0.0446234000 | 0.2372576       | 48                 | 1,57E + 06        | 56 |
| Malta            | -0.0652300548 | 0.23791421      | 26                 | 1,53E + 06        | 57 |
| Canada           | -0.0449423361 | 0.2376476       | 51                 | 1,45E + 06        | 58 |
| Germany          | -0.0458272887 | 0.2388255       | 56                 | 1,33E + 06        | 59 |
| Dominican Republic| -0.0361512610 | 0.2311814       | 72                 | 1,13E + 06        | 60 |
| Libya            | -0.0331734281 | 0.23424213      | 83                 | 9,05E + 05        | 61 |
| Paraguay         | -0.0398636638 | 0.2318633       | 77                 | 7,55E + 05        | 62 |
| South Africa     | -0.0507675494 | 0.23415533      | 75                 | 5,29E + 05        | 63 |
| Tunisia          | -0.0388679166 | 0.23431033      | 90                 | 5,18E + 05        | 64 |
| Chile            | -0.1031962953 | 0.2319439       | 31                 | 4,93E + 05        | 65 |
| Slovakia         | -0.0548139300 | 0.2318013       | 76                 | 4,55E + 05        | 66 |
| United Kingdom   | -0.1115575559 | 0.23457477      | 37                 | 3,56E + 05        | 67 |
| Iran             | -0.0655962839 | 0.2341873       | 79                 | 3,28E + 05        | 68 |
| France           | -0.1201135787 | 0.2347337       | 39                 | 2,81E + 05        | 69 |
| Luxembourg       | -0.1460786522 | 0.23317579      | 29                 | 2,68E + 05        | 70 |
| Spain            | -0.1298111403 | 0.23346097      | 38                 | 2,49E + 05        | 71 |
| Austria          | -0.0922009931 | 0.23396934      | 61                 | 2,45E + 05        | 72 |
| Portugal         | -0.0921600647 | 0.23396934      | 62                 | 2,44E + 05        | 73 |
| Ukraine          | -0.0585557217 | 0.23421173      | 85                 | 2,30E + 05        | 74 |
| Netherlands      | -0.0986612983 | 0.2337554       | 64                 | 2,11E + 05        | 75 |
| Lithuania        | -0.0780605198 | 0.23421113      | 82                 | 2,07E + 05        | 76 |
| Hungary          | -0.0996273287 | 0.2339414       | 65                 | 2,03E + 05        | 77 |
| Turkey           | -0.0476069759 | 0.2340332       | 92                 | 1,75E + 05        | 78 |
| Mexico           | -0.0809150766 | 0.2343512       | 91                 | 1,65E + 05        | 79 |
COVID-19 cases and deaths. Similar to our finding, higher risk of COVID-19 morbidity and mortality in men has been associated with higher smoking rates in Italy.48

The positive correlation between age and mortality is a well-known association that was also observed during this pandemic. According to a detailed report from the Chinese Center for Disease Control and Prevention, the overall case fatality rate was 2.3%, and increased to 8.0% for 70–79 years age group and 14.8% for 80 years and older.49 Advancing age has been considered as a risk for COVID-19 morbidity and mortality in many studies.4,42,50 Also, some clinical studies have explained a significant relationship between older age and disease severity of COVID-19.26 Moreover, previous studies displayed that developed countries with a high proportion of the population over 65 have more COVID-19 cases and high case fatality rates.40,41 According to CCA in this study, both cases and deaths are higher in populations where the proportion of the population aged 65 and over is higher. Arsalan et al. stated that developed countries such as Japan, Norway, Germany, Switzerland, Austria, Belgium, Denmark, Sweden, Netherlands, and Finland have the highest mortality risk due to their higher proportion of elderly population and countries including Ethiopia, Yemen, Sudan, Senegal have lower mortality risk due to their lower life expectancy and consequently lower proportion of elderly population.41

The number of diagnostic tests performed for case finding is an important variable that may influence the magnitude of identified COVID-19 morbidity. In this study, we found a negative relationship between tests per case and the COVID-19 cases and deaths. Chaudhry et al. (2020) reported that an increased scale of national testing was not associated with the number of critical cases, or deaths.42 On the other hand, Cao et al. (2020) found the open testing policies are associated with a decrease in case fatality rate.46

It is known that the probability of dying between ages 30 and 70 from any chronic diseases is usually higher in low- and lower-middle-income countries51 and income inequality influences a population's health status adversely.52 However, some study findings indicate a threshold association of income inequality and mortality or little overall association.53 The influence of income inequality on health is a complex issue and should be studied carefully. As revealed by the World Health Organization's Commission on Social Determinants of Health, extreme economic inequality drives other social inequalities.54 Consequently, we were expecting that more people in societies with high GINI values would suffer from poor health and be more vulnerable to infectious diseases because of income inequality. But we found that both COVID-19 cases and deaths have a negative correlation with the probability of dying from chronic diseases and the GINI coefficient according to the results of CAA. The significant and positive correlation (r = 0.265,
The GHS Index is a comprehensive assessment that ranks countries according to their level of preparedness for an epidemic or a pandemic. The GHS index for 195 countries was calculated as 40.2 on average and it was stated international preparedness for epidemics and the pandemics remains very weak. Chaudhry et al. (2020), on the other hand, stated that every ten-unit increase in the GHS score is associated with a 55% increase in recovered cases. In this study, GHSI was associated positively with COVID-19 cases and deaths.

Diabetes is another variable that was identified as predictor for COVID-19 cases and deaths. The global diabetes epidemic, which is very strongly correlated with overweight and obesity, affects the majority of adult populations in most developed countries. In this study, a weak positive correlation is found between diabetes and COVID-19 morbidity and mortality. Similar to our findings, Cao et al. also have reported a negative relationship between diabetes prevalence and case fatality rates, while Lawal (2021) found no significant correlation.

Quinn and Kumar emphasize that poverty, inequality, and social determinants of health create conditions for the transmission of infectious diseases, and existing health disparities or inequalities can further contribute to unequal burdens of morbidity and mortality. Our study findings indicate that countries with high-income and improved health-related indicators could not succeed in controlling the COVID-19 pandemic. A World Bank report also stated that the COVID-19 cases and deaths are higher in developed countries. Aged population structure may be one of the explanations of this finding. For example, many low-income African countries that have younger age population also have a lower frequency of severe COVID-19 cases. Another explanation might be the timely determination of susceptible cases with much more contact tracing and testing. It is obvious that developed countries with better national surveillance systems have greater transparency in reporting and apply different techniques in the case and death detection and counting. Increased human mobility due to the availability of travel and holiday opportunities in wealthier countries might also have a role in the increase of virus transmission. On the other hand, these countries have implemented mitigation policies such as lockdowns, compulsory use of masks in public spaces to lower the incidence and mortality rate of COVID-19 cases. For example, Sebastiani et al. stated that the government measures prevented the rise of the epidemic in Italy.

Dalglish (2020) and Emanuel et al. (2020), criticise the assumption that developed countries will have better health indicators in every situation due to better health systems they have. Dalglish (2020) stated that ‘The pandemic has given the lie to the notion that expertise is concentrated in, or at least best channelled by, legacy powers and historically rich states.’ Moreover, the United States, Italy and the United Kingdom were considered the worst responders to the COVID-19 pandemic, and they have faced an imbalance between supply and demand for medical resources such as hospital beds, intensive care beds, and ventilators.

According to the results of the MULTIMOORA method, countries between 1st and 31st rankings have the best conditions, 32nd and 62nd have less favourable, 63rd and 92nd have the least favourable conditions with regard to COVID-19 indicators. Countries with the best conditions had the lowest rate of male smokers, rate of elderly population, GINI and HDI. Slovenia, Czech Republic, and Croatia have the least favourable conditions while Singapore, New Zealand and Australia have the best. New Zealand and Singapore, besides many other Asian countries have implemented strict control policies including extensive testing, tracing, and isolating of all cases (i.e., not just severe cases) from the start of the COVID-19 outbreak. Moreover, New Zealand implemented strict lockdown policies and
the closing of their borders.\textsuperscript{61} Asia Pacific region, including New Zealand, Australia, and possibly Singapore have controlled coronavirus transmission more effectively than other countries.\textsuperscript{62}

5 | CONCLUSIONS

Findings of this study indicates significant and unexpected associations between socioeconomic factors and the COVID-19 cases and deaths. According to the CCA results, the COVID-19 cases and mortality have risen as the HDI value, percentage of male smokers, and the elderly population increased, and have decreased as the number of tests per case decreased.

The most striking findings of our study are the positive correlation of HDI and GHSI, and the negative correlation of the probability of dying from chronic diseases and GINI index with the reported cases and deaths in the countries. These results show that improved indicators regarding economy and capability to prevent and mitigate epidemics and pandemics do not guarantee success in managing the COVID-19 pandemic. Results of the MULTIMOORA method indicates that Slovenia, Czech Republic, and Croatia are in the least favourable condition while Singapore, New Zealand, and Australia are in the best. Canada, Denmark, Germany, Ireland, and Norway have less favourable conditions. Three countries, Singapore, New Zealand and Australia, that are surrounded by water seem to be more successful during the pandemic compared to other countries by better implementing policies on physical distancing, wearing masks, staying at home, closing borders and testing practices.

5.1 | Limitations

Most important limitation of our study is its cross-sectional, descriptive nature and collection of data from open sources. Also, we did not investigate the role of some variables such as lockdowns, policies regarding mask use and social distancing. So, the statistical associations should be interpreted carefully.

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CONFLICT OF INTEREST

None declared.

DATA AVAILABILITY STATEMENT

Data available on request from the authors.

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