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Are we ready to deal with a global COVID-19 pandemic? Rethinking countries' capacity based on the Global Health Security Index

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ABSTRACT

Background: The Global Health Security (GHS) Index has been developed to measure a country's capacity to cope with a public health emergency; however, evidence for whether it corresponds to the response to a global pandemic is lacking. This study performed a multidimensional association analysis to explore the correlation between the GHS Index and COVID-19-associated morbidity, mortality, and disease increase rate (DIR) in 178 countries (regions).

Methods: The GHS Index and COVID-19 pandemic data – including total cases per million (TCPM), total deaths per million (TDPM), and daily growth rate – were extracted from online databases. The Spearman correlation coefficient was applied to describe the strength of the association between the GHS Index, sociological characteristics, and the epidemic situation of COVID-19. DIRs were compared, and the impact of the GHS Index on the DIR by the time of "lockdown" was visualized.

Results: The overall GHS Index was positively correlated with TCPM and TDPM, with coefficients of 0.34 and 0.41, respectively. Countries categorized into different GHS Indextiers had different DIRs before implementing lockdown measures. However, no significant difference was observed between countries in the middle and upper tiers after implementing lockdown measures. The correlation between GHS Index and DIR was positive five days before lockdown measures were taken, but it became negative 13 days later.

Conclusions: The GHS Index has limited value in assessing a country's capacity to respond to a global pandemic. Nevertheless, it has potential value in determining the country's ability to cope with a local epidemic situation.

Introduction

Coronaviruses are a large family of viruses that usually cause mild-to-moderate upper respiratory tract diseases. However, several new coronaviruses have emerged over the past two decades and caused large-scale disease outbreaks (Cui et al., 2019). For example, severe acute respiratory syndrome (SARS) was first reported in Asia in 2003 and then quickly spread to 26 countries, resulting in over 8000 cases and 774 deaths (de Wit et al., 2016). In 2012, Middle East respiratory syndrome (MERS) emerged in Saudi Arabia and spread to 27 countries, causing 2494 cases and 858 deaths (de Wit et al., 2016; Oh et al., 2018; WHO, 2020). In January 2020, the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was first identified as the cause of an outbreak of viral pneumonia, which was later named coronavirus disease 2019 (COVID-19) and subsequently spread globally (Shu, 2020; Zhu et al., 2020). As of 31 August 2020, the outbreak has constituted a global pandemic threat, with an exponential increase in the number of patients resulting in a total of 25,275,624 confirmed cases and 846,931 deaths. The North American region had the most reported cases, followed by Asia, South America, Europe, Africa, and Oceania (https://ourworldindata.org/coronavirus).

The COVID-19 pandemic has impacted all areas of life. Public authorities have taken decisive action to respond to the emerging health threat, leading to reconsideration of the adequacy of pandemic preparedness measures (Dai and Wang, 2020). After the

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outbreak of Ebola in 2014, the Global Health Security (GHS) Index was developed to measure the ability of countries to cope with infectious diseases (Aitken et al., 2020). The GHS Index is the first comprehensive assessment and benchmark of health security and related capabilities across 195 countries (https://www.ghsindex.org/). It considers the broader context of biological risks within each country, including geopolitical considerations, the health system, and the country's capacity to control outbreaks. Questions used to evaluate the GHS Index are categorized into six groups: prevention, detection and reporting, rapid response, health system, compliance with international norms, and risk environment. It relies on open-source data from each country. The average overall GHS Index score is 40.2 out of a possible 100; a higher GHS Index indicates better preparedness.

Whether the GHS Index can be applied to assess the actual performance of countries during the COVID-19 pandemic has become a hot topic since the outbreak of COVID-19 (Abbey et al., 2020; Aitken et al., 2020; Stribling et al., 2020). Stribling et al. found that the extent of UK pandemic preparedness, expenditure on healthcare, and magnitude of the nursing workforce did not appear to impact the mortality rate of COVID-19 (Stribling et al., 2020). Abbey et al. reported an overestimation of the preparedness of some countries with a high GHS Index and underestimation of the preparedness of other countries with relatively lower GHS Indexes (Abbey et al., 2020). Public health measures applied to prevent, detect, and respond to emerging events in countries are essential for controlling infectious disease outbreaks. Many countries have postponed school openings, temporarily shut down businesses and shops, and restricted or prevented crowds from gathering (Adam, 2020; Jain, 2020). These emergency measures are not only related to the GHS Index but also have an impact on the epidemic situation, so emergency measures might affect the role that the GHS Index plays in examining the national response to COVID-19 (Chinazzi et al., 2020; Qian and Jiang, 2020; Tian et al., 2020; Wilder-Smith and Freedman, 2020; Zhang et al., 2020).

The current study performed a multidimensional association analysis to examine the correlation between the GHS Index and the epidemic situation of COVID-19 in different countries (regions) and to estimate the value of the GHS Index in predicting the growth rate of COVID-19 by the time "lockdown" measures were implemented.

Methods

Data collection

The GHS Index of each country was extracted from the Global Health Security Index website (https://ourworldindata.org/coronavirus), including total cases per million (TCDM) and total deaths per million (TDPM) for different countries (territories or areas). Sociological information was also retrieved, including continent, median age, gross domestic product (GDP) per capita, and life expectancy for the corresponding countries. The first stage of the analysis included 178 countries for which there were both GHS Index and COVID-19 data. Eleven countries with a case number <100 or a death number of 0 by 31 August 2020 were excluded. The second stage of analysis included 142 countries that adopted lockdown measures. Countries with GHS Index ranging 0–33.3, 33.4–66.6, and 66.7–100 were classified into the bottom, middle, and upper (or top) tiers, respectively (https://www.ghsindex.org).

Statistical analysis

Data were independently inputted by two people and checked for consistency. Statistical analysis was performed with R version 3.5.1 (https://www.r-project.org/). The TCDM and TDPM were logarithmically transformed before analysis. Continuous variables were presented as the median and interquartile range (IQR). Categorical variables were expressed as percentiles using contingency tables and analyzed using the χ^2 test. Between-group differences were compared by using analysis of variance or a nonparametric test. The Spearman correlation coefficient was used to describe the strength of the correlation between the GHS Index, sociological characteristics, and the epidemic situation of COVID-19. The time of lockdown was defined as when the government announced a blockade of areas or cities or closed the country's border. The average daily increase rate (DIR) was estimated by the following formula:

$$DIR = \left(\sqrt[9]{\frac{\text{Total cases of the day}}{\text{Total cases 10 days ago}}} - 1 \right) \times 100\%.$$

Then, the DIRs of different countries before and after lockdown were compared, using nonparametric tests, according to the GHS Index level. The R package "interplot" was used to estimate the impact of GHS Index on DIR by the time of lockdown, which provides a convenient way to visualize the changes in the coefficient of one variable that interacts with another variable (Berry et al., 2016; Berry et al., 2012). The significance level was set as 0.05.

Table 1
Characteristics of the 167 countries stratified by the Global Health Security Index.

Variables	Index, Global Health Security Index			All	*P*-value
	Bottom tier	Middle tier	Upper tier		
N (%)	50 (29.9)	104 (62.3)	13 (7.8)	167 (100)	
Continent, N (%)					<0.001
Africa	31 (62.0)	20 (19.2)	0 (0.0)	51 (30.5)	
Asia	6 (12.0)	32 (30.8)	2 (15.4)	40 (24.0)	
Europe	3 (6.0)	33 (31.7)	8 (61.5)	44 (26.3)	
North America	7 (14.0)	8 (7.7)	2 (15.4)	17 (10.2)	
South America	2 (4.0)	10 (9.6)	0 (0.0)	12 (7.2)	
Oceania	1 (2.0)	1 (1.0)	1 (7.7)	3 (1.8)	
TCPM*	720.50 (184.76, 2363.28)	2673.39 (679.90, 7126.69)	3389.84 (1378.11, 4842.04)	1788.87 (516.82, 5785.95)	<0.001
TDPM*	15.04 (5.04, 34.22)	47.48 (12.17, 132.94)	199.20 (60.46, 468.89)	32.69 (8.18, 112.69)	<0.001
Age (years)*	20.40 (18.45, 25.20)	32.40 (27.40, 40.00)	42.00 (40.80, 43.10)	29.90 (21.85, 39.35)	<0.001
GDP per capita (US$)*	3756.22 (1665.65, 8101.27)	15183.62 (6885.83, 28763.07)	44017.59 (38605.67, 46949.28)	13311.26 (4126.52, 28143.44)	<0.001
Life expectancy (years)*	64.88 (61.26, 72.96)	75.91 (71.72, 78.75)	82.28 (81.32, 82.80)	74.79 (66.65, 78.77)	<0.001

* : Median (interquartile range); TCPM, total cases per million; TDPM, total deaths per million; GDP, Gross domestic product.

Ethical statement

This study was exempt from ethical approval, as all data were downloaded and accessed from a public database. This study did not include information from individuals, so there was no requirement for informed consent.

Results

Characteristics of the different countries

There were 178 countries that had sufficient data in both the Coronavirus Pandemic (COVID-19) and Global Health Security Index databases. After excluding 11 countries with <100 COVID-19 cases or 0 deaths, 167 countries remained for analysis. This cutoff was established to ensure reliable exponential growth estimation for each included country, while capturing the initial period of outbreaks. Among the included countries, 50 (29.9%) were classified into the bottom tier according to GHS Index, 104 (62.3%) were classified into the middle tier, and 13 (7.8%) were classified into the upper tier. Approximately two-thirds of countries in the bottom tier were African countries. In addition, over 90% of European countries were in the middle and upper tiers. The median TCPM was 1788.87 (IQR, 516.82–5785.95), and the median TDPM was 32.69 (IQR, 8.18–112.69). Countries with a higher GHS Index had a higher TCPM and TDPM. There was also a significant difference in age, GDP per capita, and life expectancy among countries with different tiers of GHS Index (Table 1).

GHS Index and the epidemic situation of COVID-19

The framework of the GHS Index includes the following six categories: (1) prevention of the emergence or release of pathogens; (2) early detection and reporting of epidemics of potential international concern; (3) rapid response to an epidemic and mitigation of spread; (4) sufficient and robust health system for treating patients and protecting health workers; (5) commitment to improving national capacity, financing plans to address gaps, and adhering to international norms; and (6) overall risk environment and country vulnerability to biological threats. The Spearman rank correlation test was used to explore the association between the six categories and the confirmed numbers ofCOVID-19 cases and deaths. As shown in Figure 1, the overall GHS Index was positively correlated with TCPM and TDPM, with coefficients of 0.34 and 0.41, respectively ($P < 0.05$). Among the six GHS Index categories, five, excluding norms, were positively associated with TCPM and TDPM. Other factors, such as continent, median age, GDP per capita, and life expectancy were also significantly associated with the GHS Index and COVID-19 epidemic situation (Figure 1).

DIR of countries with different GHS Indexes

After the outbreak of COVID-19, 142 countries implemented lockdown measures. Among the countries included, 41 were located in Africa, 35 in Asia, 38 in Europe, 14 in North America, 11 in South America, and 3 in Oceania. As shown in Figure 2, the DIR was

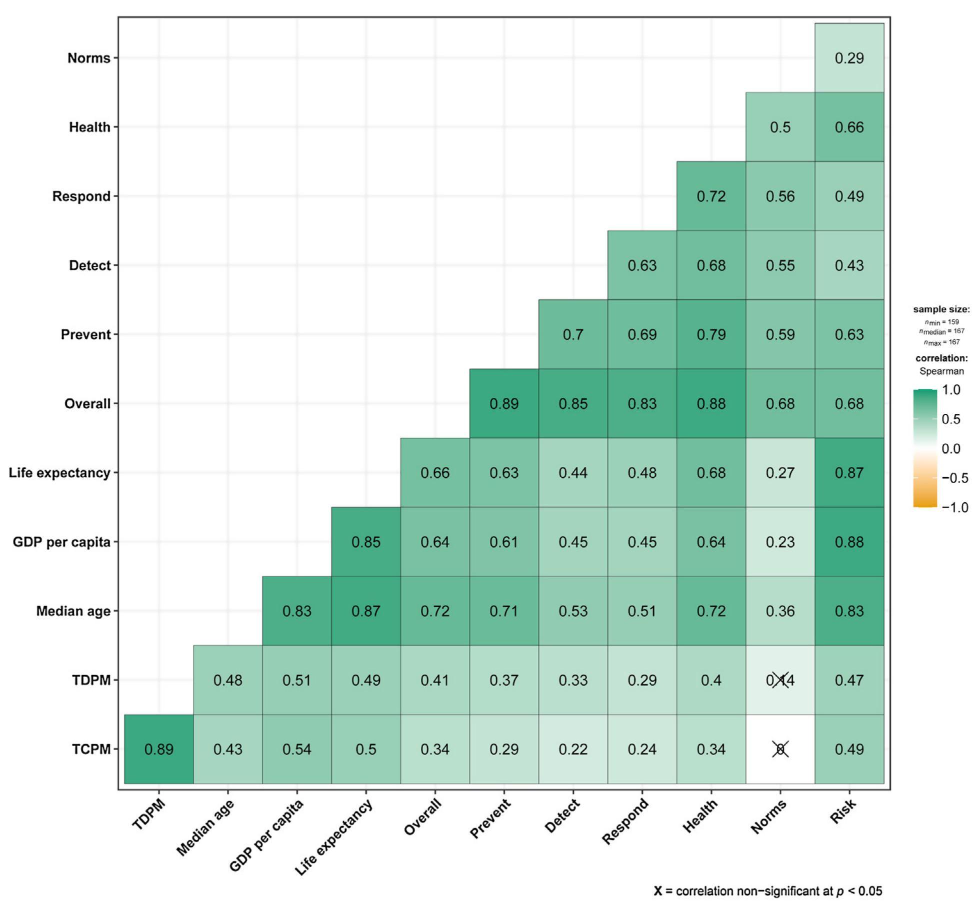

Figure 1. The correlation between the six categories of the GHS Index and the epidemic situation of COVID-19.
TCPM, total cases per million; TDPM, total deaths per million; GHS: Global Health Security.

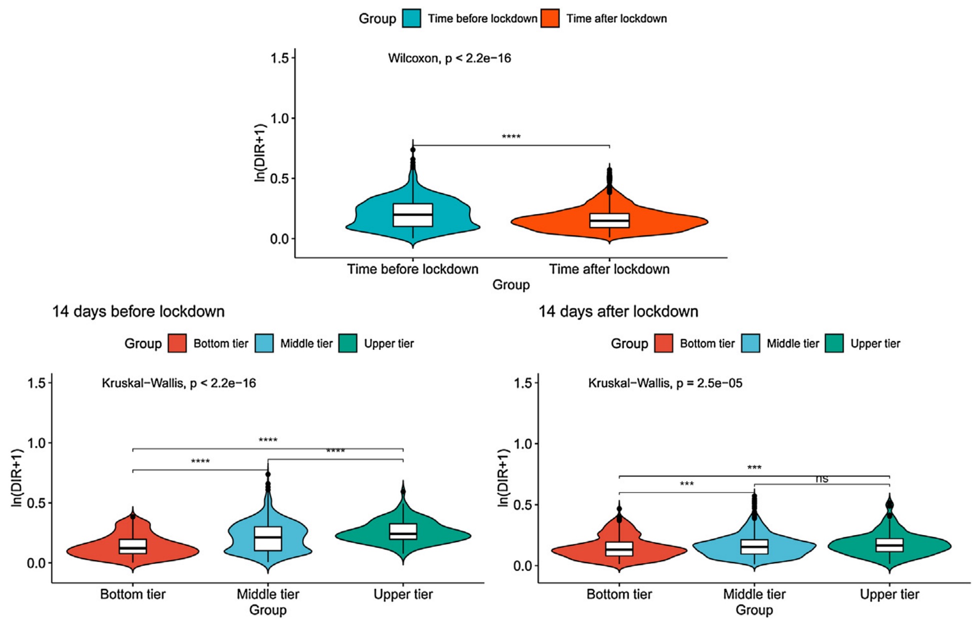

Figure 2. Comparisons of DIR among countries with different GHS Indexes before and after implementing lockdown measures.
DIR, daily increase rate; GHS: Global Health Security; ns, not statistically significant.

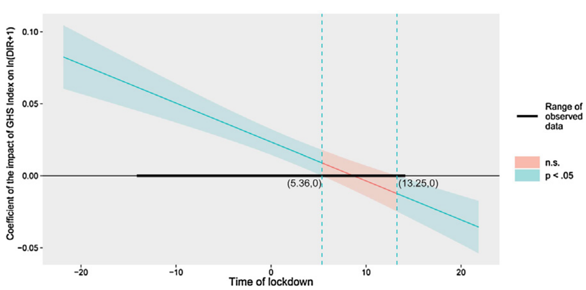

Figure 3. The coefficient of the impact of GHS Index on ln(DIR + 1) by the time of lockdown measure implementation.
DIR, daily increase rate; GHS: Global Health Security; ns, not statistically significant.

significantly different before and after lockdown ($P < 0.001$). Countries categorized into different tiers of GHS Indexhad different DIRs before implementing lockdown measures. However, after implementing lockdown measures, no significant difference was observed between countries in the middle tier and upper tier (Figure 2).

By constructing a fitted linear model with the continent, median age, GDP per capita, and life expectancy as covariates, the coefficient of the GHS Index was further explored in a two-way interaction term conditional on the time of lockdown. As shown in Figure 3, at the time of lockdown, the coefficient of the impact of GHS Index on ln(DIR + 1) decreased, and the association changed from positive to negative. From the cutoff points of 5.36 and 13.25, it was found that the coefficient of the impact of GHS index on DIR was statistically significant but in the opposite direction five days before and 13 days after lockdown.

Discussion

The GHS index has been widely applied to identify areas of weakness and opportunities to collaborate across sectors, strengthen health systems, and achieve public health goals. Some scholars have recently offered constructive critiques of the GHS Index's approach to scoring countries' capacity corresponding to the COVID-19 pandemic. The current study performed a multidimensional association analysis to explore the correlation between the GHS Index and COVID-19-associated morbidity and mortality in 178 countries worldwide. A positive association between the GHS Index and COVID-19 cases and deaths was observed but in an opposite manner than expected, meaning that the GHS Index has limited value in reflecting a country's capacity to deal with the global pandemic. Interestingly, the association between the GHS Index and the growth rate of COVID-19 changed from positive to negative after the implementation of lockdown measures, showing that the GHS Index can better reflect a country's ability to cope with a local epidemic situation. It is believed that this is the first study to explore the correlation between the GHS Index and COVID-19-associated morbidity, mortality, and DIR by considering lockdown measures.

It is difficult for countries to prevent SARS-CoV-2 spread due to its specific properties, such as its ability to cause nonspecific functional diseases, its ability to spread from asymptomatic people even before the onset of symptoms, its long incubation period, and the fact that the infectious period even lasts clinical rehabilitation (Hong et al., 2020; Jin et al., 2020; Lupia et al., 2020; Rothan and Byrareddy, 2020; Wang et al., 2020; Ye et al., 2020). Comprehensive implementation of public health measures to curb the COVID-19 pandemic has been suggested and strictly enforced, including travel restrictions, cancellation of gatherings, use of face masks in public, hand washing, and social distancing (Cui Hengjian, 2020; Kraemer et al., 2020; Lyu and Wehby, 2020; Noorimotlagh et al., 2021).

The GHS Index framework is the first comprehensive assessment tool that evaluates a country's capacity to prevent, detect, and respond to public health emergencies. In addition, the GHS Index considers national political and socioeconomic risks and adherence to international norms, which can influence a country's ability to stop outbreaks. However, in the initial stage of the epidemic, a positive association between the GHS Index and TCPM and TDPM was observed; this association is opposite of what was expected but is similar to the findings of Aitken (Aitken et al., 2020). It is worth noting that, based on the above results, it cannot be arbitrarily assumed that the GHS Index has no value. The following issues need to be considered.

First, COVID-19 is regarded as a catastrophic infectious disease on a level that has rarely occurred in recent decades, far beyond the control capacity of many countries. Based on a report by Johns Hopkins University in 2019, according to the GHS Index, no country was fully prepared to handle a pandemic (https://www.sciencedaily.com/releases/2019/10/191024115022.htm). Most countries (67%) with a GHS Index score in the bottom tier had a lower health system capacity, including healthcare workforce, access to healthcare, availability of equipment for healthcare workers, and capability to treat the sick. The average GHS Index score for the health systems category was 26.4. Similarly, 23% of countries had scores in the top tier for indicators related to political system and government effectiveness, which have a significant impact on the national capability to address biological threats. A study has demonstrated that half of countries have strong operational readiness capacities in place, suggesting that they could effectively respond to COVID-19, and collaboration between countries is needed for global outbreak control (Pung et al., 2020).

Second, at the beginning of the outbreak, the ability to detect SARS-CoV-2 was limited by access to test kits. Thus, the number of confirmed cases lagged behind the actual number of patients. This may partly explain why countries with upper-tier GHS Index scores had a higher DIR than countries in the middle or bottom tiers before implementing lockdown measures.

Third, it was observed that DIR was significantly different before and after lockdown. In the 14 days after lockdown, the ability of early detection and reporting of epidemics was of great importance. This may partly explain why countries with upper-tier and middle-tier GHS Indexes had a higher DIR than countries in the bottom tier. After implementing these strict measures, countries with higher GHS Indexes showed better capacity to cope with the COVID-19 epidemic. This reveals that the GHS Index has potential value in assessing a country's ability to respond to a localized epidemic situation.

Community resistance to outbreak mitigation measures, hospital transmission, delays in detection and isolation, and lack of funding and resources are the main barriers to the control of COVID-19. COVID-19 poses risks to global health, international security, and worldwide economy. Knowing the risks, however, is not enough. Political will is needed to protect people from epidemics, to take action to lessen the burden on overextended health systems, and to build a safer and more secure world. The COVID-19 outbreak is a stark reminder of the ongoing challenge of emerging and re-emerging infectious pathogens. There is an urgent need for constant surveillance, prompt diagnosis, and robust research to understand the basic biology of new organisms and our susceptibilities to them, and to develop effective countermeasures (Fauci et al., 2020).

This study had several limitations. First, testing and diagnostic capacity varied between countries, affecting the confirmed COVID-19 case and death counts. The morbidity and mortality rates reported by different countries might not have been accurate. Countries with lower GHS Index were more likely to lack the necessary resources for case confirmation, resulting in an underestimation of the number of cases. Second, TCPM, TDPM, and DIR were used to reflect the epidemic situation and control of COVID-19, which may not have fully reflected a country's ability to cope with an epidemic or pandemic. Third, although it constructed a fitting linear model with the continent, median age, GDP per capita, and life expectancy as covariates to explore the GHS Index in a two-way interaction term conditional on the time of lockdown, other potential confounders cannot be entirely excluded and may have affected the estimation.

Conclusions

In conclusion, the GHS Index was correlated with COVID-19-associated mobility and mortality but in an opposite manner than expected. Implementing lockdown measures could significantly reduce the increase in the rate of cases. The GHS Index has limited value in assessing a country's capacity to respond to a global pandemic. Nevertheless, it has potential value in determining a country's ability to cope with a local epidemic situation..

Ethics approval and consent to participate

All data were downloaded from the public database and followed the data access policies. This study was exempt from ethical review by the ethics committee of Nanjing Medical University. This study did not involve individual information, so there was no requirement for informed consent.

Consent for publication

Not required.

Availability of data and materials

All data generated or analyzed during this study were included in this published article.

Conflict of interests

The authors declare no conflict of interest.

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Authors' contributions

Conceptualization: YJ, JS, JW; Methodology: YJ, JS, BT, HS, ZL, JW; Software: YJ; Validation: JS, BT; Formal Analysis: YJ, JS, BT, HS, ZL, JW; Investigation: YJ, JS, BT, BT, HS, ZL; Resources: YJ, JW; Data Curation: JS, BT; Writing – Original Draft Preparation: YJ; Writing – Review & Editing: YJ, JS, JW; Visualization: YJ, JS, JW; Supervision: JW; Project Administration: JW; Funding Acquisition: JW. All authors have given final approval for the version to be published and agreed on the journal to which the article has been submitted.

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