Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.

Global Health Journal 5 (2021) 18–23

Contents lists available at ScienceDirect

Global Health Journal

journal homepage: https://www.keaipublishing.com/en/journals/global-health-journal/

RESEARCH ARTICLE

State fragility and the coronavirus disease 2019 (COVID-19) pandemic: an ecologic analysis of data from 146 countries

Yuqi Duan[a,b], Junxiong Ma[a,b], Yangmu Huang[a,b,*], Xinguang Chen[c], Zhi-Jie Zheng[a,b]

[a] Department of Global Health, School of Public Health, Peking University, 38 Xueyuan Road, Haidian District, Beijing 100191, China
[b] Institute for Global Health, Peking University, 38 Xueyuan Road, Haidian District, Beijing 100191, China
[c] Department of Epidemiology, College of Public Health and Health Professions and College of Medicine, University of Florida, Gainesville, FL 32610, USA

ARTICLE INFO

Article history:
Received 24 November 2020
Received in revised form 16 December 2020
Accepted 6 January 2021
Available online 6 February 2021

Keywords:
Coronavirus disease 2019 (COVID-19)
Pandemic
State fragility
State fragility index
Preparedness and response strengthening

ABSTRACT

Background: Global spread and impact of the coronavirus disease 2019 (COVID-19) pandemic are determined to a large extent, by resistance to the pandemic and public response of all countries in the world; while a country's resistance and response are in turn determined by its political and socio economic conditions. To inform future disease prevention and control, we analyzed global data to exam the relationship between state vulnerabilities and COVID-19 incidences and deaths.

Methods: Vulnerability was measured using the Fragile States Index (FSI). FSI is created by the Fund for Peace to assess levels of fragility for individual countries. Total FSI score and scores for 12 specific indicators were used as the predictor variables. Outcome variables were national cumulative COVID-19 cases and deaths up to September 16, 2020, derived from the World Health Organization. Cumulative incidence rates were computed using 2019 National population derived from the World Bank, and case fatality rates were computed as the ratio of deaths/COVID-19 cases. Countries with incomplete data were excluded, yielding a final sample of 146 countries. Multivariate regression was used to examine the association between the predictor and the outcome measures.

Results: There were dramatic cross-country variations in both FSI and COVID-19 epidemiological measurements. FSI total scores were negatively associated with both COVID-19 cumulative incidence rates ($\beta = -0.0135$, $P < 0.001$) and case fatality rates ($\beta = -0.0147$, $P < 0.05$). Of the 12 FSI indicators, three negatively associated with COVID-19 incidences were E1(Economic Decline and Poverty), E3 (Human Flight and Brain Drain), and S2 (Refugees and Internally Displaced Persons); two positively associated were P1 (State Legitimacy) and X1 (External Intervention). With regard to association with case fatality rates, C1 (Security Apparatus) was positive, and P3 (Human Rights and Rule of Law) and X1 was negative.

Conclusion: With FSI measures by the Fund of Peace, overall, more fragile countries are less likely to be affected by the COVID-19 pandemic, and even if affected, death rates were lower. However, poor in state legitimacy and lack of external intervention are risk for COVID-19 infection and lack of security apparatus is risky for COVID-19 death. Implications of the study findings are discussed and additional studies are needed to examine the mechanisms underpinning these relationships.

1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic has resulted in over 57 million cases and approximately 1.4 million deaths worldwide, as of November 20, 2020.[1] Despite extensive efforts from individual countries and the international community, the pandemic has not been subdued, as evidenced by the rising death toll.[2] It is imperative to augment our understanding of key factors that fuel the pandemic and its life-threatening impact as well as to develop more effective measures and strategies for prevention and control.

Although several factors may play a role in the spread of COVID-19, we cannot ignore the role of individual countries' capacities to deal with such public health emergencies as COVID-19, in terms of preparedness and responsiveness. Studies on many risk factors for the COVID-19 have been reported in the literature; however, few studies have examined the matter using national-level data. Furthermore, from these published

* Corresponding author: ymhuang@bjmu.edu.cn.

https://doi.org/10.1016/j.glohj.2021.02.002
2414-6447/Copyright © 2021 People's Medical Publishing House Co. Ltd. Publishing service by Elsevier B.V. on behalf of KeAi Communications Co. Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/)

studies, we noted that anti-epidemic measures at the national level often performed inadequately in predicting disease burdens emanating from the COVID-19 pandemic.[3-4]

State fragility is a concept that reflects a country's responsiveness to dangerous events. According to the Organization for Economic Cooperation and Development, fragile states are considered those that lack the ability to develop mutually constructive relations with society and often have a weak capacity to perform basic governance functions.[5] Consequently, fragile states tend to be vulnerable at multiple levels, including political, socioeconomic, and others.[6-7] With regard to health, vulnerability may include population susceptibility and barriers to healthcare access,[8-9] manifesting as outbreaks of epidemics, high incidence, and high mortality.[10]

The Fragile States Index (FSI), established by the Fund for Peace, is a measure used to quantify the degree of state fragility. It has served as a tool for monitoring all countries worldwide in order to earmark those located in the alert zone for assistance,[11] promote global peace and development, and identify countries in need of developmental assistance.[12] In this study, we used FSI as measure of national vulnerability to the COVID-19 pandemic.

The FSI consists of 12 indicators organized in four measurement dimensions with three sub-indexes per domain. The four domains are as follows: (1) the Cohesion Indicators; (2) the Economic Indicators; (3) the Political Indicators; and (4) the Social and Cross-Cutting Indicators, each of which contains three measurements. Previous studies have used relevant indicators to predict population health. Typical examples include studies on the impact of violence and insecurity on the risk of infectious disease transmission,[13] the inverted U-shaped relationship between economy and health,[14] and the importance of politics and social welfare in health outcomes,[15] to name a few.

In this study, we used the FSI as a predictor to assess the association of state vulnerability with the COVID-19 pandemic and its health impact at national level, using data from countries in the world. Our selection of FSI is based on its validity and widely used in empirical research, including health-related research studies.[11-13] Findings from these studies suggest FSI as a relevant tool for assessing the resistance and responsiveness of a nation to the COVID-19 pandemic, and its consequences. Furthermore, using FSI will facilitate communication of research findings to people and countries worldwide.

2. Methods

2.1. Data sources and variables

State fragility was measured using the 2020 FSI data acquired from the Fund for Peace.[16] As previously described, the FSI consists of 12 specific indicators arranged in four domain indexes (Table 1). The scores of the 12 specific indicators range from 0 to 10, with 0 representing the lowest vulnerability and 10 the highest vulnerability. Total FSI scores for individual countries (ranging from 0 to 120) were computed by summating the 12 individual scores. The total FSI scores were used to rank individual countries by fragility. In this study, we used it to assess the vulnerability to COVID-19 for individual countries.

The outcome variables for individual countries were the cumulative incidence rates and case fatality rates of COVID-19 from the first reported case up to September 16, 2020, when the analysis was completed for this study. Data for COVID-19 cases and deaths were accessible from various sources, and we used data reported by the World Health Organization (WHO). In particular, data used in this analysis were acquired from the WHO Coronavirus Disease (COVID-19) Dashboard.[1]

To compute the cumulative incidence rates by country, national population data are needed for individual countries in the world. Since 2020 population data were not available, we typically used 2019 population data instead. To ensure comparability, we acquired population data from the World Bank,[17] the most reliable population data source for global health research.[18]

Of the 216 countries/territories in the world, countries with incomplete data on the key variables (i.e., FSI, COVID-19 cases and deaths, and total population) were excluded, yielding a final sample of 146 countries that were included in the analysis.

2.2. Data analysis and statistical models

First, cumulative incidence rates (/1 000) for individual countries were computed as the ratio of total COVID-19 cases to the 2019 population, and case fatality rates (/100) as the ratio of total COVID-19 deaths to total COVID-19 cases.

Second, descriptive statistical analysis was conducted to describe geographic variations in both the outcome measures and the predictor measure. To better describe the geographic pattern for comprehension, we used the following six world regions: Africa, the Americas, Eastern Mediterranean, Europe, Southeast Asia, and Western Pacific, as established by the WHO, rather than individual countries. Therefore, we computed our predictor and outcome measures by these regions and conducted an analysis to assess cross-regional differences.

One-way ANOVA tests were used to compare the predictor and outcome measures across the six global regions. An XY plot with simple linear regression was initially used to demonstrate the overall association of total FSI scores with COVID-19 cumulative incidence rates and case fatality rates. Multiple linear regression was used to analyze the relationship between different FSI measures and the two outcome measures. COVID-19 cumulative incidence rates and case fatality rates were analyzed separately. Type I error was set at $P < 0.05$ level (two-sided) for statistical inferences. All statistical analyses were conducted using the open-source software R (version 3.6.3; R Foundation for Statistical Computing, Vienna, Austria).

3. Results

3.1. Variations in FSI scores and COVID-19 burdens across WHO regions

The results in Table 2 indicate that of the 146 countries included in this study, 39 were in the Africa Region (AFR), 27 in the Americas Region (AMR), 17 in the Eastern Mediterranean Region (EMR), 41 in the Europe Region (EUR), 10 in the Southeast Asia Region (SEAR), and 12 in the Western Pacific Region (WPR). All predictor and outcome measures differed significantly across the six WHO regions ($P < 0.01$ for all). Evidently, these results provide adequate information justifying further assessment of the relationship between these predictors and outcomes in future studies.

Specifically, regarding FSI indicators, countries in the AFR, EMR, and SEAR generally had a higher overall FSI score; they also scored higher on the four subdomain indexes. Countries in the EUR scored low overall and on the four individual domains. As regards the COVID-19 indicators, the cumulative incidence rates were high for countries in the EMR and AMR. The cumulative incidence rates in these two regions were more than five times higher than those in the AFR. As regards case fatality rates, rates in the EUR and AMR were approximately three times higher than those in the SEAR.

3.2. Relationship between total FSI scores and COVID-19 burdens

Fig. 1 indicates a significantly negative relation between the total FSI score and the log (COVID-19 cases) for all 146 countries included in the analysis. The negative relation was quantified using a linear regression with a β coefficient of −0.0135 (P <0.001) and R^2 of 0.19.

Likewise, Fig. 2 presents the relationship between total FSI scores and case fatality rates (no log transformation). Results from simple linear regression indicated a β coefficient of −0.0147 ($P < 0.05$) and R^2 of 0.02.

Table 1
Categories and indicators of Fragile States Index (FSI).

Category	Indicator	Content	Meaning
Cohesion indicators	C1: Security Apparatus	Monopoly on the use of force Relationship between security and citizenry Force Arms	The Security Apparatus indicator considers the security threats to a state
	C2: Factionalized Elites	Representative leadership Identity Resource distribution Equality and equity	The Factionalized Elites indicator considers the fragmentation of state institutions along ethnic, class, clan, racial or religious lines, as well as and brinksmanship and gridlock between ruling elites
	C3: Group Grievance	Post-Conflict response Equality Divisions Communal violence	The Group Grievance Indicator focuses on divisions and schisms between different groups in society–particularly divisions based on social or political characteristics–and their role in access to services or resources.
Economic indicators	E1: Economic Decline and Poverty	Public finances Economic conditions Economic climate Economic diversification	The Economic Decline Indicator considers factors related to economic decline within a country
	E2: Uneven Economic Development	Economic equality Economic opportunity Socio-Economic dynamics	The Uneven Economic Development Indicator considers inequality within the economy
	E3: Human Flight and Brain Drain	Retention of technical and intellectual capital Economics	The Human Flight and Brain Drain Indicator considers the economic impact of human displacement (for economic or political reasons) and the consequences this may have on a country's development
Political indicators	P1: State Legitimacy	Confidence in the political process Political opposition Transparency Openness and fairness of the political process Political violence	The State Legitimacy Indicator considers the representativeness and openness of government and its relationship with its citizenry
	P2: Public Services	General provision of public services Health Education Shelter Infrastructure	The Public Services Indicator refers to the presence of basic state functions that serve the people
	P3: Human Rights and Rule of Law	Civil and political rights Civil and political freedoms Violation of rights Openness Justice Equality	The Human Rights and Rule of Law Indicator considers the relationship between the state and its population insofar as fundamental human rights are protected and freedoms are observed and respected
Social and cross-cutting indicators	S1: Demographic Pressures	Population Public health Food and nutrition Environment Resources	The Demographic Pressures Indicator considers pressures upon the state deriving from the population itself or the environment around it
	S2: Refugees and Internally Displaced Persons	Refugees Internally displaced persons Response to displacement	The Refugees and Internally Displaced Persons Indicator measures the pressure upon states caused by the forced displacement of large communities as a result of social, political, environmental or other causes
	X1: External Intervention	Political intervention Force intervention Economic intervention	The External Intervention Indicator considers the influence and impact of external actors in the functioning – particularly security and economic – of a state.

3.3. Relationship between individual FSI measures and COVID-19 burdens

Informed by simple linear regression, Table 3 presents the results from multivariate regression models revealing ecologic linkages between specific FSI measures and COVID-19 cumulative incidence rates and case fatality rates. First, three FSI indicators negatively correlated with COVID-19 cumulative incidence rates, namely, E1 (Economic Decline and Poverty, $\beta = -1.392$, $P < 0.05$), E3 (Human Flight and Brain Drain, $\beta = -1.482$, $P < 0.01$), and S2 (Refugees and Internally Displaced Persons, $\beta = -1.202$, $P < 0.01$), and two positively correlated with COVID-19 cumulative incidence rates, namely, P1 (State Legitimacy, $\beta = 1.276$, $P < 0.01$), and X1 (External Intervention, $\beta = 1.094$, $P < 0.01$).

Second, two FSI indicators negatively correlated with case fatality rates, P3 (Human Rights and Rule of Law, $\beta = -0.447$, $P < 0.01$) and X1 ($\beta = -0.418$, $P < 0.01$), and one positively correlated with case fatality rates, C1 (Security Apparatus, $\beta = 0.595$, $P < 0.01$).

4. Discussion and conclusions

In this study, we analyzed data from 146 countries across six WHO regions worldwide. The goal was to explore the relationship between vulnerability/resistance at national level and the disease burden emanating from COVID-19. Data used for this study were derived from reliable sources, and an advanced multivariate regression method was used to examine the ecological relationship. To the best of our knowledge, this is one of the first studies to examine this relationship. The findings of this study provide time data that are prerequisite for establishing measures to control the current COVID-19 pandemic and that support future research and interventions against potential infectious disease pandemics.

Table 2
Differences in two COVID-19 outcome measures and 12 Fragile State Index indicators by World Health Organization (WHO) Region, 146 countries in 2020.

Item		AFR	AMR	EMR	EUR	SEAR	WPR	*P*
Number of countries		39	27	17	41	10	12	
Cumulative incidence rates (/1 000)		1.15±1.99	7.28±7.59	9.80±13.19	4.80±3.56	2.68±5.37	1.29±2.86	< 0.001
Case fatality rates (/100)		2.18±1.67	3.16±2.30	1.72±1.50	3.27±2.58	1.12±1.19	2.04±1.97	< 0.01
Cohesion indicators	C1: Security Apparatus	6.68±1.74	5.94±1.34	6.40±2.55	3.61±1.78	6.57±1.45	4.69±2.58	< 0.001
	C2: Factionalized Elites	7.59±1.74	5.37±2.03	7.86±1.77	4.89±2.65	8.32±0.88	5.68±2.59	< 0.001
	C3: Group Grievance	6.26±2.09	4.95±1.87	7.01±2.51	4.96±2.26	7.87±1.87	4.83±1.99	< 0.001
Economic indicators	E1: Economic Decline and Poverty	7.04±1.25	4.87±1.35	5.65±2.40	3.90±1.57	5.16±1.01	3.75±1.65	< 0.001
	E2: Uneven Economic Development	7.43±1.39	5.42±1.51	5.50±1.73	2.73±1.37	5.48±1.23	4.69±2.46	< 0.001
	E3: Human Flight and Brain Drain	6.77±0.98	5.81±1.86	5.22±2.21	3.69±1.73	6.38±0.88	4.38±2.17	< 0.001
Political indicators	P1: State Legitimacy	7.01±2.14	4.90±2.23	7.75±1.19	3.85±3.07	6.10±1.70	4.99±3.05	< 0.001
	P2: Public Services	7.66±1.64	4.88±1.76	5.10±2.89	2.42±1.21	5.89±1.57	3.85±2.73	< 0.001
	P3: Human Rights and Rule of Law	6.40±1.72	4.64±1.79	7.52±1.13	3.17±2.48	7.09±1.36	5.39±2.69	< 0.001
Social and cross-cutting indicators	S1: Demographic Pressures	8.03±1.52	4.86±1.61	5.70±2.37	2.45±1.29	6.69±1.28	4.47±2.12	< 0.001
	S2: Refugees and Internally Displaced Persons	6.53±2.03	3.59±1.63	5.87±3.05	3.80±1.90	6.18±1.69	3.15±1.66	< 0.001
	X1: External Intervention	6.67±1.62	4.83±1.95	6.74±2.32	3.65±2.51	5.90±1.72	3.91±2.61	< 0.001
Total Fragile States Index		84.07±15.41	60.06±16.41	76.32±22.48	43.14±20.27	77.64±9.09	53.81±24.24	< 0.001

P value was from one-way ANOVA. AFR: Africa Region; AMR: Americas Region; EMR: Eastern Mediterranean Region; EUR: Europe Region; SEAR: South-East Asia Region; WPR: Western Pacific Region.

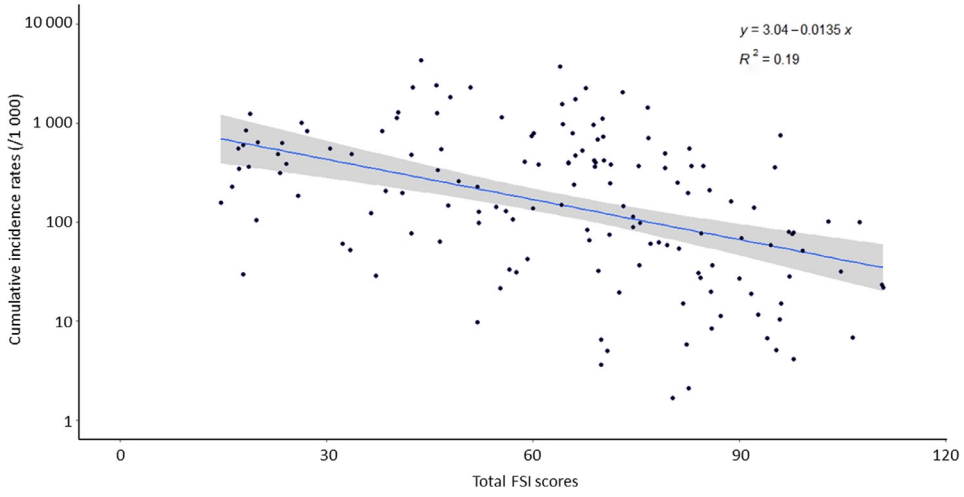

Fig. 1. Negative association of total Fragile States Index (FSI) scores and COVID-19 cumulative incidence rates (/1 000) in 146 countries in the world, up to September 16, 2020.
Data sources: COVID-19 cases were derived from WHO and population data from the World Bank.[1,17]

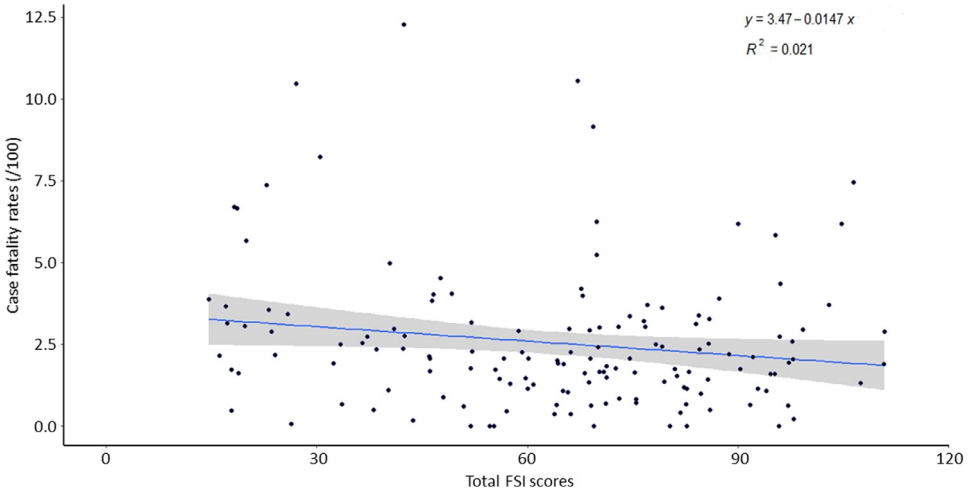

Fig. 2. Negative association between total Fragile States Index (FSI) scores and COVID-19 case fatality rates (/100) in 146 countries in the world, up to September 16, 2020.
Data source: Cases and deaths of COVID-19 were derived from WHO.[1]

Table 3
Results from multiple regression predicting COVID-19 cumulative incidence rates and case fatality rates with 12 Fragile States Index (FSI) indicators with data from 146 countries.

	12 indicators of FSI	Cumulative incidence rates (/1 000)			Case fatality rates (/100)		
		β	*t*	*P*	*β*	*t*	*P*
Cohesion indicators	C1: Security Apparatus	0.222	0.498	> 0.05	0.595	4.055	< 0.01
	C2: Factionalized Elites	−0.686	−1.389	> 0.05	0.028	0.172	> 0.05
	C3: Group Grievance	0.428	1.288	> 0.05	0.003	0.028	> 0.05
Economic indicators	E1: Economic Decline and Poverty	−1.392	−2.422	< 0.05	0.211	1.115	> 0.05
	E2: Uneven Economic Development	0.495	0.97	> 0.05	0.013	0.077	> 0.05
	E3: Human Flight and Brain Drain	−1.482	−3.238	< 0.01	−0.167	−1.113	> 0.05
Political indicators	P1: State Legitimacy	1.276	2.624	< 0.01	−0.008	−0.047	> 0.05
	P2: Public Services	−0.021	−0.031	> 0.05	0.079	0.353	> 0.05
	P3: Human Rights and Rule of Law	−0.387	−0.812	> 0.05	−0.447	−2.853	< 0.01
Social and cross-cutting indicators	S1: Demographic Pressures	0.155	0.27	> 0.05	−0.192	−1.018	> 0.05
	S2: Refugees and Internally Displaced Persons	−1.202	−3.204	< 0.01	0.193	1.566	> 0.05
	X1: External Intervention	1.094	2.719	< 0.01	−0.418	−3.16	< 0.01

Results from our intensive ecological modeling analysis indicated that countries that were generally more vulnerable were less likely to be affected by COVID-19, whether in terms of incidence or fatality. This finding was rather unanticipated. In theory, or at least according to the Fund for Peace, more fragile and more vulnerable countries are more likely to be affected by any infectious disease, vice versa. We discuss these findings further in the following two sections.

4.1. Consistent findings and implications

Despite the overall inconsistency between the FSI and COVID-19 burden, in-depth analysis revealed three fragile measures that did lead to increased risk of COVID-19, consistent with our expectations. These three measures were C1, which was associated with the risk of death, as well as P1 and X1, which were associated with cumulative incidence rates.

As a cohesion measure, countries scoring higher on C1 scores may have less secure healthcare service delivery. This may explain the prediction of a higher risk of COVID-19 deaths by a higher C1 score in our study. This is consistent with the impact of conflict on maternal and child health services delivery.[19] Countries with poor cohesion often face traditional security threats, such as political violence and armed resistance. The burden has been prevented by diverting extra attention and resources toward medical infrastructure. Fear and insecurity also lead to a shortage of health workers, which might have contributed to increased COVID-19 deaths.

Politically fragile P1 may increase the risk of COVID-19 infection. State legitimacy plays many roles in curbing the spread of infectious diseases, such as COVID-19. It reflects leadership and decision-making capacity as well as the ability to mobilize citizens to participate in coordinated action by political leaders and public health experts. Political and institutional legitimacy reflect whether a country has the functional and credible policy capacity to implement top-down governance.[20-21] People in countries with poor state legitimacy are more likely to have negative views on political leaders and health experts, engage in self-centered behaviors, and are less likely to adopt protective measures, such as wearing masks, social distancing, and vaccination.[22]

Societally, fragile measure X1 is another risk factor for COVID-19 infection. The impact of this fragile measure is evident. Lack of mutual support and international assistance will certainly weaken a country's resistance to a serious novel pandemic like the COVID-19.

These consistent findings have a significant role in the control and prevention of the current COVID-19 pandemic and in infectious disease control and prevention in the future. First, strategic plans and massive anti-pandemic interventions in any country must consider infrastructure for health security. Second, leadership development and evidence-based decision-making will be essential in inspiring confidence in people to take massive action against a pandemic. Ultimately, in fights against a pandemic, such as COVID-19, no single country can work in isolation to win the war; global health measures are paramount, such as mutual support and international assistance.

4.2. Unexpected or expected findings and implications

Most findings from this study were generally unexpected or consistent with our knowledge regarding infectious diseases, particularly COVID-19. Infectious diseases have long been used as markers of underdevelopment, poverty, and lack of hygiene. However, the findings of this study discovered that less fragile countries with high political, socioeconomic, and cohesion levels were at greater risk of COVID-19 infections and deaths. In other words, these countries are more vulnerable to infectious diseases than those that are more fragile based on FSI measures. For example, we identified a negative relationship between economic decline and COVID-19 infection, while poor countries often have higher tuberculosis prevalence.[23-24]

However, this seemingly contradictory finding appears to be reasonable based on a more precise measure of development. Two ecological studies, including one with provincial data from China[25] as well as another with national data from 28 European countries and state data from the USA,[26] demonstrated a significantly positive relationship between national gross domestic product (GDP) and cumulative COVID-19 cases. Results from these two studies are less likely to be affected by cross-entity differences in COVID-19 tests because each study focused on a considerably homogenous population. For example, the impact of the difference in COVID-19 tests between different provinces within China was minimal since all the tests were planned and delivered based on requirements.

With the strengths of the design and data, the researchers in these two studies argued that more developed countries have superior transportation systems shuttling people around. As revealed in another COVID-19 study using global data,[27] more developed countries with large, highly metropolitan cities are characterized by high population densities, facilitating viral transmission; moreover, their inhabitants have surplus dispensable income and time to spend associating with others, further promoting transmission, and they place personal values and freedom above the common, a big barrier for protection measures. Corroborated by these studies, our findings support the notion that the impact of socioeconomic and political measures can be more

important than healthcare in protecting people from diseases and promoting health.[24]

This finding has significant implications for both political leaders and health professionals. It is prudent to balance economic development and human health. It is absolutely imperative to develop a country in order to protect its people from COVID-19 or any other pandemic. All measures must be considered in terms of political and socioeconomic development to enhance a nation's resistance to infectious diseases, including high standards for modern transportation, prevention measures in infrastructure, and emphasis of individual and collective values, to name a few.

Finally, we propose revisions of the FSI measures. According to the current FSI measurements, countries that are more vulnerable to infectious diseases are classified as less fragile, while countries less vulnerable to infectious diseases are classified as more fragile. Apparently, this position seems untenable and lacks substantiation.

4.3. Limitations

This study has several limitations. First, although highly comprehensive, FSI measures may not capture the complexity of a nation's fragility level. This is particularly true when these measures are used to assess the vulnerability/resistance of a country. Second, the COVID-19 pandemic continues to evolve. The data included in this study cannot reflect the entire pandemic. Additional research is required at the time when the pandemic has ended. Third, total COVID-19 cases and deaths are potentially affected by the testing and reporting capacity of individual countries. Although studies on GDP and COVID-19 revealed a rather limited impact of testing and reporting capabilities, the impact cannot be ruled out completely. Caution is obligatory when interpreting the findings of our study. Finally, this study is an ecological research; thus, no causal relationship can be derived.

4.4. Conclusions

Despite the foregoing limitations, this study provided data supporting a novel trend in infectious disease epidemiology. In modern society, high levels of development place people at increased risk of infections. In addition to medical care and personal behaviors, national measures must be applied to increase the resistance of a country and its people to infectious diseases. Such measures are also required to end the devastating COVID-19 pandemic. The findings of this study provide support data for further studies with individual-level data to examine the mechanisms underlying the relationship between national fragility and vulnerability to COVID-19 and other infectious diseases.

Credit author statement

Yuqi Duan: Conceptualization, Methodology, Writing—original draft. **Junxiong Ma**: Conceptualization, Methodology, Data Curation, Formal analysis. **Yangmu Huang**: Conceptualization, Methodology, Writing—review & editing, Supervision. **Xinguang Chen**: Conceptualization, Methodology, Writing—review & editing. **Zhi-Jie Zheng**: Conceptualization, Methodology, Writing—review & editing, Project administration, Funding acquisition.

Funding

This paper was supported by the National Natural Science Foundation of China (NO. 72042014).

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. WHO Coronavirus Disease (COVID-19) Dashboard. World Health Organization website. https://covid19.who.int/. Accessed September 17, 2020.
2. Van Damme W, Dahake R, Delamou A, et al. The COVID-19 pandemic: diverse contexts; different epidemics-how and why? *BMJ Glob Health*. 2020;5(7):e003098. doi:10.1136/bmjgh-2020-003098.
3. Aitken T, Chin KL, Liew D, Ofori-Asenso R. Rethinking pandemic preparation: global health security index (GHSI) is predictive of COVID-19 burden, but in the opposite direction. *J Infect*. 2020;81(2):353-355. doi:10.1016/j.jinf.2020.02.001.
4. Haider N, Yavlinsky A, Chang YM, et al. The global health security index and joint external evaluation score for health preparedness are not correlated with countries' COVID-19 detection response time and mortality outcome. *Epidemiol Infect*. 2020;148:e210. doi:10.1017/s0950268820002046.
5. Organization for Economic Co-operation and Development. Fragile States 2013: Resource Flows and Trends in a Shifting World. https://www.oecd.org/dac/conflict-fragility-resilience/docs/FragileStates2013.pdf. Accessed September 9, 2020.
6. Wong MC, Teoh JY, Huang J, Wong SH. The potential impact of vulnerability and coping capacity on the pandemic control of COVID-19. *J Infect*. 2020;81(5):816-846. doi:10.1016/j.jinf.2020.05.060.
7. Sekhar CSC. Fragile states: the role of social, political, and economic factors. *J Dev Soc*. 2010;26(3):263-293. doi:10.1177/0169796x1002600301.
8. Bornemisza O, Ranson MK, Poletti TM, Sondorp E. Promoting health equity in conflict-affected fragile states. *Soc Sci Med*. 2010;70(1):80-88. doi:10.1016/j.socscimed.2009.09.032.
9. Quinn J, Stoeva P, Zeleny T, Nanda T, Tomanova A, Bencko V. Public health crisis: the need for primary prevention in failed and Fragile states. *Cent Eur J Publ Health*. 2017;25(3):171-176. doi:10.21101/cejph.a4671.
10. Bruckner C, Checchi F. Detection of infectious disease outbreaks in twenty-two fragile states, 2000-2010: a systematic review. *Confl Health*. 2011;5:13. doi:10.1186/1752-1505-5-13.
11. Sweileh WM. Health-related publications on people living in fragile states in the alert zone: a bibliometric analysis. *Int J Ment Health Syst*. 2020;14:70. doi:10.1186/s13033-020-00402-6.
12. Graves CM, Haakenstad A, Dieleman JL. Tracking development assistance for health to fragile states: 2005-2011. *Glob Health*. 2015;11:12. doi:10.1186/s12992-015-0097-9.
13. Guarino K, Voorman A, Gasteen M, Stewart D, Wenger J. Violence, insecurity, and the risk of polio: a systematic analysis. *PLoS One*. 2017;12(10):e0185577. doi:10.1371/journal.pone.0185577.
14. Spiteri J, von Brockdorff P. Economic development and health outcomes: evidence from cardiovascular disease mortality in Europe. *Soc Sci Med*. 2019;224:37-44. doi:10.1016/j.socscimed.2019.01.050.
15. Cinaroglu S. Politics and health outcomes: a path analytic approach. *Int J Health Plan Manag*. 2019;34(1):e824-e843. doi:10.1002/hpm.2699.
16. Fragile States Index. The Fund for Peace website. https://fragilestatesindex.org/data/. Accessed September 17, 2020.
17. World Development Indicators: people. The World Bank website. http://datatopics.worldbank.org/world-development-indicators/themes/people.html. Accessed September 9, 2020.
18. Chen X, Chen DG. *Statistical Methods for Global Health and Epidemiology Principles: Methods and Applications*. Switzerland: Springer; 2020. https://doi.org/10.1007/978-3-030-35260-8. Accessed September 9, 2020.
19. Mirzazada S, Padhani ZA, Jabeen S, et al. Impact of conflict on maternal and child health service delivery: a country case study of Afghanistan. *Confl Health*. 2020;14(1):38. doi:ARTN 3810.1186/s13031-020-00285-x.
20. Hartley K, Jarvis DSL. Policymaking in a low-trust state: legitimacy, state capacity, and responses to COVID-19 in Hong Kong. *Policy Soc*. 2020;39(3):403-423. doi:10.1080/14494035.2020.1783791.
21. Lægreid P, Rykkja LH. *Societal Security and Crisis Management: Governance Capacity and Legitimacy*. Switzerland: Springer; 2019 . https://doi.org/10.1007/978-3-319-92303-1. Accessed September 9, 2020.
22. Hill TD, Gonzalez K, Burdette AM. The blood of christ compels them: state religiosity and state population mobility during the coronavirus (COVID-19) pandemic. *J Relig Health*. 2020;59(5):2229-2242. doi:10.1007/s10943-020-01058-9.
23. Suk JE, Manissero D, Buscher G, Semenza JC. Wealth inequality and tuberculosis elimination in Europe. *Emerg Infect Dis*. 2009;15(11):1812-1814. doi:10.3201/eid1511.090916.
24. Suhrcke M, Stuckler D, Suk JE, et al. The impact of economic crises on communicable disease transmission and control: a systematic review of the evidence. *PLoS One*. 2011;6(6):e20724. doi:10.1371/journal.pone.0020724.
25. Mo Q, Chen X, Yu B, Ma Z. Levels of economic growth and cross-province spread of the COVID-19 in China [published online ahead of print, 2021 Jan 28]. *J Epidemiol Commun Health*. 2021; jech-2020-214169. doi:10.1136/jech-2020-214169.
26. Aycock L, Chen X. Levels of economic developement and the spread of coronavirus disease 2019 (COVID-19) in 50 U.S. states and territories and 28 European countries: an association analysis of aggregated data. *Glob Health J*. 2021;5(1):24-30. doi:10.1016/j.glohj.2021.02.006.
27. Oztig LI, Askin OE. Human mobility and coronavirus disease 2019 (COVID-19): a negative binomial regression analysis. *Public Health*. 2020;185:364-367. doi:10.1016/j.puhe.2020.07.002.

Edited by Yanjie Zhang