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Does the Public Health Security Capacity Provide Better Preparedness for Health Emergencies? A Cross-Sectional Analysis of 180 Countries During the COVID-19 Outbreak

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Original Research

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Abstract

Objectives: This study aimed to investigate the association between the health security capacities at the national level and preparedness for health emergencies in response to the COVID-19 outbreak.

Methods: Data were extracted from the GHS report to evaluate the global health security capabilities in 180 countries. A linear regression analysis was performed with COVID-19 outcomes, as measured by the rate of incidence and vaccination doses, CFR, and PCR tests. Spearman correlation was used among potential explanatory factors.

Findings: The GHS Index was inversely correlated with CFR and incidence rates, whereas it was positively associated with the vaccination and the PCR test rates. Countries with high health security capacities were significantly more likely to provide better preparedness for health emergencies in response to the outbreak. However, the vaccination doses' rate and the number of PCR tests were significantly differ depending on countries' income levels.

Conclusions: Although health security capacity is essential to control public health emergencies effectively, it cannot predict whether or how well a country will use them in a crisis. Policymakers should identify their risk factors and capacity gaps and take into consideration the building of health security capacities in national budgets for long-term public health preparedness.

With the increased interconnectedness and interdependence of people and countries, the emergence of the COVID-19 disease in late 2019 has had substantial impact on global public health. The outbreak thereby emerges as a prime and unprecedented example of a global health security threat by challenging health systems, disaster preparedness, and equal service delivery to all.[1] COVID-19 has become an important global Public Health Emergency (PHE), defined as a situation requiring immediate action to prevent the threat of an illness or health condition caused by the disease globally or regionally as it causes considerable mortality, economic, and social destructions.[2] Preparedness for PHEs plays a crucial role in mitigating outbreaks' adverse impacts.[3] Despite significant steps, like vaccination, face mask regulations, and travel restrictions, taken by countries to respond to the COVID-19 pandemic at national and global levels, over 422 million confirmed cases and over 5.8 million deaths were reported globally, as of February 20, 2022.[4] The rapid spread of highly contagious variants is an important sign that the number of cases and deaths will continue to rise.

The outbreak's threats and consequences have led to several substantial global efforts to enhance preparedness and response. In 2005, World Health Organization introduced the International Health Regulations (IHR), adopted by the World Health Assembly in 1969, and last updated in 2016, which is legally binding on 196 states parties to assess and report on the effectiveness of their public health emergency preparedness (PHEP) and response organization and plans. Furthermore, the IHR obligates States Parties to improve capacity in prevention, early detection, and timely and effective response to the international spread of disease.[5] Despite this important development, the findings of a prior report and study showed many countries remained dangerously unprepared to meet future epidemic and pandemic threats due to lacking some critical capacities to respond effectively to COVID-19.[6,7]

Similar to the 2014 Ebola virus disease outbreak in West Africa, the COVID-19 pandemic has also brought renewed attention to GHS capacity towards strengthening diagnostic and health capacity, coordinating the response, and information sharing.[8] In this context, The Global Health Security (GHS) Index, developed by the Nuclear Threat Initiative (NTI) and the Johns Hopkins Center for Health Security, is the first comprehensive indicator for providing an assessment of states' health security, and related capabilities across the countries that make up the States Parties to the IHR. Therefore, this index is an essential tool that improves understanding of the existing capacities that countries must prevent, detect, and respond to outbreaks,

whether naturally occurring, accidental, or deliberate to deal with the risks of global public health. In those ways, indices can be useful tools for public policy reforms.

With the high levels of morbidity and mortality worldwide and a highly contagious pathogen, the COVID-19 disease has stressed the increasing importance of PHEP, along with policies and effective health care systems in many countries, including low- and middle-income countries.[9] For the first time, human development indicators have declined drastically during the outbreak. In 2021, even with the availability of COVID-19 vaccines and the economic recovery in many countries, the crisis increased ill-health, with a drop in life expectancy at birth. Hence, the Human Development Index (HDI), the composite indicator of a healthy life, education, and income level, has yet to recover about 5 years of progress, according to a report in 2022.[10] Based on recent reports, countries continue to suffer harm from the COVID-19 pandemic as a result of insufficient health security capacities that differ markedly from low-income countries to high-income countries.[1,4,6,10] Therefore, the present study aimed to evaluate the association between public health preparedness to prevent, detect, and respond to infectious disease threats at the national level and health security capabilities, as measured by the GHS index, in relation to the outcomes of the COVID-19 outbreak, as measured by the rate of incidence, vaccination doses, PCR tests per population, and the CFR (case-fatality rate) in 180 countries using the recent global data. A research question was used for the study: (1) Are countries with higher health security capacities significantly more likely to have better preparedness for health emergencies in response to the COVID-19 disease control? Since the external factors, such as HDI, health expenditure, and country-level income, as well as population density, may potentially influence global health security preparedness, the second research question was also used: (2) To what extent do these potential explanatory factors predict the COVID-19 outcomes?

Methods

Data source

Although several instruments exist for measuring public health security capacities, the GHS Index uniquely offers a comprehensive assessment of preparedness for health emergencies gaps in all 195 States Parties to the IHR. Therefore, this study recruited data on 180 countries and territories around the world from the most recent GHS index annual report (December 2021),[6] conducted between August 2020 and June 2021 to observe the regional and global level of health security in the context of prevention, and detection/ reporting, as well as rapid response, health system facilities and plan, norms, and risk environment against the COVID-19 outbreak. A total of 57 high-income countries like Argentina, Denmark, Latvia, Portugal; 49 upper-middle-income countries like Paraguay, Turkey, Romania; 39 lower-middle-income countries like Kenya, Lesotho, Mongolia; and 35 low-income countries like Mali, Ethiopia, and Burundi were included in the study.

Global Health Security Index is designed to inform leaders of the foundational elements that are necessary to prepare their countries for future outbreaks and where they should prioritize planning and invest durable funding. The 2021 Global Health Security Index assesses countries across 6 categories, 37 indicators, and 171 questions using publicly available information. These 6 categories include prevention (preventing the emergence or release of pathogens), early detection and reporting (early detection and reporting for epidemics and potential international concern), rapid response (timely response and mitigation of the spread of a pandemic disease), and health systems (sufficient and strong health system for the treatment of patients and protection of health workers), as well as compliance with international standards and norms (commitments to improving national capacity, financing plans to address gaps, and adhering to global norms), and the risk environment (general risk environment and country vulnerability to biological threats). A score of 100 in the Index does not indicate that a country has perfect health security conditions, and a score of 0 does not mean that a country has no health security capacity. The scores of 0 and 100 represent the lowest or highest possible scores, respectively, of favorable health security conditions.[6]

In this study, country-level data on health expenditure (% of Gross Domestic Product-GDP) of each country per capita and country classifications by income level ($US billion) in 2021 from World Bank open data,[11] Human Development Index (HDI) from the United Nations Development Programme (UNDP) in 2020,[12] and the population density of each country in 2022 from the World Population Review,[13] were retrieved to examine the association between variables and outcomes.

Outcome variables

To examine the preparedness for global health emergencies, 4 COVID-19 outcome variables were included in the study. Publicly available data on COVID-19 related to the main health outcomes consisting of the incidence rate per 100000 population, the CFR, the vaccination dose rates per 100000 population, and the number of PCR tests per 1000 population (as of February 10, 2022) were extracted from websites such as the Johns Hopkins Centre for Systems Science and Engineering (CSSE),[14] and the World Health Organization (WHO).[4]

CFR was used in the study to measure the severity of disease during a specified period by country based on the COVID-19 related deaths that confirmed positive test results. The CFR is a ratio between deaths and confirmed or reported cases of a disease within a given time. This measurement can provide information about the efficacy of public health-related interventions and the prognosis of the outbreak.[15–17] Also, as an outcome variable in the study, the cumulative vaccination dose rates in a country can give insight into the sufficient and strong health system in the context of public health security capacity, particularly with respect to their preparedness for infectious disease emergencies.[6,18]

Statistical analysis

The 2021 Global Health Security Index comprises 6 main categories related to each country's health security conditions. Modeling the sub-indicators, indicators, and categories in the Global Health Security Index results in overall scores of 0 - 100 for each country. The overall GHS index (with each of its indicators), population density, country-specific health expenditure (% of GDP), and HDI with each outcome variable were applied with multivariate regression analysis, with 95% confidence intervals (95% CI) to determine the parameters of the most predictive of outcome variables. The interaction and multicollinearity among these covariates were also examined. Regression models were constructed for each outcome whilst controlling for all the predictor variables to explore the association between the explanatory variables and the outcomes of interest. All P values < 0.05 were considered statistically significant. Spearman correlation among potential explanatory factors was used. Correlation and regression analyses

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Table 1. Spearman correlation among potential explanatory factors

Variables	Incidence rate[c]	CFR	Vaccination rate[d]	PCR Test rate[e]
GHS Index	−0.56**	−0.22**	0.65**	0.27**
• Prevent	0.55**	−0.18*	0.62**	0.32**
• Detect	0.34**	−0.17*	0.49**	0.16*
• Respond	0.45**	−0.19*	0.52**	0.18*
• Health	−0.55**	−0.13	0.58**	0.25**
• Norms	−0.23**	−0.07	−0.26**	0.13
• Risk	0.67**	−0.39**	0.77**	0.32**
Income class[a]	−0.67**	−0.32**	0.74**	0.36**
Health expenditures	0.34**	0.08	0.30**	0.12
HDI	0.71**	−0.31**	0.80**	0.37**
Population density[b]	0. 10	−0.09	0.09	0.03

*$P < 0.05$.
**$P < 0.01$.
[a]Income class includes (1) High, (2) Upper-middle, (3) Lower-middle, and (4) Low.
[b]People per square km of land area.
[c]per 100000 population.
[d]doses per 1000 population.
[e]per 1000 population.

were performed with the Statistical Package for Social Sciences (SPSS) version 26.0 (SPSS Inc., Chicago, IL, USA).

Results

Factors associated with COVID-19 outcome variables

From the Spearman correlation matrix (Table 1), the GHS Index was correlated with COVID-19 related outcomes, including incidence rate, and the CFR, as well as vaccination rate, and PCR test rate. Each category of the GHS Index was correlated with these outcome variables. Although the income class of country was inversely correlated (r = - 0.67; $P < 0.01$) with incidence outcome, the strongest association was with HDI (r = 0.71; $P < 0.01$). There was no correlation between the population density variable and COVID-19 outcomes.

Factors affecting COVID-19 outcomes in the context of public health security capacities

Tables 2 - 5 show the findings of the multivariate regression analyses to identify the association between COVID- 19 related outcome variables and the overall GHS index score, its 6 categories, plus the various outcome variables. Countries with higher GHS Index were significantly more likely to have lower the CFR (β coefficient - 0.13; 95% CI [- 0.20 - 0.04*]; P* = 0.01) (Table 3, Model 3), and the incidence rate (β coefficient - 39; 95% CI [- 70 - 8]; $P = 0.01$). Furthermore, higher health security capacity was significantly more likely to provide better the vaccination doses rate per 100000 population (β coefficient 131; 95% CI [67 195]; $P = 0.01$) and the PCR tests per 1000 population (β coefficient 13; 95% CI [4 23]; $P = 0.001$). The incidence rate per 100000 population was significantly lower in countries with 'high' (β coefficient - 18; 95% CI [- 25 - 11]), 'upper- middle' (β coefficient - 14; 95% CI [- 20 - 6]), 'lower- middle income' (β coefficient - 0,11; 95% CI [- 17 - 3]) (all $P < 0.001$). However, the vaccination doses rate per 100000 population and the PCR tests per 1000 population significantly differed depending on the countries' income level

Table 2. Regression analyses on the incidence rate per 100000 population as of February 10, 2022 (n = 180)

Variables		Model 1			Model 2			Model 3		
		Coef.	95% CI	*P*	Coef.	95% CI	*P*	Coef.	95% CI	*P*
GHS Index								−39.986	−70.021	−8.592	**0.01**
1. Prevent					134.953	−5.715	275.621	0.06			
2. Detect					−106.718	−224.61	11.175	0.07			
3. Respond					6.417	−155.908	168.741	0.93			
4. Health					−161.765	−300.088	−23.442	**0.02**			
5. Norms					−145.949	−271.551	−20.347	**0.02**			
6. Risk					386.066	270.716	501.417	**<0.001**			
Income Class	High Income	−18.478	−25.113	−11.156	**<0.001**						
	Upper- Middle	−14.661	−20.546	−6.681	**<0.001**						
	Lower- Middle	−11.379	−17.697	−3.887	**<0.001**						
	Low Income	Reference group									
Health expenditure of GDP		55.351	14.385	97.317	**0.02**				523.605	39.56	1007.649	**0.03**
HDI		233.251	165.727	301.775	**<0.001**				35843.406	11509.08	0177.732	**0.004**
Population Density*		−0.621	−2.426	1.184	0.49				−0.591	−2.402	1.221	0.52

*People per square km of land area; Coef, Coefficient; CI, Confidence Interval.

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Table 3. Regression analyses on the Case- Fatality Ratio as of February 10, 2022 (n = 180)

Variables		Model 1 Coef.	Model 1 95% CI		Model 1 P	Model 2 Coef.	Model 2 95% CI		Model 2 P	Model 3 Coef.	Model 3 95% CI		Model 3 P
GHS Index										−0.125	−0.201	−0.048	**0.01**
1. Prevent						0.001	−0.024	0.027	0.99				
2. Detect						−0.021	−0.045	0.003	0.89				
3. Respond						0.007	−0.026	0.040	0.66				
4. Health						0.026	−0.002	0.054	0.06				
5. Norms						0.019	−0.007	0.044	0.14				
6. Risk						−0.063	−0.087	−0.040	<**0.001**				
Income Class	High Income	−76.193	−128.331	−24.783	**0.01**								
	Upper- Middle	−53.447	−87.501	−19.665	**0.03**								
	Lower- Middle	−31.133	−48.187	−14.558	**0.02**								
	Low Income		Reference group										
Health expenditure of GDP		−0.008	−0.075	0.059	0.81					−0.025	−0.093	0.042	0.45
HDI		−2.155	−3.365	−0.945	**0.002**					−3.766	−5.544	−1.988	<**0.001**
Population Density*		−1.653	−3.471	0.963	0.23					0.026	−0.377	0.430	0.12

*People per square km of land area ; Coef, Coefficient; CI, Confidence Interval.

(Table 4 - 5). Among the 6 categories in the GHS Index, 'overall risk environment and country vulnerability to biological threats' was significantly associated with a lower likelihood of the CFR (β coefficient - 0,06; 95% CI [- 0,08 - 0,04]; $P < 0.001$) (Table 3); it was however not associated with the PCR tests per 1000 population. The category 'prevention of the emergence or release of pathogens' (β coefficient 959; 95% CI [171 1747]; $P = 0.01$) and 'early detection and reporting epidemics of potential' (β coefficient 877; 95% CI [216 1538]; $P = 0.01$) were positively associated with the vaccination doses rate per 100000 population (β coefficient – 0.06; 95% CI [- 0,08 - 0,04]; $P < 0.001$) (Table 4, Model 2). Country- specific HDI was significantly associated with all COVID- 19 outcomes (Table 2- 5, Model 3). Particularly, countries with a high HDI was lower CFR caused by COVID- 19 (β coefficient - 2; 95% CI [- 3,3 - 0,9]; $P = 0.002$) (Table 3, Model 1).

Discussion

This study included 180 countries worldwide and concluded that a higher GHS index was significantly associated with better preparedness for health emergencies in terms of the COVID-19 outbreak. This finding is consistent with the prior report showing that infection prevention measures during COVID-19 were more effective in countries with higher health security.[19] Despite significant advances in public health measures and efforts to respond to the spread of infectious diseases, countries worldwide have continued to suffer harm from the COVID-19 pandemic due to insufficient health security capacity. A global health report in 2021 revealed that a large number of countries appear vulnerable to future epidemic and pandemic threats at various levels due to a lack of preparedness of health systems and policy in global emergencies situations.[6] In fact, it is difficult to say that these findings have only been recently revealed. A 2018 global survey conducted by WHO of the 54% of member states that responded, on pandemic preparedness also found that while 88% had a national pandemic influenza preparedness plan, 48% of those were developed before the 2009 influenza pandemic, and had not been updated since then.[20]

The relationship between the income status of countries and the incidence of infectious disease has been discussed by many studies. While some suggested that GDP per capita was not associated with the incidence rate of infectious disease,[21] others found a negative association between income and the prevalence of COVID-19 disease.[22] Most of these studies used aggregated data geographically, varying from small areas to countries, or limited individual-level samples. Furthermore, depending on the infection prevention and control measures, various factors affect the emergence and spread of an outbreak within countries and regions.[17,23] In this study, countries with high-level income were significantly more likely to have lower incidence rates and CFR compared to low-income countries. This also accords with previous findings from the study in 2021, which showed that the cumulative incidence and mortality rates per 100000 population were significantly and positively associated with country-level income.[24] Although the exact causes for the higher CFR and incidence rate in countries with various income levels are not clear, there are possible explanations for this result. To mitigate the effects of a COVID-19 pandemic, the ease of implementing various possible public health interventions in high-income countries, such as isolation, and quarantine, as well as social distancing, is a challenge for low and middle-income countries. Second, the external factors, including lack of access to healthcare, and poor socio-economic conditions, as well as insufficient hygiene, inadequate sanitation, and economic disparity, for the low and middle-income countries are likely to increase the incidence rate of disease. However, there are different findings in the literature. A study that assessed the CFR across different income-level countries worldwide during the outbreak showed the overall CFR for the high-income countries was 5.0%, compared with a CFR of 2.8% for low-income countries.[25] A likely explanation is that the lack of adequate testing measures and missing case report may have contributed to the low CFR reported from low and lower-middle-income countries.[26]

The framework for the equitable allocation of COVID-19 vaccines globally recommended by WHO,[1] whereas a country's income level is still a key factor in determining vaccine access.[18] In order to ensure equity in vaccine access, increasing the supply and distribution of COVID-19 vaccines need to be achieved, especially in low-and middle-income countries,[10] because inequalities in vaccine distribution have resulted in faster vaccination rates in

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Table 4. Regression analyses on the vaccination doses rate per 100000 population as of February 10, 2022 (n = 180)

Variables		Model 1				Model 2				Model 3			
		Coef.	95% CI		*P*	Coef.	95% CI		*P*	Coef.	95% CI		*P*
GHS Index										131.674	67.442	195.396	**0.01**
1. Prevent						959.623	171.417	1747.828	**0.01**				
2. Detect						877.48	216.894	1538.066	**0.01**				
3. Respond						−273.934	−1183.488	635.620	0.55				
4. Health						−8.815	−783.881	766.250	0.94				
5. Norms						−1753.136	−2456.922	−1049.351	**<0.001**				
6. Risk						3314.921	2668.576	3961.265	**<0.001**				
Income Class	High Income	142.541	101.601	183.178	**<0.001**								
	Upper- Middle	128.931	86.440	169.336	**<0.001**								
	Lower- Middle	122.336	79.378	165.337	**<0.001**								
	Low Income		Reference group										
Health expenditure of GDP		1501.121	−1170.329	4172.569	0.26					1408.898	−1332.132	4149.928	0.31
HDI		38331.114	3352.586	74102.643	**<0.001**					37479	30278.082	44679.640	**<0.001**
Population Density*		9.107	−1.132	19.345	0.08					9.163	−1.112	19.438	0.08

*People per square km of land area ; Coef, Coefficient; CI, Confidence Interval.

high-income countries relative to low-income countries.[18] Consistent with the findings of previous studies,[27] this study indicated that country-level income status is an important factor in vaccine access in the context of GHS. In response to the COVID-19 pandemic, however, a 2021 study found that the GHS index is a poor predictor of vaccine rollout, based on the percentage of the population that was fully vaccinated in OECD countries.[18] A possible explanation for this might be the different vaccination strategies adopted by each country. The relatively small number of COVID-19 cases in Australia, for example, may have resulted in the low vaccination rate.[28] Furthermore, inequities in vaccine administration, poor socio-economic determinants of health at a country-level, high vaccine hesitancy rates among the population, insufficient financial structure, and government mistrust could be potential reasons for this association.[9,18,27–29] With the vaccination doses rate, access to diagnostic testing for the COVID-19 PCR (polymerase chain reaction) tests is an essential step to reduce the disease transmission and appropriately manage those affected by the outbreak in effective responses to global health security challenges.[6,18,29] The global health security report in 2021 concluded that during COVID-19, countries with higher income levels were better emergency response capacities, such as vaccines and diagnostic tests.[6] As expected, the findings of the present study broadly support this report. The result may be explained by the fact that the greater the allocation of financial resources to cover the costs, the likelihood the impact of countries' overall response capability to health emergencies, such as COVID-19.

The level of human development index, with longer life expectation, better education, and better living standard, can portray the level of preparedness for countries to respond effectively and cope with the impacts of the COVID-19 crisis. The report on new threats to public health security in 2022 concluded that the human development levels of many countries, as measured by the COVID-19-adjusted HDI, remained well below pre-COVID-19 levels.[10] A recent study in 2021 suggested that the number of COVID-19 related deaths was inversely associated with HDI.[30] However, it is surprising to note that HDI is associated with a higher incidence rate per 100000 population in the present study. The reason for this might be the distinctive characteristics of the population worldwide, with more chronic disease, cigarettes consumption, and poor socioeconomic backgrounds. A further study is required to examine the association between components of HDI and COVID-19 related outcomes, such as infection and fatality rates.

Some limitations should be considered. The GHS Index which is not a predictive tool, provides an assessment of global health security and the level of preparedness of countries worldwide and is a new tool that improves understanding of countries' existing capacities to prevent, detect, and respond to outbreaks. This Index uses only publicly available data sources from each country and published governmental information. Therefore, there is a possibility of inaccurate data regarding public health security capacities reported from each country. Second, many factors influence the scoring system of health security capacity in a country, including political decision making, the type of disease, its mode of infection, and even random chance.[6] In this context, the GHS index is complex and only includes factors that can be measured and have transparent, such as the number of hospitals, availability of a national public health emergency response plan, vaccination rates, laboratory capacity for detecting priority diseases, and public healthcare spending levels per capita.

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Table 5. Regression analyses on the PCR tests per 1000 population as of February 10, 2022 (n = 180)

Variables		Model 1				Model 2				Model 3			
		Coef.	95% CI		*P*	Coef.	95% CI		*P*	Coef.	95% CI		*P*
GHS Index										13.428	4.849	23.132	**0.001**
1. Prevent						1.284	−0.042	2.609	0.06				
2. Detect						−0.338	−1.442	0.766	0.54				
3. Respond						−0.428	−1.953	1.097	0.58				
4. Health						−0.026	−1.322	1.270	0.71				
5. Norms						−0.388	−1.575	0.798	0.51				
6. Risk						1.071	−0.065	2.207	0.07				
Income Class	High Income	42.541	23.601	60.178	**0.002**								
	Upper- Middle	28.931	15.440	41.336	**0.001**								
	Lower- Middle	22.336	11.378	33.337	**0.001**								
	Low Income		Reference group										
Health expenditure of GDP		−0.134	−4.688	4.419	0.95					0.301	−4.486	5.089	0.75
HDI		173.124	96.410	249.839	**<0.001**					200.521	81.521	319.524	**0.001**
Population Density*		−0.002	−0.018	0.014	0.79					−0.002	−0.018	0.992	0.68

*People per square km of land area; Coef, Coefficient; CI, Confidence Interval.

Third, the quality of COVID-19-related data might be influenced by the different reporting systems and mechanisms which are unique for each country.

Conclusion

The present study aimed to examine the association of the level of public health security capacity in the context of the GHS Index with the current COVID-19 outcome variables, including incidence rate, the CFR, and the vaccination doses' rate, as well as the PCR tests. The findings of this study have shown that countries with high health security capacities are significantly more likely to provide better preparedness for health emergencies in response to the COVID-19 disease control. The ongoing COVID-19 pandemic has revealed the importance of strengthening health emergency preparedness and response capacities to prevent, detect, and respond to disease outbreaks before they become epidemics or pandemics. Leaders and policymakers at national and local levels should identify their risk factors and capacity gaps and take into consideration the building of health security capacities in national budgets for long-term public health preparedness.

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