Hierarchical Model of Multi-level Index to Assess Local Resilience Capability in COVID-19

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Research Article

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Abstract

Background

Globally, there have been 212,544,565 confirmed cases of Corona Virus disease 2019 (COVID-19), including 4,441,428 deaths by 24 August 2021, reported to WHO. Facing the global pandemic of COVID-19, countries and regions have implemented different policies and taken different non-pharmacological interventions (NPIs) according to their own circumstances. However, the quantitative assessment of national policies and local resilience capabilities is a huge challenge.

Methods

In order to assess interventions and improve local resilience from a comprehensive perspective, this study aims to establish a multi-dimensional and dynamic prevention and control system. The main body of the system is an index system. To make our evaluation system more scientific and useful, the comparative study with several widely used tools or lessons is conducted to report what they have done. Then analytic hierarchy process (AHP) is used to set up the framework under the concept of a multi-level strategy of public health management. Indicators in the system are determined by literature research and expert interviews.

Results

Emergency capability assessment includes building a well-established system, execution of the system, and measurement. The well-established system exhibits several characteristics: 1) considering indicators about whole-of-society involvement, including country-, city-, local community- and individual-level; 2) improving capability at multi-phases, from the preparedness ability to response ability; 3) at both policy level and implementation level. Categories of containment and closure, response in economic system, and response in public health system constitute the main body of the framework. The well-established system does not necessarily apply to all scenarios, and the actual situation should be taken into consideration in the process of implementation/execution. At the stage of measurement, the case of Wuhan/Hubei response is introduced to implement and test our system. Empirical researches will be conducted to verify the index system quantitatively in our future research.

Conclusions

Our index system can assess national policies and capabilities quantitatively. When enough data are available, it will become a tool to assess the local resilience capability for countries or regions.

1 Background

COVID-19 has affected most, if not all, countries around the world. Different countries' profiles are quite different. Some have rarely domestic-reported cases for a fairly long period, while some have a lot of reported cases per day or undergo several peaks again and again in waves [1]. Trends of the pandemic have varied a lot among countries and even in the same country. The apparent discrepancy also presented in the rates of attack and case fatality. The consensus on the occurrence disciplinary and the evolution of a pandemic was depicted by WHO in 2017 [2](Fig1). The emergency management includes preparedness phase, response phase, and recovery phase. Similar to other pandemics, COVID-19 also shows the same pattern – interpandemic, alert, pandemic, and transition.

Since COVID-19 was reported at the end of 2019, countries and regions faced different levels of risk at different phases and presented their own transmission characteristics. For that reason, they were strongly encouraged to release their own policies and implement different non-pharmacological interventions (NPIs) [3]. To summarize, there are six kinds of response strategies worldwide regarding the COVID-19 (Table 1): first, keeping zero out all the infective cases in the country (EXCLUSION); second, making every effort to eliminate community transmission (ELIMINATION); third, suppressing the attack rate of transmission to avoid squeezing of the local medical resources (SUPPRESSION); fourth, MITIGATION, a relatively mild control measures comparing with SUPPRESSION; fifth, no desire or ability to control the pandemic, known as NO SUBSTANTIVE, which mostly happens in some low-income countries and territories; at last, coexisting with COVID-19 (COEXISTENCE), such as England and Singapore. The strategies and measures should be also dynamically adjusted according to the real time situation.

Both effective response measures and better preparedness are of great significance for the outbreak controlling [5]– especially when many countries move towards the stage of post pandemic with policies liberalization and restrictions cancellation. Different countries release different policies to respond to COVID-19. And some are effective, while others don't obtain obvious effect. It's a question how to assess what kinds of measures might be effective and what is well preparation for another wave or next pandemic. A relative perfect framework will be essential to improve preparedness ability, enhance resilience, and support response to COVID-19 across the world. It can also tell decision-

makers how to respond and in what extent these measures should be implemented. It is unclear whether other countries can copy the relative effective experience, such as implementing the stringent measures (e.g., lockdown) which China eventually adopted.

A hierarchical index system will be constructed with a combination of many indicators and involving multiple levels. Many circumstances should be considered for developing local resilience capability, including local culture background, popular values, people's trust in their government, institutional mechanism of public health, local actual situations, and the information provided by global or their own assessment. They are related to 5 systems which are: a) strategy, vision and leadership, b) intelligence, c) management of processes, systems and planning, d) coordination and communication of operations, and e) delivery of operations [4]. The study can provide decision-making support for other countries'/areas' response, and help them understand if it is safe to 'open up' or whether they should 'close down' in their fight to tackle the coronavirus, and most of all, get well-prepared to the next coming pandemic.

2 Related Work

With the global pandemic of COVID-19, measures and policies are being taken around the world. Researchers are exploring how to develop local government resilience capability, such as, what government measures should be taken or what preparedness activities should be implemented, and how to evaluate their effectiveness and establish local resilience capability.

Infectious disease issues involve three levels, which are disaster (COVID-19), disaster carrier, and emergency management [6]. The relatively direct approach is the virus-level interventions, mainly including pharmaceutical interventions (e.g., clinical treatment, the effective vaccination, *etc*). An effective vaccine has a big significance for interrupting the spread of epidemic. Many researches tend to explore the effect of vaccine and different vaccination strategies on COVID-19 [7, 8]. However, vaccines are not enough in some countries or areas and their distribution is not inequitable [9].

NPIs, mainly disaster carrier- and emergency management-related, are as the primary tool for infection control [3, 10], especially when there is no effective vaccine. Government across the world have implemented a wide range of NPIs. The WHO's response focuses on the public health level, such as infection prevention and control, laboratory testing, national capacities review tool, risk [communication and community engagement](#), disease commodity packages, travel advice, clinical management, and surveillance case definitions (10-12 January 2020), launching the COVID-19 Solidarity Response Fund (13 March 2020), issuing guidance on the use of masks, contact tracing, considerations in adjusting public health and social measures (e.g., large-scale movement restrictions, commonly referred to as 'lockdowns') [11], *etc*. Many researches discuss the effect of different measures on the control of COVID-19, including limiting gathering sizes, closing entertainment, businesses or educational institutions, stay-at-home, wearing masks, teleworking, keeping social distance, *etc*[12-14].

Unlike the response of WHO, an important aspect of the ISO 22325 is to enhance partnership, coordination and cooperation within an organization and with other agencies and sectors, which highlights the emergency prevention and control at the society level [15]. The response of infectious diseases like COVID-19 needs the support of whole society, especially local community participation (e.g., [living material](#) support, social protection, mental health support) and public engagement (e.g., keeping stay-at-home, mask wearing, teleworking, self-isolation). In turn, the local community and population levels affect the effectiveness of policies, and ultimately determine the effectiveness of epidemic control to a large extent [16]. The deep spiritual and cultural level of human social behavior, as well as the vaccination status should be also taken into account in some researches. Local social aspects should be taken into account in order to contain the pandemic[17]. Qing *et al.* has proposed a multi-level system of public health emergency management, namely, values - beliefs, rules, and institutions - epidemic prevention measures - urban system operation and governance[18].

Many researches focus on the effectiveness evaluation of several response measures. There are not many available methods or tools to compare policy responses from the perspectives of comprehensive measures. The effectiveness of nine containment and closure policies on the response of COVID-19 is assessed for 170 countries[19]. The randomized controlled trials, compartmental models, and spillovers are used to evaluate which interventions work best in a pandemic [20]. The usefulness of school closure at the global level is explored through index cases of COVID-19 in Africa [21].

The whole-of-society involvement is required in the preparedness and response of global pandemic. Response from the country (including country, state, and regional government), local community, and individual levels is equally important. There are several reasons resulting in peaks again and again in America, such as the commands/coordination from the country or state level are relatively independent. The number of cases falling fast in China results from the powerful grassroot community and the public who do the bidding of the government commands. Therefore, COVID-19 response requires the comprehensive measures and well preparedness at all levels. However, very few studies point out the concept of multi-levels and consider indicators at these levels together. They focus on either partial levels or partial indicators at a certain level, since the acquisition of relevant data is quite difficult.

The response of COVID-19 can't just think about the measures in the public health level. Basic living needs and community support have big significance for the effective response and the building of resilient societies [22]. If the community can guarantee the basic living necessities for their resident, measures, such as stay-at-home orders, social distancing, and self-isolation can be executed more effectively. As important components of resident, social protection for the poor and vulnerable households should be taken into account [23]. The practical experience illustrates the great importance of the guarantee, community support, social protection, *etc.* for COVID-19 response. They have been taken into account in the building of our index system. Simultaneously, most of researches and experience aim at the response phase. The business control theory tells that emergency management should be considered as a continuous process. It has great significance for the control of COVID-19 to consider these multi-level preparedness and response measures comprehensively.

3 Methodology

Based on the framework of emergency capability assessment of ISO 22325 [16], the process is divided into three steps. First, a well-established system (similar to a handbook) should be built, which includes all levels and all potential indices. Second, the process control is introduced to discuss the implementation/execution of the system, i.e., how to use the well-established system according to the actual situation. The third step is the measurement of the system through test and exercise. The comparative study and analytic hierarchy process (AHP) are used to build the basic framework of our index system. Then a comprehensive index system is established based on literature research and expert interviews. At last, a practical case will be used to illustrate the implementation and measurement of our system.

3.1 Comparative Study of Related Work

To make our evaluation tool more scientific and useful, the comparative study with several widely used tools or lessons is conducted to report what they have done and form our evaluation framework, without making any judgement on the effectiveness of the approaches or recommending any specific tool. It's a question to select the compared tools (i.e., the bases of our study), and some principles are listed as below:

- Widely used or referenced in the evaluation of COVID-19 response measures,
- Demonstrated by experts,
- Similar in the purpose and scope,
- Different in internal relation,
- Comparable in indicators,
- Unified in concepts to ensure comparability.

Four analogical evaluation tools or lessons were finally selected, including Oxford COVID-19 Government Response Tracker (OxCGRT, University of Oxford), Four Levels of Response Measures (FLRM, Tsinghua University), Universities' Preparedness and Response Towards Multi-Hazards (UPTRMH, International Institute of Disaster Science (IRIDeS) at Tohoku University, Keio University, and Tsinghua University), and the Manchester Briefings COVID-19 (ManBC, The University of Manchester). They either track in a systematically way by evaluating the time and stringency or hold periodically seminar sharing their experience, cases, and lessons in response to COVID-19. Above tools have similarities and commonalities in the aim of evaluating and prompting the response for COVID-19. However, they have unique characteristics to serve for their own evaluation purposes, and many aspects are different, such as concept, aim, framework, and indicators. The detailed information is described as shown in Fig2.

OxCGRT developed by Oxford, is a relatively perfect framework to track and compare policy responses around the world. It has evolved several versions with the development of COVID-19 and policies, starting with 9 indicators, to 20 indicators, then to 23 indicators. Empirical researches have been conducted based on the data from more than 180 countries to record the number and strictness of government policies. The tool pays more attention on the public health system and some closure/containment measures at the city level and during the response phase. It mainly focuses on policy making, rather than the implementation of policy. For example, indicators affecting policy execution (i.e., the public acceptance and the reaction of policies) are not taken into consideration in this tool [24-27].

FLRM conducts a correlation analysis between the strictness of government response measures and epidemic trends of COVID-19. It consists of seven categories with 51 indicators to assess the measures from 13 selected countries. It is a whole-of-society approach, including country, city, community, and individual levels. The individual involvement is taken into account to obtain the public support during the fight to COVID-19. However, the system is not built, and the framework and indicators are relatively incomplete.

UPTRMH keeps a record of what happened and success/failures to learn from the experience and prepare for the next hazardous events. 26 case studies from 13 countries and regions are analyzed in this project. It focuses on the response of a typical community – campus, to

strengthen their current strategy and plan to reduce multiple disaster risks and respond efficiently [28], which can increase the understanding of the response at local community level.

The Manchester Briefings on COVID-19 (ManBC) are series of international lessons and examples which may prompt thinking on the recovery from COVID-19, as well as other information from a range of sources[4]. It can provide experience for government emergency planners and resilience officers through reporting what others have done. The effect of community participation and support on the COVID-19 response is discussed, such as public leadership, social protection, volunteer policy, and partnerships [29].

Our index system is intended to become an assessment tool for countries or regions. Several requirements should be satisfied. 1) Indicators should involve multi-levels, including country-, city-, local community- and individual-level. 2) Both policy level and implementation level are taken into account. 3) The assessment is treated as a continuous process, including response phase and preparedness phase. 4) Community support and individual involvement will be considered in our system. 5) Empirical researches will be conducted in our future research when relevant data/database is supplemented.

3.2 Analytic Hierarchy Process (AHP) for Setting Up the Index

AHP is a decision-making method that decomposes the elements into goals, criteria, programs, and other aspects. Both qualitative and quantitative analysis can be carried out. AHP is used to set up the framework under the concept of a multi-level strategy of public health management. It is a multi-level hierarchy which includes Level, Category, and Indicators. The Level consists of country, city, local community, and individual from top to bottom. There are several categories for each level based on the function of each level. For example, the Country level has the power to express commands and deploy national resources (e.g., sending medical teams to key areas). Similar to the OxCGRT, containment and closure, response in economic system, and response in public health system constitute the main body of the framework. Containment and closure are replaced by the category of command, control and coordination in the Country level. The participation and support of local community have big significance through current researches and practical experience. Individuals are only responsible for implementing measures, including wearing masks, staying at home, keeping social distancing, *etc.* The Individual level is not classified into categories further. Each Category includes several indicators through literature research and expert interviews, which will be specified in the next section. The hierarchical model is defined as the hierarchical index system assessing local resilience capability in COVID-19, as shown in Fig 3.

4 Indicators Of Multi-level Index System

Each category at different levels is refined into several indicators further. Literature research and expert interviews are used to determine Indicators. Based on business continuity management, better preparedness also can enhance resilience of regional or local government, which determines the effectiveness of response measures when an emergency occurs to a certain degree. Therefore, the preparedness and response should be considered integrally, rather than just staying at the response phase. Some indicators at the preparedness phase are taken into account, such as national response mechanism and local community support. There is a principle to follow that as few indicators as possible should be selected under the premise of ensuring safety and evaluation effect. Some indicators are of little importance, which should not be considered in our index system based on the marginal effect theory.

Indicators are quantified as ordinal (0, 1, 2, 3) or Numerical, as shown in Table 2. Ordinal indicators measure policies on a simple scale of severity or intensity, allowing us to describe the degree or strength of government response in each level and category. For these indicators, the rank orders of different levels are meaningful, but we make no claims regarding the scale of the intervals. Instead, each level has a specific meaning, which allows different values to be used as categorical variables. An indicator is quantified when its corresponding policy is implemented, rather than announced. Many have a further label to note whether they are targeted (applying only to a subregion of a jurisdiction or to a specific sector) or general (applying throughout that jurisdiction or across the economy). For the newly added indicator - vaccination policy, the label indicates whether the vaccine is funded by the government or individuals themselves. Numerical indicators measure a specific number, reporting fiscal values in US dollars. There are 49 indicators in our index system. We give examples of each indicator quantification when our paper preparing or the policy is implemented to lay a foundation for a tool to assess local resilience capability for countries or regions.

5 Case Study

Our index system aims to build a multi-dimensional public health prevention and control network. The network is comprehensive and well-established. However, all levels and all indicators are not necessarily required, nor are they applicable to all regions and all times. The density of the network varies in different areas and at different time according to actual situation. External area should be tight for external risk, while internal area should be tight for internal risk. For example, border control of customs at the country level should be the strictest for the high

risk of overseas import, and policies at the city, local community, and individual levels can be relatively lax. The precise prevention and control measures should be implemented in the targeted areas at the right time.

The case of Wuhan/Hubei response to COVID-19 is taken as an example to illustrate the implementation, test, and exercise of our system. The timeline is as shown in Fig 4. When some pneumonia cases of unknown cause were reported by Hubei Hospital of Integrated Traditional Chinese and Western Medicine, epidemiological and on-site investigations, laboratory detection, and clinical analysis were conducted by National Health Commission (NHC), Wuhan Health Commission (WHC), and Chinese Center for Disease Control and Prevention (CDC) quickly. The pathogen was preliminarily identified as novel coronavirus through pathogenic microorganism analysis. Then China informed the WHO, US and other countries, and other provinces of the real-time situation, and released the genome sequence of the novel coronavirus. At the country level, a series of guidelines were issued and the response mechanism was immediately established. The system of command, control and coordination was well established across the national-, provincial-, and the city-level.

Wuhan city was “lockdown” to stop the spread of COVID-19 on Jan 23rd. Three days later, public transport was prohibited inside Wuhan city to further strengthen the strictness in controlling movement of residents. The strictest closure and traffic restrictions were enforced on all outbound routes from Wuhan and Hubei. International passenger flights, ferries, and long-distance passenger transport services were suspended in many parts of the province. Road and waterway passenger services were also bound between Wuhan and other areas. Airports and railway stations were closed and intra-city public transport halted in Wuhan and many other parts of Hubei. All these restrictions effectively stopped the virus from spreading nationwide, especially in rural Hubei where public health infrastructure was relatively weak.

At local community level, the community-based line of defense was well guarded. Strict access control and grid-based management were exercised in communities. Human and material resources were channeled down to the community level to reinforce implementation of targeted measures. Task forces were set up by both full-time and part-time community workers. They performed their duties as a team, including officials at the sub-district/township and community/village levels, health workers of community medical facilities, and family doctors. Through all these efforts, communities and villages were turned into strongholds to ensure full implementation of response measures down to the lowest level.

For the individuals, the whole population acted in concert to strictly follow government orders. Though it is Spring Festival, all residents were at home, and social activities shrank to a minimum or none. Visits to friends/relatives or other gathering activities were canceled; people quarantined themselves, wore masks, began to take their body temperature regularly, and practiced other social distancing measures. People stayed at home for an extended period of time. They took online courses or online meeting, worked at home, and spent time with their families.

The feedback and feedforward are quite important in process control. Feedback is passive and has the delayed effect. Feedforward is active and usually ahead of time. At the beginning of the outbreak, the response of Wuhan was delayed, while it was look-ahead at the later period. The implementation time of policy/measure is also quite important, which is not reflected in our indicators. But it is illustrated by this case very well. Decision making and policy implementation is a dynamic and continuous process. Policy is not always sustainable and needs on-and-off, because development and safety should be coordinated during the global pandemic response. When we look back upon the China's fight against COVID-19 based on our comprehensive system, we can find that China would rank relatively high.

6 Discussion And Conclusions

This study aims to build a comprehensive index system for the assessment of national policies and capabilities from multi-levels including country-, city-, local community-, and individual-level. Comparative study with several classical assessment tools or practical experience is used in the framework design. Categories of containment and closure, response in economic system, and response in public health system constitute the main body of the framework. The command, control and coordination of Country level and the support of community are considered in our index. The quantification of each indicator and the corresponding example are given to lay a foundation for assessing local resilience capability. We will conduct an empirical research to verify our system quantitatively in the future research.

Both policy level and implementation/execution level are considered in our index system. However, not all indicators can be quantified by available data, which increases the difficulty of empirical researches. The missed data will be obtained, or the relevant database will be built to supplement the data in the future. Our index system aims to assess the multi-level government ability, from the country government to city, local community as well. The whole process of emergency management is considered in our framework based on the business continuity management, from the preparedness ability when there are no COVID-19 cases to the response ability. Sometimes, local community in China has the function of preparedness similar to country function, such as preventing imported cases. The meaning of ‘lockdown’ in some foreign countries is different from that in China. When the situation of COVID-19 is too bad, some cities or local communities will be forced to close, while they will close in China when there are no confirmed cases within local regions.

A pandemic of infectious diseases results from coupling of multiple factors or multi-hazards. For example, COVID-19 involves the spread of **novel coronavirus**, climate environment [30-32], Spring Festival travel, high-risk residence communities [33], and cold chain. COVID-19 is a long-term emergency, then many other emergencies or disasters (typhoon, flood disaster, food shortage, *etc.*) may happen simultaneously during the response of COVID-19. The co-processing of different disaster management tasks is an important direction of future research.

Abbreviations

NPIs

non-pharmacological interventions; COVID-19: Corona Virus disease 2019; AHP: analytic hierarchy process; NHC: National Health Commission; WHC: Wuhan Health Commission; CDC: Center for Disease Control and Prevention

Declarations

Ethics approval and consent to participate: The effort towards disease control is part of the Centre for Disease Control and Prevention's routine responsibility in Jiangsu Province, China. Therefore, institutional review and informed consent were not required for this study. All data analyzed were anonymized.

Consent for publication: Not applicable.

Availability of data and materials: Data supporting the conclusions of this article are included within the article.

Competing interests: The authors declare that they have no competing interests.

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Tables

Table 1. Classification of Different Response Strategies

Response strategies	Major countries and regions	Public health measures
EXCLUSION	North Korea, some Pacific Island countries	Strive to avoid the epidemic
ELIMINATION	China, New Zealand, etc.	Clear away fully and dynamically the inland transmission
SUPPRESSION	England, Italy, North America, etc.	Control the intensity of attack rate
MITIGATION	Switzerland (at least early)	Flatten the peak of the epidemic
NO SUBSTANTIVE	Some low-income countries	Resignation
COEXISTENCE	England, Singapore, America (at the later stage), etc.	Coexisting with the virus

Table 2. Framework and Indicators of our Multi-level Index

Level	Category	No.	Indicators	Value Set	Targeted/General	EXP
Country (Country, State, and Regional government) level	Command, Control, Coordination	1	National laws and guideline issued	Ordinal (0, 1, 2, 3)	General	USA-3
		2	National response mechanism established	Ordinal (0, 1, 2, 3)	General	
		3	Border control	Ordinal (0, 1, 2, 3)	General	
		4	Restrictions on international travel	Ordinal (0, 1, 2, 3)	General	South Korea-3
		5	Support of local government/community when outbreak happened	Ordinal (0, 1, 2, 3)	General	China-3
		6	Collaboration with other countries and international organization	Ordinal (0, 1, 2, 3)	General	
		7	Expansion of medical and health related resources	Ordinal (0, 1, 2, 3)	General	China-3
		8	Development of wonder drugs and vaccines	Ordinal (0, 1, 2, 3)	General	USA-3
	Response in economic system	1	Income support, debt/contract relief for households	Ordinal (0, 1, 2, 3)	General	USA-2
		2	Payment of the medical fees	Ordinal (0, 1, 2, 3)	General	China-3
		3	Fiscal measures	Ordinal (0, 1, 2, 3)	General	China-3
		4	Investment in COVID-19 vaccines	Numerical	Funding	USA-3
	Response in public health system	1	Emergency investment in health care	Ordinal (0, 1, 2, 3)	General	China-3
		2	Vaccination policy	Ordinal (0, 1, 2, 3)	General	TBD
		3	Information sharing and health alert between different departments	Ordinal (0, 1, 2, 3)	General	China-2
		4	Risk assessment	Ordinal (0, 1, 2, 3)	General	China-3
		5	Lab response network	Ordinal (0, 1, 2, 3)	General	China-1
		6	Efficient surveillance system in outbreaks of COVID-19	Ordinal (0, 1, 2, 3), Geographic	General	China-3
City level	Containment and closure	1	School or workplace closing	Ordinal (0, 1, 2, 3)	Geographic	
		2	Implementing personnel control measures in public	Ordinal (0, 1, 2, 3)	General	
		3	Public transport closing	Ordinal (0, 1, 2, 3)	Geographic	
		4	Stay-at-home requirements	Ordinal (0, 1, 2, 3)	Geographic	
		5	Lockdown	Ordinal (0, 1,	Geographic	

				2, 3)		
	Response in public health system	1	Nucleic acid testing	Ordinal (0, 1, 2, 3)	General	
		2	Control of nosocomial infections	Ordinal (0, 1, 2, 3)	Geographic	
		3	Contact tracing	Ordinal (0, 1, 2, 3)	General	
		4	Expansion of medical and health related resources	Ordinal (0, 1, 2, 3)	Geographic	
		5	Execution of Vaccination	Ordinal (0, 1, 2, 3)	Geographic	
	Response in economic system	1	Recover and renew of businesses	Ordinal (0, 1, 2, 3)	General	
		2	Income support, debt/contract relief for households	Ordinal (0, 1, 2, 3)	General	
	Local community level	Containment and closure	1	Access control	Ordinal (0, 1, 2, 3)	Geographic
			2	Stay-at-home requirements	Ordinal (0, 1, 2, 3)	Geographic
			3	Quarantine of close contacts or high-risk population	Ordinal (0, 1, 2, 3)	General
Response in public health system		1	Budget allocation in personnel protections	Ordinal (0, 1, 2, 3)	General	
		2	Reinforce propaganda and education	Ordinal (0, 1, 2, 3)	General	
		3	Nucleic acid testing	Ordinal (0, 1, 2, 3)	Geographic	
		4	Execution of Vaccination	Ordinal (0, 1, 2, 3)	Geographic	
Community support		1	Assistance of living material	Ordinal (0, 1, 2, 3)	Geographic	
		2	Social protection for poor and vulnerable households	Ordinal (0, 1, 2, 3)	General	
		3	Mental health support	Ordinal (0, 1, 2, 3)	General	
	4	Reinforce propaganda and education	Ordinal (0, 1, 2, 3)	General		
	5	Volunteer policy	Ordinal (0, 1, 2, 3)	Geographic		
Individuals		1	Wearing masks	Ordinal (0, 1, 2, 3)	General	
		2	Social distancing	Ordinal (0, 1, 2, 3)	General	
		3	Self-isolation	Ordinal (0, 1, 2, 3)	General	
		4	Performing hand hygiene frequently	Ordinal (0, 1, 2, 3)	General	
		5	Ensuring room ventilation	Ordinal (0, 1, 2, 3)	General	
		6	Acceptability of	Ordinal (0, 1,	General	

	vaccines	2, 3)	
7	Psychological counseling	Ordinal (0, 1, 2, 3)	General

Figures

Figure 1

The continuum of pandemic phases

Figure 2

Comparative study of four representative tools for COVID-19 response

Framework of our Index for Local Resilience Capability Assessment in COVID-19	
Country	<div> <div>Command, Control and Coordination</div> <div>8</div> <div>→</div> </div> <div> <div>Response in Economic System</div> <div>4</div> <div>→</div> </div> <div> <div>Response in Public Health System</div> <div>6</div> <div>→</div> </div>
City	<div> <div>Containment and Closure</div> <div>5</div> <div>→</div> </div> <div> <div>Response in Economic System</div> <div>2</div> <div>→</div> </div> <div> <div>Response in Public Health System</div> <div>5</div> <div>→</div> </div>
Local Community	<div> <div>Containment and Closure</div> <div>3</div> <div>→</div> </div> <div> <div>Community Support</div> <div>5</div> <div>→</div> </div> <div> <div>Response in Public Health System</div> <div>4</div> <div>→</div> </div>
Individual	<div> <div></div> <div>7</div> <div>→</div> </div>

Figure 3

Hierarchical Model of Multi-level Index System Assessing Local Resilience Capability in COVID-19

Figure 4

The timeline of Wuhan battle for COVID-19