JIDC | THE JOURNAL OF INFECTION IN DEVELOPING COUNTRIES

Coronavirus Pandemic

Status and weaknesses of epidemiological investigation and emergency response in Guizhou Province, China

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Abstract

Introduction: Epidemiological investigation and emergency response are crucial during public health emergencies. This work investigated the status and weaknesses of the Center for Disease Control and Prevention (CDC) system in Guizhou Province, China, before and after the coronavirus disease 2019 (COVID-19) pandemic to address the weaknesses of public health emergency preparedness.

Methodology: This research was observational. It adopted a cross-sectional design, and designed two electronic questionnaires to collect data. One questionnaire was for 98 CDC agencies and the other was for 1026 individuals in Guizhou Province, China. The questionnaires focused on workforce, epidemiological investigation capacity, detection capacity, emergency material preparation, information technology application, and emergency response. Respondents completed electronic questionnaires via a WeChat application or by visiting a website link directly.

Results: The workforce and detection capacity of CDC agencies have considerably increased. Among the factors influencing individual capacity, willingness to learn (OR = 4.649, 95% CI = 2.782, 7.767) was the most related to workers with strong capacity. Furthermore, weaknesses involving epidemiological investigation and emergency response were found in each CDC level.

Conclusions: Remarkable improvements occurred during the COVID-19 pandemic in Guizhou Province, China. This study identified the weaknesses of epidemiological investigation and emergency response. It could provide decision-makers with directions for improvement, targeting each weakness at each CDC level to prepare for future disasters.

Key words: COVID-19; workforce; weaknesses; detection; epidemiology.

J Infect Dev Ctries 2026; 20(6):913-925. doi:10.3855/jidc.22288

(Received 28 June 2025 – Accepted 25 October 2025)

Introduction

The coronavirus disease 2019 (COVID-19) caused an extensive crisis at the end of 2019, affecting people's daily lives, resulting in the loss of millions of lives, and leaving the health system in shock [1]. Meanwhile, research, education, health, and community services were developed in response to the disease in the United Kingdom, Egypt and China [2–4]. The Chinese Center for Disease Control and Prevention (CDC) system operates under a multi-tiered management model, spanning four levels: national, provincial, municipal, and county. In its response to the COVID-19 pandemic, Guizhou Province, one of provinces in China, implemented innovative measures with outstanding performance. These measures included leveraging big data to create a "Health Code and Travel Code" smart tracking system for precise epidemiological investigations, establishing a four-tier province-municipal-county-township joint prevention mechanism, achieving full emergency response deployment within 48 hours, sealing off epidemic areas, conducting rapid regional nucleic acid testing, and coordinating with hospitals to cure cases correctly.

Guizhou Province achieved the following key outcomes. During the initial phase of the COVID-19 pandemic in 2020, the province had an incidence rate that was only one-seventh of the national average, and a lower death rate (1.37%) than the national official death rate of China (5.03%) [5]. Moreover, the province coordinated with hospitals; community health centers; customs; universities; and animal, agriculture, and environmental institutions to form joint prevention and control mechanisms.

However, the problems of the lack of professional personnel, low capacity due to polymerase chain reaction (PCR), equipment deficiency, and inadequate capital investment soon emerged in Guizhou Province. In China, including in Guizhou Province, all government levels have implemented effective and efficient strategies to expand emergency response capacity to fill the above gaps. Remarkable changes have occurred during the pandemic from the end of 2019 to 2023. However, these changes have been minimally studied in China. The weaknesses of epidemiological investigation and emergency response and how to prepare for the next pandemic are pressing

issues. The present research aims to investigate the status and changes in epidemiological investigation and emergency response in Guizhou Province. Moreover, it seeks to identify the weaknesses and capacity level of Guizhou Province to contribute to the development of outstanding institutions and teams for epidemiological investigation and emergency response. The CDC systems in China and Guizhou Province are undergoing institutional reforms. This study can provide baseline data for current reforms in China's undeveloped areas and a data reference to other similar developing regions. Most importantly, this study is dedicated to identifying the weaknesses of epidemiological investigation and emergency response at each CDC level. Such work could provide decision-makers with directions for improvement by targeting each weakness at each CDC level.

Methodology

Questionnaires and survey

This research was observational. It adopted a cross-sectional design, and used an electronic questionnaire to collect data. Several strategies had a delayed effect after the Chinese government announced a change in policy on 8 January 2023, that ended the COVID-19 pandemic era. Hence, the period of this study was extended to December 2023 to ensure the stability and uniformity of data. The questionnaires did not include personal information or commercial interests, did not interfere with public behavior, and did not cause harm to the human body. The collected data were anonymized and used only for scientific research. Based on the above information, this study met the requirements for ethical exemption. Therefore, the research group applied for and obtained a waiver for ethical review from the ethics committee (Ethical waiver protocol number: Q2025-02).

Two electronic questionnaires were created with the Questionnaire Star software, a professional online questionnaire survey and evaluation platform that provides users with a powerful and user-friendly series of services for online questionnaire design, data collection, and survey result analysis. Questionnaire Star has the apparent advantages of being faster and easier to use than traditional survey methods. It has been widely employed by numerous enterprises and individuals. One questionnaire was sent to all CDC agencies in Guizhou Province, including 88 county-level CDC agencies, 9 municipal-level CDC agencies, and 1 provincial-level CDC agency. Another questionnaire was sent to the personnel who participated in the epidemiological investigation and emergency response in Guizhou Province. For the purpose of this research, two questionnaires were compiled on the basis of the actual situation in Guizhou Province and relevant literature. These questionnaires were modified by 3 experts who all held senior professional titles in the fields of epidemiology and health statistics and had over 15 years of experience in conducting epidemiological investigations and emergency response.

The research group conducted a preliminary survey with the initial version of the questionnaires. Three CDC agencies were selected as pilot sites for conducting the preliminary survey. Discussions were held with the relevant pilot CDC personnel to communicate the current situation of each CDC, the changes that occurred during the COVID-19 period, and existing problems. The participants provided feedback on the 2 questionnaires. The discussion points and existing issues in the questionnaires were used for further modification. Finally, the modified questionnaires were again submitted to the three experts for revision. Subsequently, the final version was obtained.

The questionnaire for CDC agencies was composed of 4 parts and contained 43 questions covering demographic data, approaches for reporting emergency events, laboratory apparatus and detection capacity, and emergency material reserves.

The research group formulated another questionnaire for individuals. This questionnaire was composed of 3 parts and included 54 questions involving demographic data and working experiences, self-assessments of professional capacities, and evaluation of the importance of work processes. The questionnaire clearly defined the scoring standards for several key issues to reduce the influence of subjective factors in self-assessment. The scoring for the evaluation of a participant's ability to manage public health events is as follows: a score of 1 indicates that the participant has no idea about the specific measures; 2 implies that the participant knows some measures but is unsure about numerous aspects; 3 denotes that the participant knows the basic process but does not know how to proceed without a leader; 4 indicates that the participant can complete the task independently but may overlook some minor details; and 5 signifies that the participant can successfully complete the task independently. In addition, this study set up cross-validation designs for some key issues, such as whether the respondent had independently participated in public health events in the past 3 years. The questionnaire asked the role of the participant in public health events,

with the responses being A: as a novice in the workplace without any knowledge; B: has had several experiences under the guidance of the superior; C: has acted as part of the main force numerous times but still cannot complete tasks independently; D: can accomplish a task independently, but he can overlook some details; and E: can independently complete tasks perfectly. By using the method mentioned above, questionnaires with significant errors were eliminated after verification by the supervisor. If the responses to two questions regarding cross-validation designs were in contradiction, the questionnaire was eliminated.

This research obtained official support and was issued a formal document requiring all levels of CDC institutions and individuals to complete the questionnaires. The document stated the purpose and operating steps of this research and acknowledged support. The two questionnaires were provided along with their corresponding QR codes and website links. One questionnaire was for CDC agencies and was completed by employees. The other was completed by individuals who were responsible for epidemiological investigation and emergency response. At the same time, the research team called each CDC leader individually and requested that staff complete the questionnaire within 2 weeks. The official document supported that both questionnaires were factual and reliable. The respondents completed two electronic questionnaires via a WeChat application where they could scan the QR code or visit a website directly. After all respondents completed the questionnaires, their data were downloaded from the Questionnaire Star software.

Data collection and statistical analysis

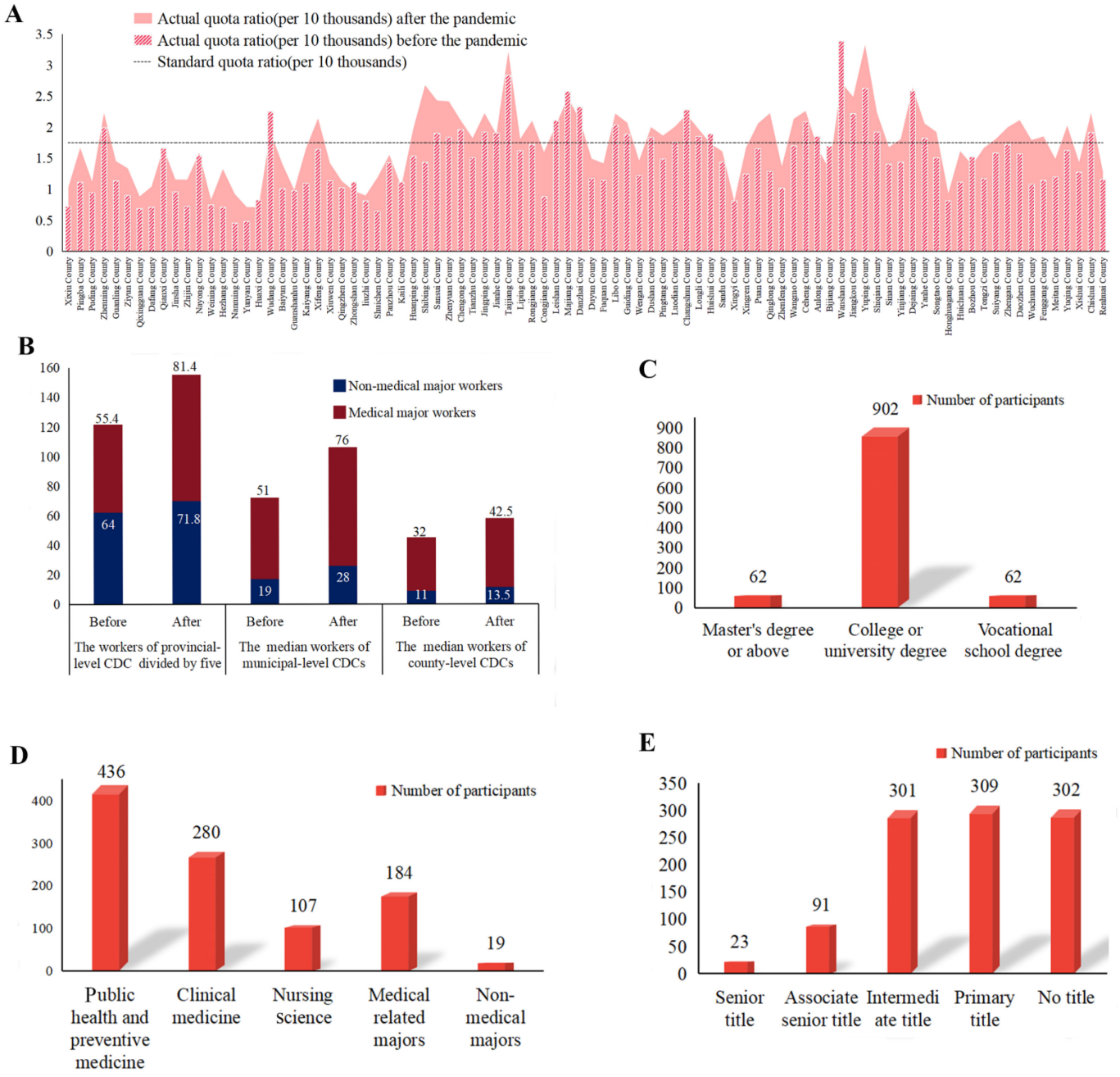
Two researchers were responsible for collecting, enrolling, and cross-checking data. Thereafter, their superiors verified the data before proceeding. Data were analyzed by using Microsoft Office Excel, SPSS statistics software version 31.0, and SPSSPRO. Microsoft Office Excel was employed for data collation and basic calculation, such as summation and the calculation of averages and constituent ratios. SPSS was utilized for descriptive statistics, binary logistic regression analysis, and the evaluation of the reliability and validity of the questionnaire. Given that the SPSS software cannot support the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), the research group chose SPSSPRO to accomplish TOPSIS. Continuous variables with normal distribution were presented in the form of means and standard deviations. Continuous variables with non-normal distribution were described by their median and interquartile range. Categorical variables were summarized as the counts and percentages of each category. This study successfully reached 98 CDC agencies, covering all the CDC agencies in Guizhou Province. They included 88, 9, and 1 county-, municipal-, and provincial-level agencies, respectively. All agencies were valid. According to official statistics, 1100 employees are responsible for the epidemiological investigation and emergency response in Guizhou Province. A total of 1100 individual questionnaires were obtained. After excluding duplicate and unqualified questionnaires, 1026 questionnaires were eventually deemed valid.

The ability to manage public health emergencies is closely related to the competence of professional employees. The researchers designed a customized questionnaire for the 1100 employees in all CDC agencies in Guizhou Province, including 88, 9, and 1 county-, municipal-, and provincial-level agencies, to explore the capability of the employees. Five options were provided. Respondents self-assessed their capabilities on a scale of 1 to 5 by using the individual questionnaire. A score of 1 meant very bad, that of 2 meant not bad, that of 3 meant fairly good, that of 4 meant pretty good; and that of 5 meant extremely good. In accordance with the research group experts' discussion, those who scored above 4 can complete the work required when emergencies occur. Therefore, respondents with scores of 4–5 were sorted into the strong capability group, whereas those with scores of 1–3 were sorted into the non-strong capability group. The binary logistic regression analysis based on backward likelihood ratio (LR) was used for the statistical analysis of influencing factors concerning epidemiological investigation and emergency response capacity. The classification table was stable, and the omnibus tests of the *p* values of model coefficients were validated with the regression model, which was established successfully. The *p* values obtained with the Hosmer-Lemeshow Fit test all exceeded 0.05, indicating that the logistic equation was valid and significant.

A total of 20 procedures involving epidemiological investigation and emergency response were drawn up in the agency questionnaire by combining the literature [6] and Guizhou Province's actual situation. Respondents estimated items by using a 5-point scale (1 = not important or difficult, 5 = very important or difficult). SPSSPRO was used for TOPSIS comprehensive evaluation analysis based on the entropy weight method. TOPSIS comprehensive evaluation is a method used to sort a limited number of

evaluation objects in accordance with the degree of proximity between a limited number of evaluation objects and the ideal target. This ranking method evaluates the relative merits and demerits of existing objects. As a sorting method approaching the ideal solution, TOPSIS comprehensive evaluation only requires each utility function to increase or decrease monotonically. It is a commonly used and effective method in multi-objective decision analysis and is also known as the good and bad solution distance method. SPSSPRO was utilized for this analysis. First, personnel evaluated the importance and difficulty of

Figure 1. Workforce of the Centers for Disease Control and Prevention (CDC) in Guizhou Province.



A: Ratio of the number of CDC workers to the population they served. **B:** Median workers at each CDC level. The number of provincial-level CDC staff was considerably larger than municipal and county levels, which resulted in the inability to clearly display the numbers at the municipal and county levels in the graph; so this research divided the actual provincial level number by 5 to draw a better image. **C:** Number of participants with different educational backgrounds participated in the epidemiological investigation and emergency response. **D:** Number of participants with different majors who participated in the epidemiological investigation and emergency response. **E:** Number of participants with different professional titles who participated in the epidemiological investigation and emergency response.

each item. Two researchers then calculated the average scores. Second, the entropy weight method was used to affirm the weight of indices after cotrending and normalization processing. Third, the optimal and worst matrix vectors were identified. Fourth, the distance (D+) between the evaluation object and positive ideal solution and that (D−) between the evaluation object and the negative ideal solution were calculated. Fifth, the comprehensive scores (C) was calculated in accordance with D+ and D−. The formula used for this statistical method is $C = (D^-)/(D^+ + D^-)$. A large C value is far from the negative ideal solution, indicating weakness in this study. In simple terms, large values of importance and difficulty are indicative of weakness. Sixth, the weaknesses of epidemiological investigation were identified on the basis of ranking by comprehensive scores (C). The weaknesses of the epidemiological investigation and emergency response in Guizhou Province were found through the ranking method TOPSIS.

Results

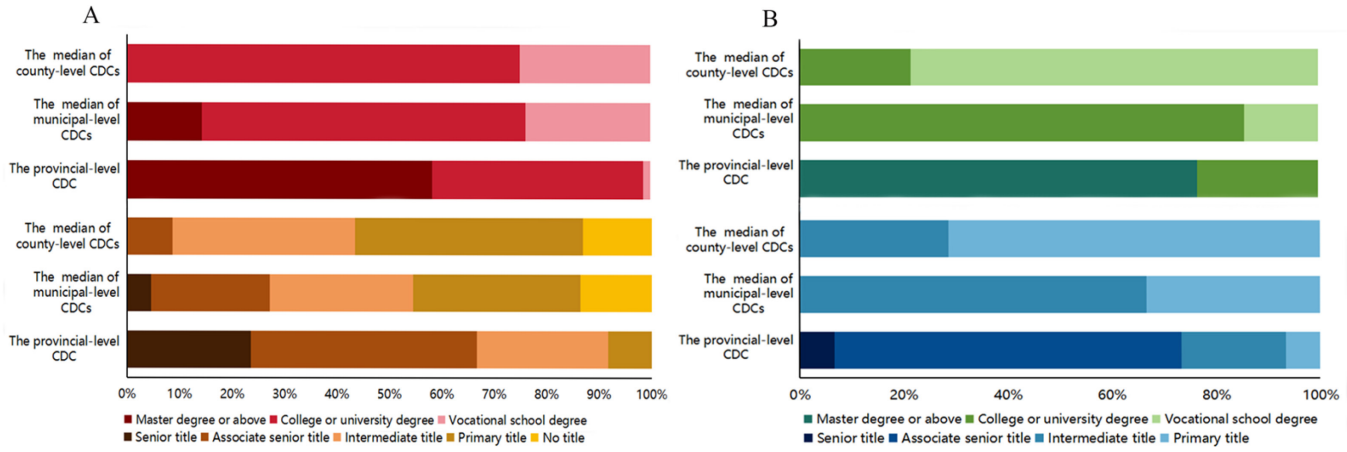
Status of the CDC workforce in Guizhou Province

The ratio of the number of CDC workers to the population they served in each county in 2019 and 2023 was calculated. The official data showed that the population of Guizhou Province was 36 million in 2019 and increased to 38.56 million in 2023. The population of the counties ranged from 0.11 million to 1.29 million in 2019 and from 0.12 million to 1.25 million in 2023. According to a Chinese official document on the CDC workforce, the standard quota ratio of the CDC workforce is 1.75 per 10 000, indicating that 1.75 CDC workers are needed to serve 10 000 citizens in public health. However, only 30.7% (27/88) of CDC agencies met this standard before the COVID-19 pandemic. The development of the CDC workforce during the pandemic resulted in 48.9% (43/88) of CDC agencies meeting this standard at the end of 2023, with the remaining 45 CDC agencies that did not meet the standard showing marked increases (Figure 1A). The median majors of workers at each CDC level in the province were surveyed through questionnaires (Figure 1B). This research investigated all the employees participating in epidemiological investigation and emergency response during the COVID-19 pandemic via online questionnaires. The number of respondents with different educational backgrounds (Figure 1C), majors (Figure 1D), and professional titles (Figure 1E) were calculated. Medical-related majors including basic medical science, Chinese and Western integrative medicine, public health management, and medical radiology were grouped together because of the fewer counts.

Median constituent rates of educational backgrounds and professional titles at each CDC level

The educational backgrounds and professional titles of all CDC agency personnel responsible for epidemiological investigation and emergency response when emergencies occurred during the COVID-19 pandemic were investigated (Figure 2A). The educational backgrounds and professional titles of laboratory personnel responsible for detecting COVID-19 were also surveyed (Figure 2B).

Figure 2. Median constituent rate of educational backgrounds and professional titles at each CDC level.



A: Median workers' constituent rate of educational backgrounds and professional titles at each CDC level that involves epidemiological investigation and emergency response staff. **B:** Median workers' constituent rate of educational backgrounds and professional titles at each CDC level with laboratory staff.

Improvement in laboratory detection capacity and apparatus during the COVID-19 pandemic

Remarkable changes have occurred, especially regarding experimental instruments and staff capacity involving COVID-19 tests. The provincial-level CDC acquired advanced equipment to detect the SARS-CoV-2 virus and had an adequate number of qualified personnel before the pandemic. Before the COVID-19 pandemic, only less than 30% of county-level CDC agencies could detect viral nucleic acids due to insufficient equipment and skilled personnel. However, after the pandemic, 100% of county-level CDC agencies can detect viral nucleic acids as a result of the financing and training programs funded by the government. The primary equipment of municipal- and county-level CDC agencies also improved, as illustrated in Figure 3.

Status of personal protective emergency materials at each CDC level

The stockpile of primary protective emergency materials was adequate after the COVID-19 pandemic in all CDC agencies. However, it was generally inadequate at the beginning of the pandemic, with some agencies even having less than a quarter of the national standard. This research calculated the constituent rate of CDC agencies for each emergency material to be consistent with the authorities' standards, over half of the standard, over a quarter of the standard, and less than a quarter of the standard (Figure 4).

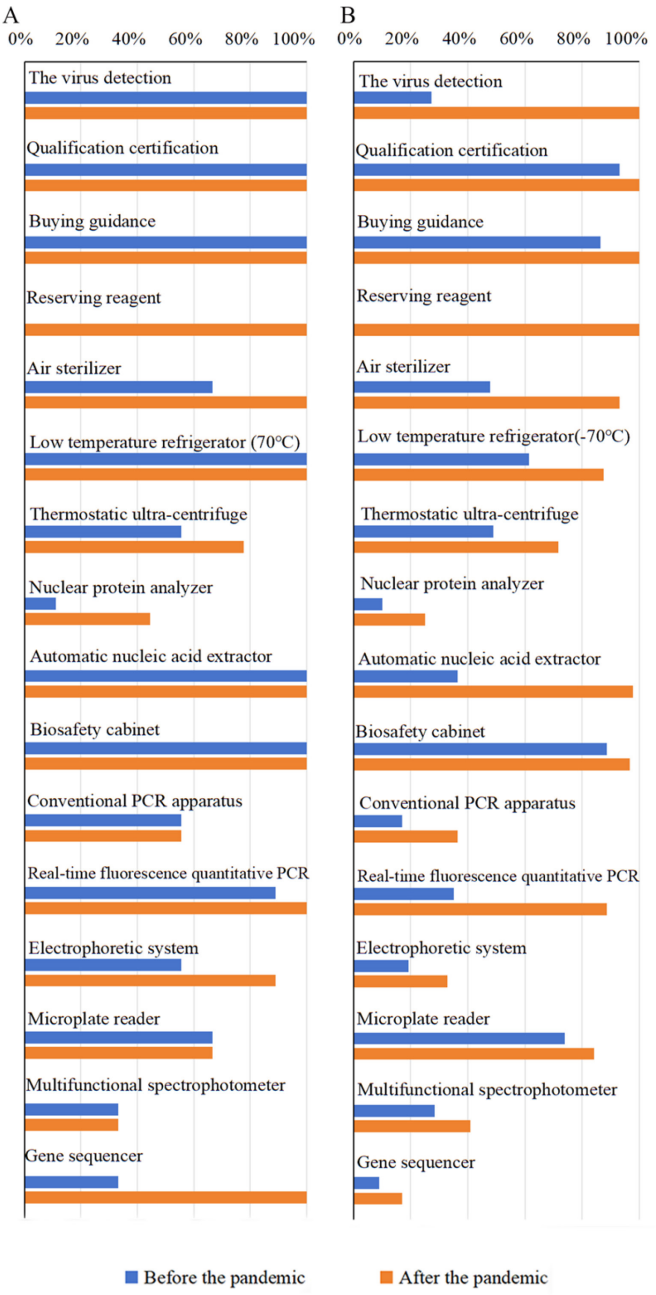
Current status of public health emergency response

Several items for emergency response were listed and the proportion of each CDC level with essential items in emergency response was added, as shown in Table 1, to determine the capacity of public health emergency response in Guizhou Province. In terms of information technology, Guizhou Province had improved and promoted approaches for epidemic reporting. These approaches are convenient, efficient, and enhance timeliness on the premise of ensuring safety. Table 2 presents the rating of each CDC level for several approaches and locations of reporting events.

Influencing factors of personal capacity regarding epidemiological investigation and emergency response

This study performed binary logistic regression analysis based on backward LR to explore the factors influencing epidemiological investigation and emergency response. Consequently, a college or university degree, participation in municipal-level epidemic response, and willingness to learn were found to be related to the strong capacity of workers. However, several variables, including gender, major, and professional title, were not associated with personal capacity. Table 3 shows the significant variables.

Figure 3. Constituent ratio of detection capacity and central apparatus before and after the COVID-19 pandemic.



A: Municipal-level CDC agencies. **B:** County-level CDC agencies.

Figure 4. Constituent rate of agencies regarding emergency materials at each CDC level before the COVID-19 pandemic.

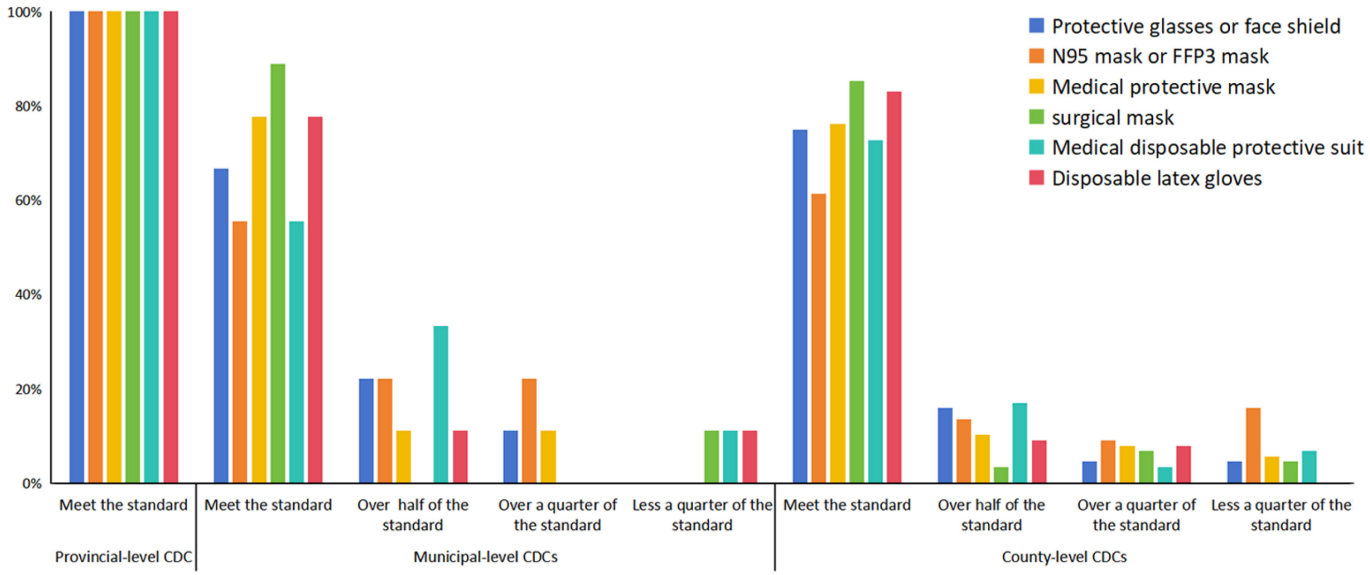


Table 1. Proportion of preparedness of each Centers for Disease Control and Prevention (CDC) level regarding key items in emergency response.

Key items	Provincial-level CDC agency	Municipal-level CDC agencies	County-level CDC agencies
Set up an unaffiliated emergency department	100% (1/1)	88.9% (8/9)	22.7% (20/88)
Set up an emergency expert committee	100% (1/1)	88.9% (8/9)	79.6% (70/88)
Emergency response within 2 hours	100% (1/1)	100% (9/9)	100% (88/88)
Make emergency plans	100% (1/1)	100% (9/9)	100% (88/88)
Frequency of updating emergency plan	100% (1/1) updated in 3 years	55.6% (5/9) CDC updated within 3 years; 33.3% (3/9) CDC updated within 5 years; 11.1% (1/9) CDC updated over 5 years;	84.1% (74/88) CDC updated within 3 years; 14.8% CDCs (13/88) updated within 5 years; 1.1% (1/88) CDC updated over 5 years;
Build an emergency team	100% (1/1)	100% (9/9) average 67.6 people	97.7% (86/88) average 34.5people
Update the list of the team in a timely manner	100% (1/1)	100% (9/9)	95.5% (84/88)
Frequency of holding the emergency drill	100% (1/1) once a year	66.7% (6/9) CDC once a year; 22.2% (2/9) CDC once per 2 years; 11.1% (1/9) CDC are indeterminacy;	89.8% (79/88) CDC once a year; 4.6% (4/88) CDC once per 2 years; 5.7% (5/88) CDC once per 5 years
Special fund for emergency drill	100% (1/1) is adequate	22.2% (2/9), of which 100% (2/2) CDC are adequate	27.3% (24/88), of which 91.7% (22/24) CDC are adequate

Table 2. Proportion of preparedness of each Centers for Disease Control and Prevention (CDC) level regarding the approaches and locations of reporting events.

Reporting Events	Provincial-level CDC agency	Municipal-level CDC agencies	County-level CDC agencies
Methods of reporting			
Report by Chinese report system	100% (1/1)	100% (9/9) CDC	100% (88/88) CDC
Report by Guizhou Province report system	100% (1/1)	66.7% (6/9) CDC	69.3% (61/88) CDC
Report by telephone	100% (1/1)	66.7% (6/9) CDC	68.2% (60/88) CDC
Report by traditional paper	100% (1/1)	55.6% (5/9) CDC	53.4% (47/88) CDC
Locations of reporting			
Report by computer in their offices	100% (1/1)	100% (9/9) CDC	100% (88/88) CDC
Report by computer installed specific system when working from home	100% (1/1)	44.4% (4/9) CDC	58.0% (51/88) CDC
Report by tablet computer installed a specific system at any place	100% (1/1)	55.6% (5/9) CDC	40.9% (36/88) CDC
Report by smartphone installed a specific system at any place	100% (1/1)	22.2% (2/9) CDC	19.3% (17/88) CDC

Table 3. Factors influencing personal capacity for epidemiological investigation and emergency response were found via binary logistic regression analysis.

Various	B	Wald	*p* value	OR	95% CI
Age	0.046	29.325	< 0.001	1.047	[1.030, 1.064]
Education background (Vocational school degree)		7.471	0.024		
College or university degree	0.928	7.280	0.007	2.530	[1.289, 4.965]
Master's degree or above	0.783	3.020	0.082	2.187	[0.905, 5.287]
Participating in provincial-level epidemic response	0.380	4.086	0.043	1.462	[1.012, 4.965]
Participating in municipal -level epidemic response	0.580	14.241	< 0.001	1.785	[1.321, 2.413]
Participating in national- level training programs	0.489	4.426	0.035	1.630	[1.034, 2.570]
Participating in provincial- level training programs	0.380	5.905	0.015	1.463	[1.076, 1.988]
Participating in epidemic response over 10 times within 3 years	0.512	12.464	< 0.001	1.669	[1.256, 2.217]
Willingness to learn	1.537	34.420	< 0.001	4.649	[2.782, 7.767]

Weaknesses of the epidemiological investigation and emergency response in Guizhou Province

Epidemiological investigation and emergency response are the most critical processes in public health events. The foremost vital processes of the epidemiological investigation, which could reflect weaknesses and strengths through the TOPSIS comprehensive evaluation statistical method based on the entropy weight method, are listed in this article. Table 4 presents the ranking of the weaknesses related to epidemiological investigation and emergency response. Index 16, namely, field environment elimination, showed the largest C value at the provincial level, indicating that it is the weakest process and needs strengthening. Table 5 shows the top five weaknesses in epidemiological investigation and emergency response. The top five weaknesses are listed because these processes must be improved immediately.

Discussion

This study found that the after the COVID-19 pandemic, CDC agencies experienced considerable growth and improvements in their capabilities as their workforce grew. In 2019, 30.7% of county-level CDC agencies met the national staffing standard. This value

Table 4. Ranking of the weaknesses regarding epidemiological investigation and emergency response.

	Provincial-level				Municipal-level				County-level			
Items	D+	D-	C	Rank	D+	D-	C	Rank	D+	D-	C	Rank
index 1	0.7180	0.3112	0.3024	19	0.5507	0.4504	0.4499	14	0.4962	0.5590	0.5298	14
index 2	0.8408	0.2367	0.2197	20	0.7022	0.3420	0.3275	18	0.7858	0.3015	0.2773	20
index 3	0.3937	0.6282	0.6147	9	0.3945	0.7793	0.6639	4	0.2713	0.8580	0.7597	4
index 4	0.4211	0.5806	0.5796	11	0.2952	0.8688	0.7464	1	0.2439	0.7867	0.7633	3
index 5	0.4878	0.5587	0.5339	14	0.4478	0.5585	0.5550	10	0.3360	0.7072	0.6779	11
index 6	0.3988	0.6250	0.6104	10	0.4321	0.5884	0.5766	7	0.2759	0.7264	0.7247	7
index 7	0.3625	0.6762	0.6510	5	0.5833	0.6704	0.5347	11	0.2515	0.8603	0.7738	1
index 8	0.4194	0.7317	0.6357	6	0.4475	0.5604	0.5560	9	0.2871	0.7733	0.7293	6
index 9	0.4406	0.6003	0.5767	12	0.3931	0.6488	0.6227	6	0.2468	0.7638	0.7558	5
index 10	0.5068	0.5173	0.5052	16	0.8268	0.5620	0.4046	16	0.5593	0.4569	0.4496	18
index 11	0.3961	0.7638	0.6585	4	0.3512	0.6982	0.6653	3	0.3040	0.7554	0.7130	8
index 12	0.2957	0.8290	0.7371	2	0.2893	0.7736	0.7278	2	0.2338	0.7851	0.7705	2
index 13	0.4088	0.6705	0.6212	8	0.4328	0.5669	0.5671	8	0.3673	0.6616	0.6430	12
index 14	0.2948	0.7478	0.7173	3	0.3454	0.6732	0.6609	5	0.2994	0.7005	0.7005	10
index 15	0.4768	0.5493	0.5353	13	0.7579	0.2876	0.2751	20	0.5655	0.4813	0.4598	17
index 16	0.1578	0.8900	0.8494	1	0.4716	0.5338	0.5309	12	0.2877	0.7127	0.7124	9
index 17	0.4977	0.5119	0.5070	15	0.4923	0.5095	0.5086	13	0.4348	0.5651	0.5652	13
index 18	0.3672	0.6373	0.6344	7	0.6525	0.3615	0.3565	17	0.6782	0.5837	0.4625	16
index 19	0.7244	0.5341	0.4244	17	0.8222	0.3929	0.3234	19	0.7838	0.6204	0.4418	19
index 20	0.7730	0.4416	0.3636	18	0.6359	0.4918	0.4361	15	0.5697	0.6392	0.5287	15

The indexes represent the following processes. Index 1. Prepare transportation tools. Index 2. Prepare relevant technical papers and tools. Index 3. Find abnormal signals of public health emergencies. Index 4. Report and manage process of public health emergencies. Index 5. Case verification. Index 6. Case definition. Index 7. Case search. Index 8. Case handling. Index 9. Sample collection, preservation and transport. Index 10. Case investigation. Index 11. Investigation of cluster outbreaks. Index 12. Proposing targeted prevention and control measures. Index 13. Personal protection knowledge and skills. Index 14. Risk-assessment capacity. Index 15. Write the epidemiological investigation report. Index 16. Field environment elimination. Index 17. Basic office software skills. Index 18. Basic statistical techniques. Index 19. High-level statistical techniques. Index 20. Analytical epidemiological study.

Table 5. Top 5 weaknesses involving epidemiological investigation and emergency response.

Rank	Provincial-level	Municipal-level	County-level
TOP 1	Field environment elimination	Report and manage process of public health emergencies	Case search
TOP 2	Proposing targeted prevention and control measures	Proposing targeted prevention and control measures	Proposing targeted prevention and control measures
TOP 3	Risk-assessment capacity	Investigation of cluster outbreaks	Report and manage process of public health emergencies
TOP 4	Investigation of cluster outbreaks	Find abnormal signals of public health emergencies	Find abnormal signals of public health emergencies
TOP 5	Case search	Risk-assessment capacity	Sample collection, preservation and transport

increased to 48.9% in 2023. Laboratory diagnostic capability expanded given that 100% of the county-level CDC agencies could conduct PCR testing in 2023, whereas less than 30% could conduct PCR testing in previous years, and emergency supply access shifted from seriously deficient to being able to obtain standard equipment. Regression revealed that having a college or university degree, experience in response to higher-tier epidemics, and a strong willingness to learn were helpful predictive measures for individual response capacity, whereas gender and position title were not important factors. The TOPSIS evaluation highlighted several specific weaknesses at the administrative level. These weaknesses included field environmental elimination in response at the provincial level and case search, specimen collection, and preservation at the county level. Nevertheless, this study has several limitations that warrant consideration. It included only one province's data because of the limits of its authority. Readers should be cautious when considering its results because of the natural defects of cross-sectional research design and a potential recall bias in self-assessment data. The current study is the first in Guizhou Province to document efforts during the COVID-19 pandemic. It can provide baseline data for the reform of the current CDC system and future studies while outlining the persistent deficits that need targeting and remediation by public health policymakers.

In addition, the present study found considerable upgrades in equipment, including automatic nucleic acid extractors, thermostatic ultracentrifuges, conventional PCR apparatus, real-time fluorescence quantitative PCR systems, and even gene sequencers. In terms of information technology, Guizhou Province has improved and promoted approaches for epidemic reporting, which can be markedly convenient and efficient, as well as enhanced timeliness on the premise of ensuring safety. Employees can report events via the internet system and telephones at their offices, their homes, or others areas while ensuring the safety of data. This work investigated the status of epidemiological investigation and emergency response in Guizhou Province, focusing on workforce, epidemiological investigation capacity, detection capacity, emergency material preparation, information technology application, and emergency response. Haldane *et al*. stated that 6 areas require urgent action to build resilient health systems globally: governance, financing, health workforce, medical products and technologies, health service delivery, and public health functions [7]. In terms of workforce, only 30.7% of agencies met national standards in 2019; this finding is consistent with the situation in other Chinese provinces and other countries, the public health workforce of which had long experienced the loss of many employees [8–10]. Most Guizhou CDC agencies had a rare chance to fill this gap before the pandemic. However, the COVID-19 pandemic ended this situation due to the increase in the number of public health workers needed to engage in emergency events. Nevertheless, the ratio of agencies that met standards increased to 48.9% after the COVID-19 pandemic. This situation is similar to that observed in other Chinese provinces and consistent with that in some countries, such as Ghana and the US, which increased workforce investments because of the pandemic [11,12]. A review of strategies for emergency response pursued in 8 European countries hypothesized that it can be categorized according to their culturally determined preference for policy response style, including rule-based strong, medium and lower regulatory systems [13]. China and Guizhou province also highlighted their political situation and cultural characteristics during the COVID-19 pandemic. China is a nation that prioritizes life above all else. Therefore, it implemented relatively stringent policies, such as localized lockdowns in specific areas and mass nucleic acid testing nationwide. The government also distributed care packages to citizens during important ethnic festivals.

The Guizhou government invested human and financial input to increase laboratory detection capacity and emergency response preparedness. In alignment with the capacity of laboratories in other provinces in

China [14], only less than 30% of county-level CDC agencies could detect viral nucleic acids before the pandemic, which led to a remarkable shortage in testing capacity when mass nucleic acid testing was initially required. After the pandemic, all county-level CDC agencies had established fully equipped laboratories for testing for COVID-19 and acquired advanced experimental skills by investing in finance and training programs that purchased equipment for nucleic acid detection.

The stockpile of primary protective materials was inadequate at the beginning of the pandemic. Some counties had a scarcity of protective materials, especially N95 masks which were less than a quarter of the standard, and this was a painful lesson during the COVID-19 pandemic. However, the stockpile of primary protective emergency materials is now adequate. Approaches for epidemic reporting with increased convenience and efficiency have been developed in the province. Employees can report and receive information about emergency events everywhere through a computer or smartphone installed with a specific system to ensure information safety. Even though the authorities took a series of measures to enhance emergency response capacity, such as setting up unaffiliated emergency departments, making emergency plans, building emergency teams, and holding emergency drills, they obtained inconsistent results because of differences in government management and the absence of special funds. Studies from the US have found that the public health system has also experienced disinvestment for a long period of time, especially in the past decade [15]. These studies have suggested that the government should invest additional special funds and pay attention to emergency response and public health. The early warnings and preparedness are critical for emergencies including environmental and human hazards, which can help pave the way towards more resilient health systems and better-prepared societies.

This study analyzed the factors influencing personal capacity in epidemiological investigation and emergency response. Willingness to learn was the most important influence on individual capacity. Furthermore, extensive working experience and training programs could promote capacity. A previous study demonstrated that the COVID-19 pandemic highlighted the need for training and the continued need for training support in skill domains [16]. The present study showed that extensive work experience and training programs could promote capacity. However, several variables, including gender, major, and professional title, were not associated with personal capacity. This finding is surprising because professional title and major were assumed to be important influencing factors. Senior professional titles usually indicate that a person has a relatively high level of academic achievement. rather than practical abilities. This situation can explain why professional titles were not a significant predictor. Thus major was not the ultimate criterion for evaluating the ability of an employee. Indeed, authorities have offered various training programs, including theoretical training, practical coaching, and further studies at high-level departments, to enhance work capabilities. In particular, during the COVID-19 pandemic, officials launched numerous training programs and provided many practical opportunities. Employees can easily upskill as long as they have a medical specialty background and are willing to study hard. In fact, if a worker is not in public health and prevention medicine but keeps studying hard and continuously hones their skills through practice, they can still progress. This finding indicates that workers whose majors were medical specialties did not remarkably differ from others even if their majors were public health and preventive medicine, clinical medicine, or nursing science. However, this study had a potential recall bias in self-assessment data, because of the relatively long research period. It suggests that investigators can alleviate recall bias by leveraging special events, shortening the recall period, and designing structured and specific questions. Moreover, the triangulation or external validation can mitigate recall bias in future studies.

This research determined the weaknesses of 20 epidemiological investigation and emergency response processes, of which the top 5 processes are listed. Index 16, field environment elimination, had the largest C value at the provincial level, indicating that it was the weakest process and needed promotion. Authorities need to conduct training and improvement programs. Meanwhile, provincial-level members should also personally perform field environment elimination work during each epidemic response. Index 2, which was the preparation of relevant technical papers and tools, had the lowest C value at the provincial level. This finding indicates that it was the strongest process and did not need any improvement. Index 4, the reporting and management of public health emergencies, ranked first at the municipal level. Leaders may increase the number of participants when an epidemic occurs to improve this index. Index 7, case search, had the highest C value at the county level. Employees can learn from

their superiors how to conduct case searches and what aspects need to be considered to prevent missing any cases in searches. Activities that involve competitions for professional skills and knowledge to enhance these skills can also be organized. A team of employees from the provincial, municipal, and county levels of CDC agencies convene for epidemiological investigation and emergency response when emergency public health events occur. Employees of provincial-level CDC agencies, as team leaders, are responsible for providing professional guidance and proposing measures that should enhance and challenge essential knowledge and skills to guide and teach other team members. They should not ignore basic and crucial skills, such as field environment elimination. County-level CDC employees, as primary-level team members on the front line, perform practical work and should master elementary skills. Importantly, they should be aware of and report abnormal signals. The staff of municipal-level CDC agencies must supervise the quality of work at the county level. They should have made the initial discovery of the spread of the epidemic when elementary workers were still unaware of it.

This article lists the top 5 weaknesses. Authorities should focus on the weaknesses of each CDC level and capacity of personnel and implement measures to improve professional skills in accordance with the identified weaknesses. Evaluation and quality improvement endeavors should focus on retention, recruitment, and onboarding, enabling public health organizations to attract and retain the most qualified candidates [17]. The robustness of emergency response mechanisms increases as faculty members professionally advance. At the provincial level, long-term professional seminar projects usually lasting 1–2 years are organized for participants to attend in batches. The training objective is to cultivate the trainees as experts in their field. Given the neglect of grassroots practice, appropriately enhancing practical ability at the grassroots level is advisable. For example, members should personally perform field environment elimination work. At the municipal level, the management capacity for public health emergencies must be enhanced. Employees can be sent to high-level departments for long-term training, usually for half a year to one year. Leaders should also organize training courses on diseases and emergencies and encourage as many people as possible to participate. Providing and sustaining mental health support will undeniably balance the needs of CDC workers [18]. A robust, comparable, and systematic research approach to public health and social measures must be adopted [19] to prepare for future epidemics and pandemics. Authorities can enhance employees' experience by combining simulation-based training and continuous education. A sustainable simulation toolkit based on augmented reality (AR) / virtual reality (VR) technology can be considered. Trainees can engage in immersive learning driven by virtual technology. For instance, scenario-based teaching modules could simulate outbreaks of respiratory epidemics, plague and cholera, or natural disasters. Such authentic scenario simulations can replace high-cost physical training, alleviating issues of excessive resource consumption in resource-constrained settings. Furthermore, researchers should deepen future studies on technological inclusivity and collaborative standard-building. This will position simulation-based education as a transformative technology benefiting all humanity. In addition, adopting cutting-edge technologies that improve real-time monitoring, predictive analytics, and resource allocation, such as artificial intelligence, big data, and the internet of things, is currently a major study topic [20].

As policymakers around the world want the recovery from the COVID-19 to be durable and resilient, a return to the business practices of the pre-COVID-19 era characterized by environmentally destructive investment patterns and economic activities is undesirable. Increasing human population and anthropogenic activities, destroyed habitats, and increased wildlife trade, augment health risks that can fuel pandemics like COVID-19 and zoonotic diseases. Therefore, policymakers need to change perspectives and policies to build a greener and fairer economy and society that conforms to the culture [21]. Prevention is still better than the cure. The priorities of Guizhou Provincial CDC in epidemiology and emergency response include strengthening surveillance and early warning for infectious diseases; enhancing rapid response capabilities at the grassroots level for public health emergencies; improving emergency plans and conducting regular drills with sufficient stockpiles of medical supplies; bolstering disease control networks in rural and remote areas, targeting health interventions in ethnic minority communities; advancing big data applications to optimize epidemic analysis and risk prediction; and deepening multisector collaboration mechanisms that include health, agriculture, and environment agencies for joint prevention and control. Besides, similar developing regions may use the present study as a reference to address their weaknesses and improve their public health emergency preparedness for advancing sustainable development and building

resilient health systems globally.

Conclusions

The problems within the Chinese CDC system were exposed during the COVID-19 pandemic. The Chinese CDC system currently faces institutional reform, which urgently needs baseline data involving the system's personnel composition, organizational setting, special funds, and weaknesses. Remarkable improvements occurred during the COVID-19 pandemic in Guizhou Province. This work studied the status and the weaknesses of epidemiological investigation and emergency response. It can help decision-makers formulate a comprehensive project. The government should invest in special projects, such as intelligent surveillance networks, project funds, and emergency drill funds. Authorities should conduct institutional reforms to respond to public health emergencies. For example, they should promote the integration of medical care and prevention, and facilitate multi-departmental cooperation. Professional employees are the core of improvement. Several specific measures should be taken. They include long-term professional cultivation projects, further studies at higher-level departments, and basic skills training courses, as well as competitive activities for professional skills and knowledge. Researchers should aim to build institutions and teams to resist unforeseen shocks and future disasters. This research can provide baseline data for the reform of the current CDC system and further research regarding the persistent deficits that need targeting and remediation.

Acknowledgements

This work was supported by the Guizhou Center for Disease Control and Prevention. We want to acknowledge colleagues and those who contributed to this investigation and are working for local CDC agencies in Guizhou Province.

Authors contributions

YG, ML, study design; YH, CY, CH, proposed essential amendments; ZT, JH, BD, data analysis and interpretation; YG, YH, wrote the manuscript. All authors provided a critical review and approved the final manuscript.

Funding

This work was supported by Guizhou Province Health Commission Science and Technology Fund Project gzwjkj2020-1-196 and gzwkj2021-549. It was also supported by the Qian Ke He Support Plan [2021]-Normal 027.

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Conflict of interest

No conflict of interest is declared.

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