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ORIGINAL RESEARCH

Evidence-Based Framework and Implementation of China's Strategy in Combating COVID-19

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Introduction: In less than two months, the COVID-19 outbreak in China was controlled through the stringent strategies of screening and isolation. This article aims to use empirical data from all cases from a prefecture-level city of China to introduce and examine the feasibility and efficiency of the screening and isolation strategies and how these were essential in combatting the COVID-19 outbreak.

Methods: For this retrospective study, all confirmed COVID-19 patients were recruited from the Taizhou prefecture-level city of Zhejiang province, China.

Results: Of the city's total population, 24% were screened for COVID-19 and isolated at home or designated locations for two weeks. From these, a total of 146 confirmed cases of COVID-19 were analysed. Of all cases, 51% were traced from Wuhan, and 21% of patients were in close contact with confirmed cases from outside of the city. Initially, 13% of all patients reported having no clear symptoms, while 42% of patients presented with fever and/or other symptoms. Compared with local patients, new arrivals to the city had fewer days between their exposure and the development of symptoms of COVID-19 ($P<0.001$), and fewer days from the time they developed symptoms to the confirmation of COVID-19 ($P<0.001$), respectively.

Conclusion: This study has fully confirmed that controlling the COVID-19 outbreak through screening and isolation is effective, efficient, and essential. The evidence-based framework and implementation of China's strategy to combat COVID-19 can explain how China contained the COVID-19 outbreak in a short time period. This study offers important references and implications for containing the COVID-19 pandemic in the global community.

Keywords: COVID-19, pandemic control, screening, isolation, China

Introduction

The Coronavirus Disease 2019 (COVID-19) has spread throughout all 34 provincial areas of China after it started in Wuhan, capital of Hubei province in December 2019.[1,2] Despite previous epidemics, COVID-19 has been the most serious one in China since 1949.

COVID-19 has a very similar presentation to the severe acute respiratory syndrome coronavirus (SARS-CoV), which caused a huge outbreak in China in 2003. The methods used to combat and control SARS during the previous outbreak were confirmed to be effective and were put in place to contain and control COVID-19.[3–7] Specifically, the Chinese central government initiated these stringent methods by first placing the entire city of Wuhan under isolation on January 23. To aid in its smooth implementation, Chinese authorities adopted measures to ensure

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and persuade people to stay in their homes. After this first step, further isolation policies were put into place across the country within each prefecture-level city, which rank below a province and above a county in China's administrative structure, and below, including isolation policies applied at the village or community level in most areas.[8,9] To further safeguard the isolation policy, all newcomers who returned to or visited from outside the isolated areas, Wuhan in particular, were screened using physical tests such as measuring body temperature, and then told to stay at home, denied entry to the city, or placed in designated places for two weeks.[8]

As a result of the stringent isolation and screening measures put in place in January 25, 2020, the outbreak in China has been under control as of early March. Specifically, on January 28, 2020, there were 1772 new daily confirmed cases, and the number of new daily cases dropped to 20 on March 10, with a total number of 80,735 cases as of the same date.[10] An outbreak that reaches 5000 cumulative cases is considered to be too large to control within 12 to 16 weeks and is categorised as an uncontrollable outbreak.[7] These numbers are significant especially because of the time period involved. The appearance of COVID-19 coincided with Chinese New Year on January 25, which is the biggest holiday in China with the highest amount of travel, making the implementation of any plan of action to combat the virus even more complicated. Under normal circumstances, about three billion trips are made by the Chinese public within China during the week of festivities following the New Year.[11,12] For example, Wuhan, being a central transportation hub, already had about five million residents who left the city by the time the quarantine was announced.[9,13] However, through the active strategies of containment, isolation, and testing, the outbreak in the whole country was under control in six weeks, a testament to the policies of the Chinese central government, and a first in the world's history of public health emergencies.

This successful method resulting in the incredibly swift containment of a deadly virus is a recent phenomenon. Most previous studies on COVID-19 were concerned about its epidemiology and clinical treatments.[14–18] One study also discussed the feasibility of controlling COVID-19 outbreaks through isolation using a mathematical model.[7] However, no previous studies have used empirical data to confirm the feasibility and efficiency of screening and isolation and how these are essential in combatting a COVD-19 outbreak. Therefore, the objective of this paper is to describe the process of controlling a COVID-19 outbreak utilising screening and isolation. Considering that the actual implementation and control of COVID-19, including the screening, isolation, and treatment of the noted cases, takes place in and is under the auspices of that particular prefecture-level in the whole country, the paper will focus on a single prefecture-level city wherein the rate of COVID-19 cases seemed beyond control based on understood norms. The city, however, has exceeded expectations and has proven its ability to contain and control COVID-19, utilising the aforementioned methods of screening and isolation. Therefore, it is important to examine and confirm whether these methods are essential for controlling a COVID-19 outbreak. This article will also serve as a reference for combatting COVID-19 and other potential viral outbreaks in the world which generate respiratory tract infections.

Methods

Study Site

This study site is the Taizhou prefecture-level city of Zhejiang province with a population of 6.14 million, located in the east of China. All confirmed COVID-19 patients and residents who were screened or under isolation were recruited within the city.

Ethics Approval

The study was approved by the Ethics Committee of the Taizhou Prefecture-level City Center for Disease Control and Prevention (CDC). All adult patients provided written informed consent and a parent or legal guardian of any patients under the age of 18 years provided written informed consent on their behalf. This study was conducted in accordance with the declaration of Helsinki.

Data Collection

For this study, data for all patients with COVID-19 were collected from Taizhou CDC. All patients with COVID-19 in Taizhou were registered at the prefecture-level city CDC then admitted centrally to the Public Health Medical Center servicing the entire Taizhou without selectivity. All patients were diagnosed via real-time reverse transcription polymerase chain reaction (RT-PCR) using throat swabs or blood specimens. These diagnostic criteria were based on the uniform diagnostic standard of COVID-19, as defined by the National Health Commission of China.

Data were collected between January 21, 2020, when the first confirmed case was reported, and March 30, 2020, the beginning of the study. In total, there were 146 confirmed cases of COVID-19 in Taizhou. All confirmed patients in Taizhou were recruited without selectivity for this study. In addition, the last case was confirmed on February 15, 2020, and no new cases of COVID-19 have been reported in Taizhou from February 16 to March 30, 2020.

Confirmed patients' information were obtained from the patients' medical and tracing records. Patient information included demographics, epidemiological data, close contact history, whether patients were from Wuhan or other places outside of Taizhou, dates when the cases were confirmed, exposure tracing dates, dates when first symptoms presented, first hospitals where and when patients were admitted for symptoms, and clinical outcomes. Data on screening and isolation of residents and all official documents about the prevention and control of COVID-19 from the Taizhou city government also came from Taizhou CDC.

Statistical Analysis

Continuous measurements are presented as means (SD) and ranges if they are normally distributed or as medians (IRQ) if they are not, while categorical variables are presented as counts (%). ANOVA was used to compare the continuous variables while categorical variables were compared using the Chi-square test. Linear regression was also utilized to analyze the determinants that affected the number of days between exposure and confirmation, or "waiting days" (ie, days between exposure and contraction of symptoms). *P*-values were defined as 0.05. SPSS (version 26.0) was used for all analyses.

Results

Description of Confirmed Cases of COVID-19

Among the 146 total COVID-19 cases, patients' ages ranged from 4 to 87 years, with a mean age of 47.3 years. Patients were more likely to be male, between 40 and 59 years old, and to have worked in areas of business. Initially, 13% of all patients reported having no clear symptoms. Otherwise, 42% of patients had a fever and/or other symptoms, while the remaining 45% of patients displayed symptoms without fever. Those presenting symptoms chose to go to county-level hospitals with tertiary hospitals as a second choice. The mean number of days between exposure and the presentation of symptoms was 6.4 days; mean days from presentation of symptoms to confirmation of COVID-19 were 5.7 days. Table 1 details the confirmed cases of COVID-19 in Taizhou.

Description of Screening for COVID-19 Cases and Contacts

In order to identify the aforementioned cases of COVID-19, the framework of screening for high-risk populations and isolation of close contacts or suspected cases was utilized by Taizhou CDC (Figure 1). Since January 25, 2020, all people entering Taizhou from elsewhere underwent screening measures, including taking their body temperature and checking for related symptoms, and their personal information was registered. Those who showed signs or symptoms of infection or possible infection such as fever were isolated in designated hospitals or other designated places for two weeks. Citizens returning home were isolated in their homes for two weeks following screening. After initial screening and having returning residents isolate at home or placing others in designated sites, they were checked twice a day by community health workers over the entire two-week quarantine period. When isolated individuals presented with clear symptoms such as fever or cough, they were sent to a designated hospital within the city for further testing. Once a suspected case of COVID-19 was confirmed, all close contacts of the patient were traced through epidemiological investigations with the help of big data analyses of mobile communications. These contacts were subsequently isolated in designated places for two weeks. Among the entire population of Taizhou, the total number of people screened for COVID-19 was 1,488,005, which is 24.2% of the total Taizhou population.

Tracing of Confirmed Cases

According to the framework shown in Figure 1, Taizhou CDC traced close contacts of confirmed cases to find new cases. Table 2 shows that Taizhou underwent four rounds of tracing to identify all cases. Among all confirmed cases of COVID-19 in Taizhou, 58.2% of patients were identified in the first round (involving patients coming from outside Taizhou) and 51.4% originated in Wuhan, the epicentre of COVID-19 in China. From the second round, 21.2% of the patients were identified close contacts of confirmed cases from the first round.

Table 1 Description of All Confirmed Cases of COVID-19 in Taizhou

Variables	All Cases	New Arrivals	Local Patients	*P* value
Age, years				0.08
Mean (SD)	47.3(14.2)	45.6(13.0)	49.8(15.5)	
Range	4–87	4–74	13–87	
≤19	4(2.7%)	2(2.4%)	2(3.3%)	
20–39	38(26.0%)	23(27.1%)	15(24.6%)	
40–59	76(52.1%)	49(57.6%)	27(44.3%)	
≥60	28(19.2%)	11(12.9%)	17(27.9%)	
Sex				0.42
Male	78(53.4%)	43(50.6%)	35(57.4%)	
Female	68(46.6%)	42(49.4%)	26(42.6%)	
Occupation				0.58
Without jobs or household work	14(9.6%)	6(7.1%)	8(13.1%)	
Agriculture worker	39(26.7%)	23(27.1%)	16(26.2%)	
Factory workers	11(7.5%)	4(4.7%)	7(11.5%)	
Business workers	68(46.6%)	43(50.6%)	25(41.0%)	
Government workers or teachers	4(2.7%)	3(3.5%)	1(1.6%)	
Retired	5(3.4%)	3(3.5%)	2(3.3%)	
Students or infants	5(3.4%)	3(3.5%)	2(3.3%)	
First symptoms				0.04*
Without symptoms	19(13.0%)	13(15.3%)	6(9.8%)	
Symptoms with fever	61(41.8%)	41(48.2%)	20(32.8%)	
Symptoms without fever	66(45.2%)	31(36.5%)	35(57.4%)	
First hospitals				0.05
Private clinics	15(10.3%)	7(8.2%)	8(13.1%)	
Township or community health centers	15(10.3%)	10(11.8%)	5(8.2%)	
County-level hospitals	71(48.6%)	35(41.2%)	36(59.0%)	
Tertiary hospitals	45(30.8%)	33(38.8%)	12(19.7%)	
Days between exposures to symptoms				0.001**
Total number	100	54	46	
Mean (SD)	6.4(3.7)	5.4(3.3)	7.7(3.7)	
Range	1–17	1–14	2–17	
Days between symptoms to confirmation				0.08
Total number	128	73	55	
Mean (SD)	5.7(3.6)	5.2(3.4)	6.3(3.8)	
Range	1–17	1–16	1–17	

Notes: *P<0.05; **P<0.01.

The third and fourth rounds identified 17.1% and 3.4% of patients, respectively. Table 2 also showed the dates of confirmation of COVID-19 and speculated exposure to the virus from the four rounds of tracing in Taizhou. For example, through speculation and tracing, the last day of exposure to cases in Taizhou occurred on January 30, 2020. Incoming people travelling from Wuhan to Taizhou were the key population for isolation. There is clear evidence regarding the effective management of COVID-19 in the succeeding rounds of transmission, starting on January 21, followed by January 25, 30, and February 2.

Upon comparing the cases between the first round (those coming from outside Taizhou) and the other three rounds (local cases), there were no significant differences found with regard to sex, age, and occupation. There were also no differences in the hospitals or their level of attendance, regardless of which hospital patients went to. However, there were significant differences in the first symptoms experienced by patients

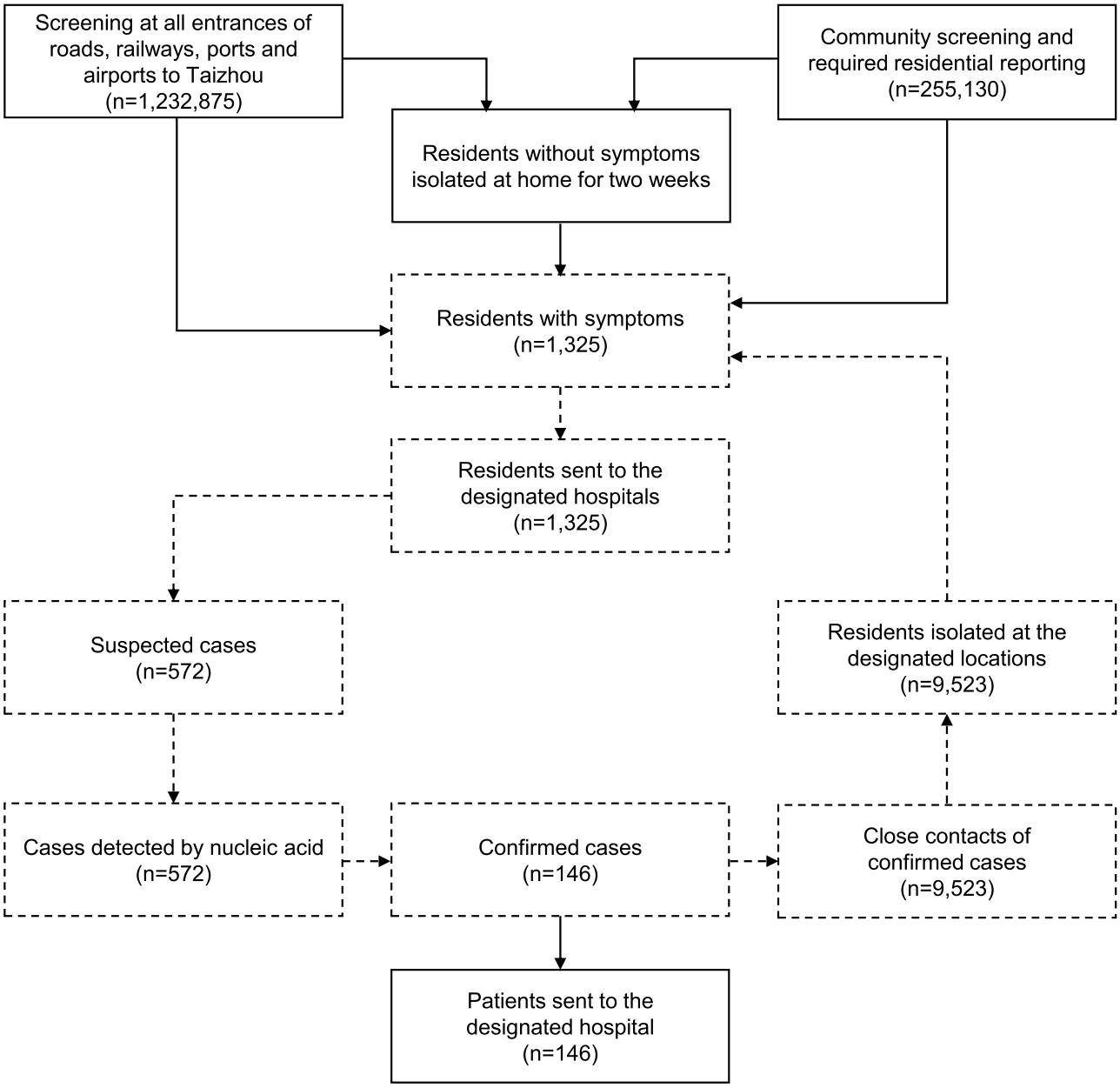

Figure 1 Framework and implementation of screening, isolation and confirmation of COVID-19 in Taizhou.
Note: The full line means a single direction, and the dotted line represents multiple cycles.

in the first round from subsequent rounds ($P<0.05$). There were more patients identified in the first round who exhibited fever with symptoms, while those from following rounds (involving local residents) developed symptoms without accompanying fevers. In terms of days of exposure to symptoms, patients who arrived from outside had significantly less exposure than local patients ($P<0.001$). Monitoring the days between the presentation of symptoms and actual confirmation revealed no significant differences between patients in different rounds. Detailed analyses for comparisons between the cases in the first round and subsequent rounds are shown in Table 1.

Determinants of Early Detection and Confirmation

Linear regression analyses in Table 3 showed that new arrivals in Taizhou had fewer days between exposure to the presentation of symptoms of COVID-19 than local patients ($P<0.001$). Table 3 also showed that arrivals to Taizhou experienced fewer days between the presentation

Table 2 Description of Tracing All Confirmed Cases of COVID-19 in Taizhou

Variables	First Round (New Arrivals)		Second Round	Third Round	Fourth Round
	Wuhan	Other areas			
Number of cases (%)	75(51.4)	10(6.8)	31(21.2)	25(17.1)	5(3.4)
Dates of confirmation onset	1/21	1/22	1/25	1/30	2/2
Last Day of confirmation	2/7	2/15	2/12	2/14	2/8
First day of exposure to confirmation	1/10	1/11	1/13	1/15	1/23
Last day of exposure to confirmation	1/24	1/27	1/24	1/24	1/30
Cases of missing exposure dates (persons)	18	2	0	8	1

Notes: Cases in the second round were close contacts of cases from the first round, and so on. This table uses date format type as month/date. For example,1/21 means January 21; all dates are in 2020.

Table 3 Determinants of Early Detection and Confirmation of COVID-19 in Taizhou

Variables	Days Between Exposures to Symptoms			Days Between Symptoms to Confirmations		
	β	Std. Error	*P*	*β*	Std. Error	*P*
Age	0.010	0.027	0.708	0.016	0.023	0.494
Sex	0.022	0.717	0.975	0.792	0.625	0.208
Occupation	0.343	0.267	0.201	0.426	0.237	0.075
New arrivals or local patients	2.424	0.713	0.001**	2.449	0.706	0.001**
First symptoms				1.681	0.613	0.007**
First hospitals				−0.269	0.376	0.477
Days between exposures to symptoms				−0.270	0.092	0.004**
R square of the model	0.120			0.295		

Notes: This table did not include the patients whose data on days between exposure to symptoms were missing. The total number of cases of this table is 100. ***P*<0.01.

of symptoms to confirmation than those who contracted the virus locally ($P<0.001$). Compared to patients with fevers, it took longer for patients without fevers to confirm the presence of COVID-19 ($P<0.01$). The results showed that the number of days between exposure and the presentation of symptoms and from the presentation of symptoms to confirmation were significantly associated ($P<0.01$).

Discussion

This is the first study to use and comprehensively register the data of all cases of COVID-19 from a prefecture-level city in China with the aim of describing the whole process of combatting COVID-19 through screening, tracing, and isolation. All cases in a prefecture-level city in China should be treated in the same designated hospital, except for those in Hubei province because there were too many patients. Additionally, all close contacts should be centrally isolated under the regulations set by the prefecture-level city. Looking beyond Taizhou, the framework of screening and isolation is essentially the same in different prefecture-level cities across China. Although this study only considered one representative sample of a prefecture-level city in China, the findings regarding the process of controlling the COVID-19 outbreak through screening and isolation may apply to the entire country.

With regard to each of the noted demographic characteristics of COVID-19 cases in Taizhou, the study found that the demographic distribution of COVID-19 cases was similar to those found across the country as reported by the WHO-China Joint Commission.[19] For example, among 55,924 laboratory-confirmed cases, the majority of cases (77.8%) were between 30 and 69 years of age, with the median age falling at 51 years old (range 2 days – 100 years old). Of these cases, 51.1% were male, and 21.6% were farmers or laborers by occupation. Previous studies of COVID-19 cases from Wuhan showed that 54% of 138 cases were male.[20] Prior studies that looked at earlier outbreaks and argued that most cases were male may be misleading.[15,17,21] Through comparisons of demographics between Taizhou and national data, it can be deduced that the transmission of COVID-19 follows a regular pattern with respect to population demographics. Specifically,

there are no differences with regard to sex, and it affects a wide age range. Again, it is important to note that there are no significant differences in the demographics of those entering Taizhou and local residents who contracted the virus within the city. Due to the similar demographics of all the COVID-19 cases, it was difficult for local governments to identify the high-risk population of the newly arrived COVID-19.

The most popular method of screening incoming persons and close contacts, who were subsequently isolated for two weeks in designated areas regardless of symptoms, was to measure body temperatures. Previous studies on COVID-19 using small samples gathered early in the outbreak argued that 98% of the cases were accompanied by fever.[17,21] However, the results of this study have found that 13% of total cases in Taizhou had no clear symptoms before confirmation, and only 48% of total cases in Taizhou exhibited fever along with other initial symptoms. Another study from a very early outbreak in Wuhan conducted from January 1 – January 20 noted that 83% of 99 cases had fevers when admitted to a hospital.[15] Other findings from previous studies state that asymptomatic cases were confirmed using CT scans that revealed visible changes in lung imaging and blood markers of the disease.[22] However, earlier findings that supported screening using only temperature have fallen out of favour as a result of more recent studies.[6] The results of this study are reinforced by a more recent study of Wuhan COVID-19 cases, which argues that elevated body temperature is not a general presentation. At present, it has been determined that high body temperature is not an indicative symptom and many cases will be missed if this is the only marker used. Only through stringent isolation and monitoring for all incoming persons and their close contacts for two weeks is it possible to avoid missing the detection of cases. It is confirmed that the screening and isolation of all incoming individuals and their close contacts are essential.

The results of this study reveal that Taizhou city underwent four rounds to trace all cases. Findings show that 58% of all cases in this study were traced in the first round, and 51% of all cases were from Wuhan. Outcomes from the first round fully confirmed that screening for COVID-19, particularly among all people arriving from Wuhan city, has played a crucial role in controlling the outbreak in Taizhou. As Wuhan is the epicentre and source of the outbreak in China, there were higher percentages of cases detected in prefecture-level cities in the first round among all cases across the nation, reflecting better screening implementation. The high percentage of cases detected in the first round among all cases also confirmed that interventions involving screening and isolation have been implemented to successfully interrupt the chains of transmission at an early stage in Taizhou.[23] The second round has been discovered to be one of the best methods in evaluating the performance of the prefecture-level city government in controlling the outbreak. The results show that the exposure date of any case in the second round was speculated, resulting in a better outcome for the quality of tracing and isolation of cases and close contacts involved in the first round. The results of this study are in accordance with the WHO-China Joint Mission report on COVID-19 involving 75, 465 cases nationwide, which demonstrated that highest number of recorded cases of the virus in China were imported from or had direct links to Wuhan, and that community transmission was very limited due to the screening and precautions in place.[19] Subsequent to the replications of methods and data in the reports, it can be deduced that all prefecture-level cities in China (except for Wuhan) implemented good quality, effective, and efficient interventions involving screening and isolation to interrupt the chains of transmission of COVID-19 in the early stage of the COVID-19 outbreak.

The efficiency and thoroughness of the intervention program for new arrivals from outside Taizhou was evidenced by the significantly shorter number of days between detection and confirmation. This outcome was largely due to people coming into Taizhou being isolated and closely monitored during the period of screening, while all close contacts were also isolated and closely monitored when related cases were confirmed. Thus, this provides evidence that early detection and early confirmation play a vital role in interrupting the chain of transmission of COVID-19 and related respiratory viruses. Screening and isolation among all incoming persons to Taizhou are the most important factors which contributed to how Taizhou put an end to the COVID-19 outbreak in a short time period.[23] It may be deduced that the method of screening and isolation among all incoming individuals is key, leading to COVID-19 being under control in China within six weeks. If cases had been diagnosed passively and only confirmed when patients went to hospitals after the onset of clear symptoms, it would have been impossible for China to eliminate COVID-19 or the threat of further outbreak within six weeks.

Although the aforementioned framework of controlling COVID-19 through screening and isolation has been fully confirmed in Taizhou, the process of controlling an outbreak is an extremely difficult job. Results showed that a quarter of the total number of residents in Taizhou were screened for the virus. Without full support and cooperation from the prefecture-level city government, it would have been impossible to complete the inordinately large amount of screenings and subsequent isolations in a very short period of time. The Chinese central government's forceful response and strong enforcement of procedures which were put into place has not only protected its citizens from a great health risk, but has drawn praise from global health officials. World Health Organization (WHO) officials have congratulated China for setting "a new standard for outbreak response."[24]

This study offers important findings and implications for combatting COVID-19 in any country in the world. Even though there are no vaccines and pharmaceutical measures, the COVID-19 pandemic can be completely conquered through screening and isolation strategies. China's experience has shown that all countries should initiate the highest level of national response management protocols and regional joint cooperation mechanisms to ensure the all-of-government and all-of-society approach needed to contain the COVID-19 pandemic.[25] Most countries all over the world utilized screening and isolation strategies in response to the global COVID-19 pandemic.[26–28] Although the effectiveness of screening and isolation were clear, many countries gave up this strategy because stringent screening and isolation measures had a negative impact on the economy.[29] This study did not analyze cost-effectiveness of the screening and isolation that took place in the chosen city. Previous studies, however, have confirmed the cost-effectiveness of screening and isolation as they are used for confronting and stopping the spread of infectious disease among high-risk populations.[30,31] A previous study analyzing the feasibility of controlling COVID-19 outbreaks through isolation of cases and contacts using a mathematical model argued that case isolation and contact tracing alone are insufficient to control the outbreak, and that in some scenarios, even those with near perfect contact tracing, will still be insufficient.[7] Some countries' implemented policies for combatting the pandemic further confirmed the validity of the mathematical model.[32] Furthermore, previous research has confirmed that China implemented extraordinary public health measures to combat COVID-19 at great socioeconomic cost.[32] However, the consequences of noncontainment will be measured in lives lost and socioeconomic disruption, which will be far worse than the cost of rigorously implemented containment combined with mitigation efforts. Furthermore, lessons from the failures of some countries to address the COVID-19 pandemic have fully confirmed that the containment of COVID-19 must remain the top priority rather than any other consideration.

Limitations

This study has several potential limitations. First, this study focuses on controlling the COVID-19 outbreak; it does not take into consideration the actual daily treatment of cases. The final outcomes of cases showed that there were no fatalities among all reported cases in Taizhou, and 100% of all cases have been cured. The final outcomes from this prefecture-level city will continue to be reported. Second, the process of screening and isolation from the study only represents prefecture-level cities in China except Wuhan because Wuhan implemented screening and isolation measures for its entire population. However, a key population for screening in any prefecture-level city in China except Wuhan are outsiders coming in from Wuhan. It should be noted that the process and workload of screening, tracing, and isolating were conducted in accordance with and will vary based on the quantity of those coming to an area from elsewhere. Consequently, this protocol may not be necessary based on the quality of the first round and quantity of arrivals. For example, it is not necessary for Tibet to carry out more than one round of contact tracing because there was only one confirmed case in the entire provincial area as of the beginning of the study.

Conclusions

This study has fully confirmed that controlling the COVID-19 outbreak through screening and isolation is effective, efficient, and essential. The framework and implementation of China's strategy to combat COVID-19 based on evidence from the Taizhou prefecture-level city has explained how China miraculously got the pandemic under control in a very short time. This study offers important findings and implications in containing the COVID-19 pandemic for the global community. The COVID-19 pandemic can be completely conquered through screening and isolation strategies, even with no vaccines or pharmaceutical measures. All countries should

adopt the all-of-government and all-of-society approach needed to combat the pandemic of COVID-19.

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Disclosure

The authors report no conflicts of interest for this work.

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