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Vital Surveillance

Reported Vector-Borne Diseases — China, 2018

Qiyong Liu^{1,*}; Yuan Gao¹

ABSTRACT

Introduction: Vector-borne diseases are an important type of infectious disease in China. This study aims to present a summary of vector-borne diseases reported in China in 2018 to provide information on their control and prevention.

Methods: A descriptive analysis was utilized to explore the epidemiological characteristics.

Results: A total of 51,599 cases with vector-borne diseases were reported in 2018 with an incidence rate of 3.69/100,000. Scrub typhus, hemorrhagic fever with renal syndrome (HFRS), and dengue contributed to 85.08% of all the cases. A total of 377 fatalities were included with a case fatality rate of 0.73%. Japanese encephalitis (JE), severe fever with thrombocytopenia syndrome (SFTS), and HFRS accounted for 95.76% of all fatalities. Different vector-borne diseases show disparities in gender, age groups, seasons, and regions.

Conclusions and Implications for Public Health Practice: In 2018, vector-borne diseases caused substantial morbidity and mortality in Mainland China with heterogeneity in populations affected and geography. Different regions should adopt targeted strategies and measures according to vulnerable populations and diseases.

INTRODUCTION

Vector-borne diseases are human illnesses caused by parasites, viruses, and bacteria that are transmitted by vectors such as mosquitoes, sandflies, triatomine bugs, ticks, and lice. They pose a serious threat to public health and cause a large global disease burden. It is reported that vector-borne diseases account for more than 17% of global infectious diseases causing more than 700,000 deaths annually (1).

Vector-borne diseases are an important component of infectious diseases in China. Of the 10 notifiable

vector-borne diseases, filariasis has been eliminated since 2007 and indigenous malaria case has not been found since 2017 (2). This report summarizes detailed reported data for 2018 on the epidemic of the vector-borne diseases in Mainland China.

METHODS

There were 8 nationally notifiable vector-borne diseases because no cases of plague or filariasis were reported in 2018, and 3 non-notifiable infectious diseases were included in our study.* The date of illness onset was in 2018. Cases were reported to China CDC through the National Notifiable Disease Reported System (NNDS), using standard surveillance case definitions. Clinically-diagnosed and laboratory-confirmed cases were included. Probable cases were excluded.

A descriptive analysis was utilized to explore the epidemiological characteristics by IBM SPSS Statistics for Windows (version 20.0; IBM Corp., Armonk, NY, USA). A spatial mapping description was conducted to explore the geographic characteristics by ArcGIS (version 10.2, ESRI, Redlands, CA, USA). Cases were matched via the present residence address. Incidence rates were calculated using cases and the midyear demographic statistics 2018 (3).

RESULTS

A total of 51,599 cases with vector-borne diseases were reported in 2018 with an incidence rate of 3.69/100,000, including 31,935 clinically-diagnosed cases and 19,664 laboratory-confirmed cases. Scrub typhus, hemorrhagic fever with renal syndrome (HFRS), and dengue contributed to 85.08% of all the cases. A total of 377 fatalities were included to represent a case fatality rate (CFR) of 0.73%. Japanese encephalitis (JE), severe fever with thrombocytopenia

* Notifiable diseases: Class A (plague); Class B (hemorrhagic fever with renal syndrome, dengue, Japanese encephalitis, malaria, schistosomiasis, leptospirosis); Class C (typhus group rickettsiosis, kala-azar, filariasis). Non-notifiable diseases: severe fever with thrombocytopenia syndrome, scrub typhus, zika.

syndrome (SFTS), and HFRS accounted for 95.76% of all fatalities. Cases were reported from all provincial-level administration divisions (PLADs) with 2,280 counties in Mainland China, primarily in Guangdong (10,905 cases, 21.13% of the total) and Yunnan (10,393, 20.14%) (Figure 1).

A total of 11,739 (22.75% of all the cases) HFRS cases were reported from 1,319 counties of all the PLADs, including 95 deaths (Figure 2). The incidence rate was 0.84/100,000 (Table 1). The male-to-female ratio was 2.69. There were two seasonal peaks: the primary peak was in November and a smaller peak occurred in May (Figure 3). The median age of HFRS cases was 49 years (interquartile range [IQR]=37–60). The median age of death cases was 55 years (IQR=46–64). The morbidity was higher in Shaanxi (1,722 cases, 4.49/100,000), Heilongjiang (1,230, 3.25/100,000), Liaoning (1,116, 2.55/100,000), Jilin (573, 2.11/100,000), Hubei (907, 1.54/100,000), Jiangxi (671, 1.45/100,000), Shandong (1,199, 1.20/100,000), and Fujian (424, 1.08/100,000).

A total of 5,270 (10.21%) dengue cases were reported from 545 counties of 27 PLADs (Figure 2), including 1,292 imported cases. There was 1 fatality, and the case fatality rate was 0.02%. Of all the cases, 2,942 (55.83%) cases were individuals between 18 and 44 years (Table 1). Overall, 65.84% of all the cases had the illness onset between September and October

(Figure 3). The median age of dengue cases was 37 years (IQR=27–50). The morbidity was higher in Guangdong (3,332, 2.98/100,000), and Yunnan (928, 1.93/100,000).

All 2,633 (5.10%) malaria cases were imported cases and reported from 996 counties of 30 PLADs (Figure 2). There were 7 fatalities with case fatality rate of 0.27%. Of all the cases, 2,441 (92.71%) cases were male cases and 2,530 (96.09%) cases were individuals between 18 and 59 years (Table 1). The median age of malaria cases was 40 years (IQR=30–48), and 2 cases were infected via blood transfusion.

A total of 1,804 (3.50%) JE cases were reported from 645 counties of 25 PLADs (Figure 2) including 152 fatalities. The incidence rate was 0.13/100,000 and the case fatality rate was 8.43%. Of all the cases, 1,722 (95.45%) cases had illness onset from July to September with a seasonal peak in August (Table 1, Figure 3). The median age of JE cases was 52 years (IQR=19–65). The morbidity was higher in Ningxia (162, 2.38/100,000) and Gansu (504, 1.92/100,000).

A total of 147 (0.28%) schistosomiasis cases were reported from 62 counties of 12 PLADs (Figure 2). The male-to-female ratio was 1.94. Most cases (81.63%) were individuals aged older than 44 years (Table 1). Of all the cases, 138 (93.29%) cases were chronic schistosomiasis and 9 (6.04%) cases were not classified. The median age of schistosomiasis cases was

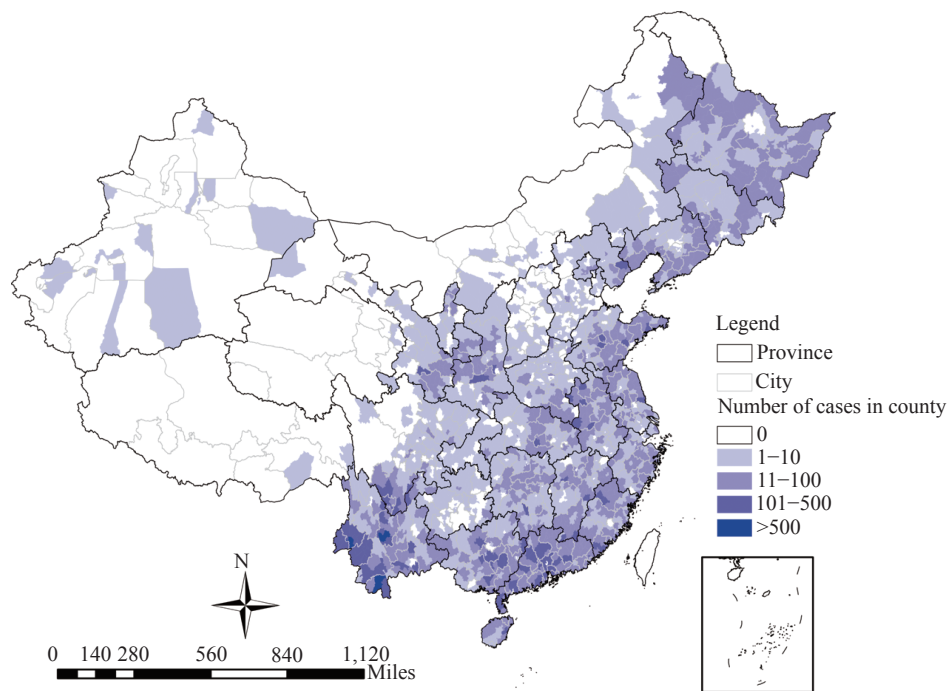


FIGURE 1. Spatial distribution of overall cases of vector-borne diseases in Mainland China, 2018.

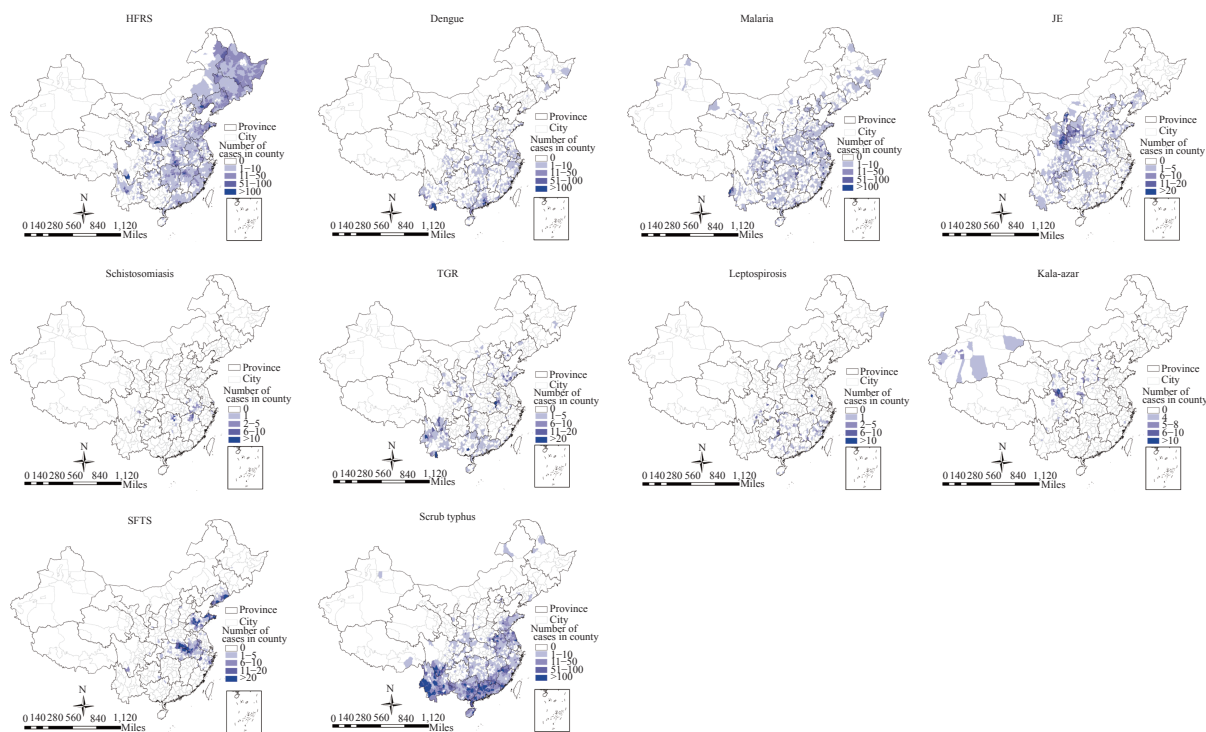


FIGURE 2. Spatial distribution of vector-borne diseases by type in Mainland China, 2018. HFRS=hemorrhagic fever with renal syndrome; JE=Japanese encephalitis; TGR=typhus group rickettsiosis; SFTS=severe fever with thrombocytopenia syndrome.

61 years (IQR=48–70). Schistosomiasis cases were mainly distributed in central (68.03%), and eastern (25.85%) China, including Hunan (47.62%), Jiangxi (19.05%), and Anhui (19.05%).

A total of 154 (0.30%) leptospirosis cases were reported from 106 counties of 16 PLADs (Figure 2), including 1 fatal case. Male cases were represented more than female cases. The male-to-female ratio was 4.31 (Table 1). An estimated 66.23% of the cases occurred from July to September with the seasonal peak in August (Figure 3). The median age of leptospirosis cases was 54.5 years (IQR=45.75–63.25).

A total of 962 (1.86%) typhus group rickettsiosis (TGR) cases were reported from 320 counties of 22 PLADs (Figure 2). Overall, 339 (35.24%) cases had the illness onset between July and September (Table 1), and 59% of TGR cases occurred from July to November. The median age of TGR cases was 48 years (IQR=27–62). TGR cases were mainly distributed in southwestern (36.17%), southern (21.62%) and eastern (20.45%) China, including Yunnan (26.09%), Guangdong (13.72%), Shandong (12.16%), and Sichuan (9.67%).

A total of 155 (0.30%) kala-azar cases were reported from 68 counties of 13 PLADs (Figure 2). The male-

to-female ratio was 1.50. Individuals under the age of 18 years contributed to the most cases (41.94%). The median age of kala-azar cases was 32 years (IQR=3–47). Overall, 100 (64.52%) cases had the illness onset between January and June (Table 1). Kala-azar cases were mainly distributed in northwestern (61.94%), northern (20.65%), and southwestern (11.61%) China, including Gansu (38.06%), Shanxi (19.35%), Shaanxi (13.55%), Xinjiang (10.32%), and Sichuan (9.68%). No domestic cases were reported in eastern, northeastern, and southern China.

A total of 1,845 (3.58%) SFTS cases were reported from 231 counties of 17 PLADs (Figure 2), including 114 fatalities. The incidence rate was 0.13/100,000 and the case fatality rate was 6.18%. The median age of SFTS cases was 64 years (IQR=54–71). The illness onset peaked in May with 483 (26.18%) cases, and then decreased monthly (Figure 3). The morbidity was higher in Shandong (736, 0.74/100,000), Anhui (328, 0.52/100,000), Hubei (237, 0.40/100,000), Liaoning (123, 0.28/100,000), and Henan (272, 0.28/100,000).

A total of 26,889 (52.11%) scrub typhus cases were reported from 947 counties in 27 PLADs (Figure 2), including 7 fatalities. The incidence rate was 1.92/100,000 and the case fatality rate was 0.03%.

TABLE 1. Selected characteristics of reported cases of vector-borne diseases by type in Mainland China, 2018.

Item	HFRS (N=11,739) n (%)	DF (N=5,270) n (%)	Malaria (N=2,633) n (%)	JE (N=1,804) n (%)	Schistosomiasis (N=147) n (%)	TGR (N=962) n (%)	Leptospirosis (N=154) n (%)	Kala-azar (N=155) n (%)	SFTS (N=1,845) n (%)	ST (N=26,889) n (%)	Zika (N=1) n (%)	Total (N=51,599) n (%)
Age group												
<18	472 (4.02)	428 (8.12)	34 (1.29)	417 (23.12)	1 (0.68)	190 (19.75)	2 (1.30)	65 (41.94)	12 (0.66)	2,706 (10.06)	0 (0)	4,327 (8.39)
18–44	3,893 (33.16)	2,942 (55.83)	1,623 (61.64)	308 (17.07)	26 (17.69)	225 (23.39)	33 (21.43)	42 (27.10)	142 (7.70)	5,633 (20.95)	0 (0)	14,867 (28.81)
45–59	4,338 (36.96)	1,175 (22.30)	907 (34.45)	404 (22.39)	44 (29.93)	262 (27.23)	66 (42.86)	33 (21.29)	514 (27.86)	9,011 (33.51)	1 (100)	16,755 (32.47)
≥60	3,026 (25.86)	725 (13.75)	69 (2.62)	675 (37.42)	76 (51.70)	285 (29.63)	53 (34.41)	15 (9.68)	1,177 (63.79)	9,539 (35.48)	0 (0)	15,650 (30.33)
Gender												
Male	8,558 (72.90)	2,970 (56.36)	2,441 (92.71)	938 (52.00)	97 (65.99)	468 (48.65)	125 (81.17)	93 (60.00)	885 (47.97)	12,478 (46.41)	1 (100)	29,054 (56.31)
Female	3,181 (27.10)	2,300 (43.64)	192 (7.29)	866 (48.00)	50 (34.01)	494 (51.35)	29 (18.83)	62 (40.00)	960 (52.03)	14,411 (53.59)	0 (0)	22,545 (43.69)
Period of onset												
January–March	2,397 (20.42)	55 (1.04)	673 (25.56)	2 (0.11)	36 (24.49)	97 (10.08)	8 (5.19)	48 (30.97)	24 (1.30)	649 (2.41)	0 (0)	3,989 (7.73)
April–June	3,247 (27.66)	240 (4.55)	681 (25.86)	52 (2.89)	38 (25.85)	255 (26.51)	25 (16.23)	52 (33.55)	985 (53.39)	4,596 (17.09)	0 (0)	10,171 (19.71)
July–September	1,536 (13.08)	2,552 (48.43)	706 (26.81)	1,722 (95.45)	45 (30.61)	339 (35.24)	102 (66.24)	27 (17.42)	670 (36.31)	13,556 (50.41)	0 (0)	21,255 (41.19)
October–December	4,559 (38.84)	2,422 (45.96)	573 (21.76)	28 (1.55)	28 (19.05)	271 (28.17)	19 (12.34)	28 (18.06)	166 (9.00)	8,088 (30.08)	1 (100)	16,183 (31.36)
Outcome												
Recovered	11,644 (99.19)	5,269 (99.98)	2,626 (99.73)	1,652 (91.57)	147 (100)	962 (100)	153 (99.35)	155 (100)	1,731 (93.82)	26,882 (99.97)	1 (100)	51,222 (99.27)
Death	95 (0.81)	1 (0.02)	7 (0.27)	152 (8.43)	0 (0)	0 (0)	1 (0.65)	0 (0)	114 (6.18)	7 (0.03)	0 (0)	377 (0.73)

Note: Date of onset missing for one case of dengue. Notifiable diseases: Class A (plague); Class B (hemorrhagic fever with renal syndrome, dengue, Japanese encephalitis, malaria, schistosomiasis, leptospirosis); Class C (typhus group rickettsiosis, kala-azar, filariasis). Non-notifiable diseases: severe fever with thrombocytopenia syndrome, scrub typhus, zika.

Abbreviation: HFRS=hemorrhagic fever with renal syndrome; DF=dengue fever; JE=Japanese encephalitis; TGR=typhus group rickettsiosis; SFTS=severe fever with thrombocytopenia syndrome; ST=scrub typhus.

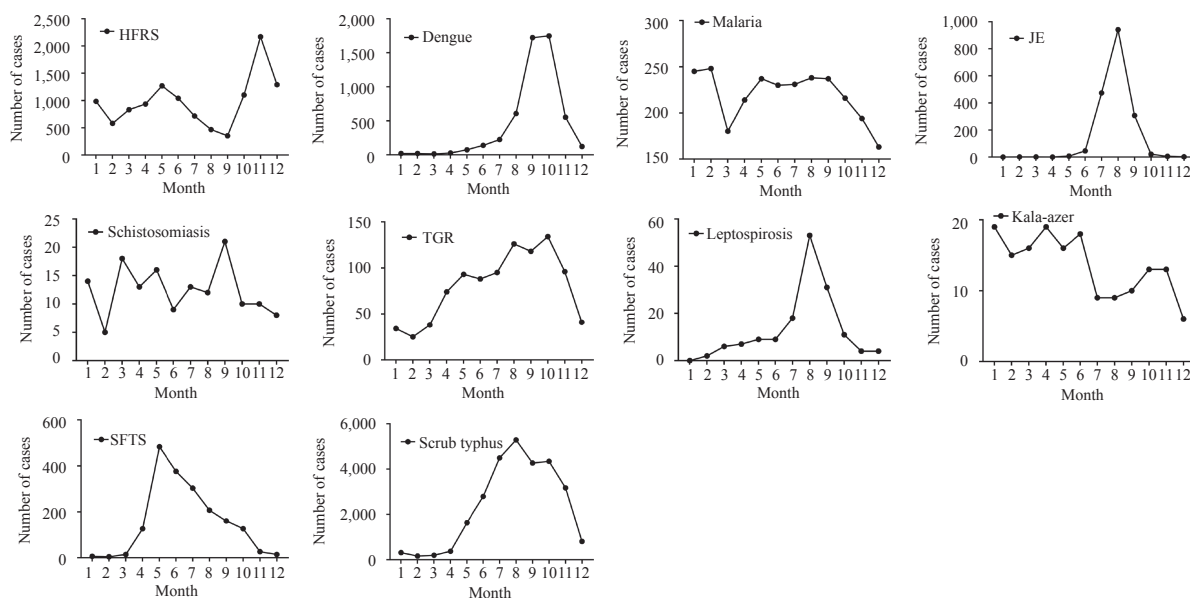


FIGURE 3. Time-series analyses of vector-borne diseases by type in Mainland China, 2018. HFRS=hemorrhagic fever with renal syndrome; JE=Japanese encephalitis; TGR=typhus group rickettsiosis; SFTS=severe fever with thrombocytopenia syndrome.

Overall, 18,392 (66.11%) cases had the illness onset during July to October. The median age of scrub typhus cases was 53 years (IQR=40–64). The morbidity was higher in Yunnan (8,672, 18.07/100,000), Guangxi (3,399, 6.96/100,000), Guangdong (6,775, 6.06%), Hainan (460, 4.97/100,000), and Fujian (1,628, 4.16/100,000).

One case of Zika was reported to be imported from the Maldives. The patient was a male aged 56 years. He lived in Yuxiu District, Guangdong Province.

DISCUSSION

Vector-borne diseases are an important component of infectious diseases in China. All malaria cases in 2018 were imported. Malaria was an ongoing concern for blood and tissue safety because two cases infected via blood transfusion were reported. In 2018, vector-borne diseases caused substantial morbidity in Mainland China, especially scrub typhus, HFRS, and dengue. The number of scrub typhus increased year by year and the figure in 2018 was 18.74% higher than that of 2017 (4). Although dengue morbidity was not significant high in 2018, dengue poses a growing threat in recent years because the distribution range has expanded significantly northward (5). High-risk areas and populations for dengue transmission are predicted to expand using representative concentration pathway scenarios in the future (6). Moreover, JE, SFTS, and HFRS caused significant mortality burdens. The characteristics of the JE epidemic have changed in recent years. Adults have experienced higher incidence and fatality rates than children, and northwestern China has become the new region of the JE epidemic (7). Fewer cases of SFTS were reported in 2018 than the figure in 2017. However, the number of cases reported was still higher than that in other years before 2017 (8). Given the higher case fatality rate, more attention and awareness should be paid by the governments, health care providers, and public. Cases with TGR, kala-azar, schistosomiasis, and leptospirosis were sporadic.

In addition, the epidemiology varied by season and geography. Different vector-borne diseases were prevalent through different spatiotemporal patterns. For example, JE and leptospirosis were prevalent from July to September with a peak in August. Overall, 79.12% of dengue, TGR, and scrub typhus cases occurred between July and November. In comparison, the seasonal peak of SFTS was in May, while the seasonal peak of HFRS was in November. On the

other hand, the main threat for northeastern China was HFRS, while the main threats for northwestern China were HFRS and JE. Vector-borne diseases posed multiple threats to Guangdong and Yunnan, including TGR, HFRS, dengue, malaria, scrub typhus, and JE. Natural factors, such as climate, ecological environment, and land use, may influence the distribution of the host and vector (9).

Prevention and control of vector-borne diseases is very difficult because of emerging and reemerging vector-borne diseases, imported cases, and local outbreaks in China. It is crucial to monitor vector dynamics and disease outbreaks and inform public health prevention efforts promptly. For vaccine available vector-borne diseases, such as JE and HFRS, vaccination remains the most effective measure. While vaccines are not available, prevention depends on efforts to minimize alternative routes of transmission (10). Interventions, such as vector surveillance, sustainable vector management, environmental governance, and public health promotion will be necessary to implement.

The findings in this report are subject to three limitations. First, the data are obtained from a passive surveillance system. The actual number may be underreported. Second, epidemiological history is not detailed in the NNDS, so some important information may not be obtained, such as the detailed infection location and route. Third, the underreporting rate is different in notifiable and non-notifiable infectious diseases.

Understanding the epidemiology, seasonality, and geographic distribution is important for clinical recognition and personal protection. This report provides scientific information on spatiotemporal patterns of different vector-borne diseases in Mainland China, which is of great value for public health targeting priorities in different regions.

Conflict of interest: No conflicts of interest were reported.

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Preplanned Studies

Prevalence and Risk Factors of Anemia of Pregnant Women — 6 Provinces in China, 2014–2018

Huanqing Hu¹; Aiqun Huang¹; Qi Yang¹; Wei Zhao¹; Yu Ma¹; Jiangli Di^{1,*}

Summary

What is already known about this topic?

Anemia during pregnancy is a global public health problem affecting both maternal and children's health. The "National Nutrition Plan (2017–2030)" and "Healthy China Action (2019–2030)" issued by the State Council of China in 2017 and 2019, respectively, specified nutrition targets: by 2030, the anemia rate in pregnant women should be reduced to less than 10%. The anemia prevalence of pregnant women reported by the Chinese Nutrition and Health Surveillance in 2006 and 2010–2012 was 42.0% and 17.2%, respectively.

What is added by this report?

Past surveillance in 2010–2012 did not divide pregnant women by gestation week, and the sample size was only 4,315 cases. In this study, the information of 206,753 registered pregnant women from their first antenatal care (ANC) examination to childbirth was collected from 2014 to 2018. The overall prevalence of anemia among pregnant women was 41.98%.

What are the implications for public health practice?

The overall prevalence of anemia among pregnant women in the monitoring areas was high, far from the target of 10%. Anemia remains a serious health problem among pregnant women in China. It is urgent to develop effective strategies and take measures to reduce the prevalence of anemia in China.

Anemia affects roughly one third of the world's population (1). Approximately 40.1% of pregnant women worldwide were estimated to be anemic in 2016 (2). Evidence shows that maternal anemia is associated with poor birth outcomes, including low birth weight, prematurity, maternal and perinatal

mortality, and also poor cognitive and motor development outcomes in children (2–3). Furthermore, anemia remains a persistent problem among women in China. An estimated 26.4% of women of reproductive age (15–49 years) were anemic in 2016, which translates to 95.0 million women affected, an increase of 16.9 million in absolute numbers from 2012 (20.7% among women of reproductive age) (1).

In 2011, the "Development Outline for Chinese Women (2011–2020)" (4) released by the State Council of China put forward a target of reducing the prevalence of moderate and severe anemia during pregnancy by 2020. The "National Nutrition Plan (2017–2030)" (5) and "Healthy China Action (2019–2030)" (6) issued by the State Council of China in 2017 and 2019, respectively, specified nutrition targets: by 2030, the anemia rate in pregnant women should be reduced to less than 10%. Therefore, this study aims to understand the current levels of anemia during pregnancy in China and to determine how far they are from the 2030 target.

The data of this study were obtained from the Maternal and Newborn Health Monitoring System* (MNHMS) set up by the National Center for Women and Children's Health (NCWCH) for Maternal and Newborn Health Monitoring Program† (MNHMP) in 2013. All pregnant women who were residents or who had lived more than six months in these places were enrolled at their first antenatal care (ANC) examination, the information about their ANC during pregnancy was collected from the Maternal and Child Care Handbooks, and the information of delivery was collected from their delivery registrations. Finally, all the data was recorded in the MNHMS.

* The MNHMS was established to monitor the prenatal health care and pregnancy outcomes of pregnant women from 16 districts/counties of 8 provinces. Because 2 of the provinces have been included in the program since 2015, to maintain the continuity and integrity of the data, the study only selected data from the other 6 provinces for analysis. The 6 provinces (with the selected districts) are: Hebei (Xinhua and Zhengding), Liaoning (Lishan, Tiedong, and Taian), Hunan (Yueyanglou and Yueyang), Fujian (Haicang and Jimei), Sichuan (Gongjing and Rong County), and Yunnan (Tonghai and Huaning). Taian stopped surveillance in 2016, and Tiedong County became the participant since then.

† To ensure the quality of the information, the system set many logic checks to prevent wrong inputs. In addition, the staff of the NCWCH conducted field supervision on data accuracy every year. MNHMP was approved by the Ethics Committee of NCWCH (No.FY2015-007).

In the MNHMS, a total of 210,526 women (delivered live births between January 1, 2014 and December 31, 2018) had received at least 1 hemoglobin (Hb) test during prenatal care. Women whose last menstrual period (LMP) was missing (150 persons) and with multiple pregnancies (3,623 persons) were excluded. Finally, the data of 206,753 registered pregnant women were analyzed in this study.

According to World Health Organization (WHO) criteria (7), anemia in pregnancy was defined as Hb < 110 g/L at any antenatal examination of any gestation week. Mild, moderate, and severe anemia are defined as Hb measurements between 100 and 109 g/L, 70–99 g/L, and less than 70 g/L, respectively. Since the altitude of the two counties of Yunnan Province was 1,900 meters, a revised diagnostic criteria for anemia of Hb < 117 g/L was used. For the two counties, mild, moderate, and severe anemia was defined as Hb measurements between 108 and 117 g/L, 78–107 g/L, and less than 78 g/L, respectively.

Prevalence rates were estimated overall and by subgroups. T-tests and Rao-Scott chi-square tests were conducted to explore the differences between groups in variables and prevalence. Multivariable logistic regression models were used to explore the factors associated with prevalence of anemia among the pregnant. All statistical analyses were conducted by SAS software (version 9.4, SAS Institute Inc, Cary, USA).

The number of participants in the anemic and non-anemic groups was 86,802 and 119,951, respectively. The overall prevalence of anemia among pregnant women was 41.98% (86,802/206,753). Table 1 shows the maternal characteristics of the anemic group versus

the non-anemic group. Gestation week of the first ANC, maternal age, gravidity, parity, number of ANC examinations, number of Hb tests, and delivery week between the anemic group and the non-anemic group were statistically significant (Table 1).

There was no significant differences in the prevalence of anemia in different years. For each year between 2014 to 2018, the prevalence was 41.24%, 43.51%, 43.67%, 43.82%, and 36.76%, respectively. For details, the prevalence of anemia of different levels among pregnant women from each year between 2014 to 2018 are shown in Supplementary Figure S1 (available in <http://weekly.chinacdc.cn>).

A total of 206,753 women were assessed to evaluate the associated risk factors. The prevalence of anemia among pregnant women based on location, maternal age, educational status, parity, number of prenatal examinations, number of Hb tests, and week of delivery were statistically significant (Table 2).

The results of multivariate logistic regression analysis showed that age under 25 years; residing in China's northwest region, southwest region, or urban areas; having delivered before; and being in the second or third trimester were the predictors of anemia in pregnancy. Anemic pregnant women may have received more than five ANC examinations or more than three Hb tests during gestation. The details are shown in Table 3.

DISCUSSION

Anemia during pregnancy is a global public health problem affecting both maternal and children's health in developing and developed countries. In this study,

TABLE 1. Demographic and reproductive health characteristics among pregnant women — 6 provinces in China, 2014–2018.

Variables	Non-anemia (N=119,951) X±SD	Anemia (N=86,802) X±SD	Total (N=206,753) X±SD	t	P
Hb (g/L)	126.72±10.08	103.32±7.23	116.90±14.63		
Gestation week of the first ANC	14.05±6.85	14.56±6.55	14.26±6.73	-16.80	<0.001
Maternal age	28.03±4.61	27.85±4.68	27.95±4.64	8.88	<0.001
Gravidity	2.00±1.10	2.06±1.10	2.03±1.10	-12.77	<0.001
Parity	0.51±0.57	0.55±0.58	0.53±0.57	-17.91	<0.001
Number of ANC examinations	7.62±3.40	8.41±2.99	7.95±3.26	-54.45	<0.001
Number of Hb tests	3.57±1.85	4.37±1.91	3.91±1.91	-95.76	<0.001
Week of delivery	39.07±3.05	39.12±2.35	39.09±2.78	-4.22	<0.001

Note: The six provinces (with the selected districts) are: Hebei (Xinhua and Zhengding), Liaoning (Lishan, Tiedong and Taian), Hunan (Yueyanglou and Yueyang), Fujian (Haicang and Jimei), Sichuan (Gongjing and Rong County) and Yunnan (Tonghai and Huaning). Taian stopped surveillance in 2016, so Tiedong County became the participant since then.

Abbreviation: ANC=antenatal care, Hb=hemoglobin.

TABLE 2. Prevalence of anemia among pregnant women in different trimesters — 6 provinces in China, 2014–2018.

Variables	First trimester (<13 weeks)			Second trimester (<28 weeks)			Third trimester (≥36 weeks)			Total		
	Number	Prevalence of anemia (%)	χ^2	Number	Prevalence of anemia (%)	χ^2	Number	Prevalence of anemia (%)	χ^2	Number	Prevalence of anemia (%)	χ^2
Regions			242.45 [*]			128.04 [*]			916.09 [*]			2614.20 [*]
Northeast	14,581	4.62		36,875	43.05		24,881	80.85		76,337	48.03	
Central	37,018	8.56		22,646	43.12		24,372	69.60		84,036	35.58	
Southwest	17,478	8.29		12,918	48.53		15,984	78.33		46,380	43.64	
Age			34.23 [*]			32.20 [*]			179.53 [*]			89.04 [*]
<25	15,740	8.41		14,679	46.11		15,258	78.39		45,688	43.90	
25–35	47,196	7.24		50,312	43.51		43,475	76.16		140,983	41.44	
>35	5,875	8.75		7,155	43.48		6,207	69.79		19,252	41.38	
Education			143.29 [*]			120.16 [*]			72.80 [*]			354.32 [*]
Junior high or lower	25,983	8.94		25,151	46.33		26,946	77.72		78,080	44.72	
Senior high school	18,333	7.94		16,565	45.10		16,417	75.86		51,315	41.66	
University or above	23,139	6.08		30,098	41.83		21,252	74.41		74,489	40.02	
Parity			48.23 [*]			2.33			3.49			306.23 [*]
0	34,580	6.93		36,893	43.88		30,128	76.24		101,601	40.90	
≥1	28,712	8.40		34,345	44.45		34,264	75.61		97,321	44.78	
Number of ANC examinations			50.59 [*]			1902.86 [*]			2327.02 [*]			1820.44 [*]
<5	4,311	4.87		9,252	23.02		6,099	50.93		19,662	27.70	
≥5	64,766	7.85		63,187	47.13		59,138	78.62		187,091	43.48	
Number of Hb tests			85.19 [*]			4731.27 [*]			7043.13 [*]			5764.56 [*]
<3	13,552	5.77		20,676	23.97		15,388	50.79		49,616	27.32	
≥3	55,525	8.12		51,763	52.07		49,849	83.83		157,137	46.61	
Delivery week			6.12 [†]			29.25 [*]			114.35 [*]			215.88 [*]
<37 weeks	2,822	6.45		69,158	44.27		63,342	76.34		198,755	42.30	
≥37 weeks	66,255	7.71		3,281	39.47		1,895	65.70		7,998	34.03	

Note: The six provinces (with the selected districts) are: Hebei (Xinhua and Zhengding), Liaoning (Lishan, Tiedong, and Taian), Hunan (Yueyanglou and Yueyang), Fujian (Haicang and Jimel), Sichuan (Gongjing and Rong County) and Yunnan (Tonghai and Huaning). Taian stopped surveillance in 2016, and Tiedong County became the participant since then. Rao-Scott chi-square tests were conducted to test for differences in prevalence for unordered categorical variables. Based on the economic development level and administrative divisions, Hebei and Liaoning provinces represented the northeast region, Hunan and Fujian provinces the central region, and Sichuan and Yunnan provinces the southwest region. In addition, pregnant woman were classified as natives or outsiders of the counties on the basis of the census registration. Gestational week was based on the number of days between the first day of an expectant mother's LMP and the date of antenatal examination. The first, second, and third trimester were defined as a gestational age less than 13 weeks, 13–27 weeks, and 28–42 weeks, respectively.

^{*} $p < 0.001$.

[†] $p < 0.05$.

the overall anemia prevalence among pregnant women was 41.98%, which is consistent with the global estimates of anemia prevalence during pregnancy (40.1%) in 2016 (2), but significantly higher than the anemia prevalence during pregnancy (17.2%) reported by the Chinese Nutrition and Health Surveillance in 2010–2012 (7). Further analysis of data from the Chinese Nutrition and Health Surveillance found that the surveillance was conducted from 2010 to 2012 and

that the sample size was only 4,135 pregnant women. Moreover, the gestational age of pregnant women and the altitude of the monitoring areas were not taken into account (8).

From 2014 to 2018, the overall prevalence and the prevalence of moderate and severe anemia remained unchanged, indicating that no effective intervention has taken place in these areas. If current trends continue, the 2020 target of reducing the prevalence of

TABLE 3. Factors associated with anemia among pregnant women — 6 provinces in China, 2014–2018.

Variables	OR	95% CI	p value
Region			
Central	Ref		
Northeast	1.242	1.208–1.278	<0.001
Southwest	1.191	1.151–1.222	<0.001
Age (years)			
<25	1.186	1.151–1.222	
25–35	Ref		<0.001
≥35	0.93	0.894–0.967	<0.001
Education			
Junior high or lower	Ref		
Senior high	0.897	0.871–0.924	<0.001
University or above	0.842	0.818–0.867	<0.001
Parity			
0	Ref		
≥1	1.132	1.103–1.161	<0.001
Number of ANC examinations			
<5	Ref		
≥5	1.632	1.564–1.702	<0.001
Number of Hb tests			
<3	Ref		
≥3	3.289	3.192–3.388	<0.001
Trimester			
First (<13 weeks)	Ref		
Second (<28 weeks)	11.248	10.863–11.646	<0.001
Third (≥36 weeks)	47.220	45.530–48.973	<0.001

Note: The six provinces (with the selected districts) are: Hebei (Xinhua and Zhengding), Liaoning (Lishan, Tiedong and Taian), Hunan (Yueyanglou and Yueyang), Fujian (Haicang and Jimei), Sichuan (Gongjing and Rong County) and Yunnan (Tonghai and Huaning). Taian stopped surveillance in 2016, so Tiedong County became the participant since then. Based on the economic development level and administrative divisions, Hebei and Liaoning provinces represented the northeast region, Hunan and Fujian provinces the central region, and Sichuan and Yunnan provinces the southwest region. In addition, pregnant woman were classified as natives or outsiders of the counties based on their census registration. Gestational week was based on the number of days between the first day of an expectant mother's LMP and the date of antenatal examination. The first, second, and third trimester were defined as a gestational age less than 13 weeks, 13–27 weeks, and 28–42 weeks, respectively.

Abbreviation: ANC=antenatal care. OR=odds ratio. CI=Confidence interval.

moderate and severe pregnancy anemia (4) will not be met. In 2018, anemia affected 41.98% of pregnant women in the monitoring areas — more than triple and quadruple the Healthy China Action (2019–2030) (6) targets of less than 14% by 2022 and less than 10% by 2030, making it extremely challenging to achieve the targets.

The results of this study show wide variations in prevalence across regions — from 35.58% in China's central region, 43.64% in the southwestern region, and 48.03% in the northeastern region. These results are supported by another multi-center study: the anemia

prevalence in Guangzhou (eastern region) (38.8%) and Chengdu (western region) (23.9%) was significantly higher than in Beijing (central region) (19.3%) (9). These variations across regions might be attributed to the different socioeconomic conditions, lifestyle, diet, or health-seeking behaviors across different cultures (10).

Although the prevalence of anemia was high in this study, the prevalence of mild anemia was highest (40.82%) and the proportion of mild anemia was almost 90%. This statistic suggests that as long as the health agencies pay attention to the prevention and

control of anemia and deal with mild anemia effectively as soon as it is found, the prevalence rate of anemia could be effectively controlled.

One of the strengths of this study is the use of anemia data from individual clinical data of pregnant women in all midwifery institutions in the monitoring areas. Thus, the study findings are more accurate, more convincing, and more instructive for policy decision-making than aggregated data. However, the study used convenience sampling, and the monitoring area was limited to 12 counties/districts in 6 provinces, so the results might not be representative of the regional and national levels.

Nevertheless, the results of this study provide a basis for policy makers to understand the current situation of anemia among pregnant women and to formulate targeted intervention measures as soon as possible.

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Notes from the Field

Weekly Assessment of the COVID-19 Pandemic and Risk of Importation — China, March 25, 2020

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Along with the announcement of COVID-19 as a global pandemic by the World Health Organization (WHO) on March 12, 2020, COVID-19 appeared to be spreading rapidly around the world. By 10:00 CET on March 25, 2020, a total of 331,619 confirmed cases and 15,146 deaths were reported from 195 foreign countries and regions on 6 continents plus the Diamond Princess international cruise ship, and among them, 124 countries and regions had local transmission. Cumulatively, the WHO website reported 15,918 confirmed COVID-19 cases from 16 countries and regions in the Western Pacific excluding China, 220,516 cases from 60 countries and regions in Europe, 2,344 cases from 10 countries and regions in South-East Asia, 29,631 cases from 21 countries and regions in the Eastern Mediterranean, 60,834 cases from 48 countries and regions in the Americas, and 1,664 cases from 39 countries and regions in Africa (1).

In this report, using data and information on the websites of governmental agencies, international organizations, professional platforms and mainstream media, the COVID-19 trend in the context of the world was predicted and the risk of case importation into China was analyzed with the help of mathematic modeling.

RESULTS

Equivalent-Mortality Lines of Countries Most Severely Affected

According to the total number of confirmed COVID-19 cases and deaths, the cumulative incidence and crude case fatality ratio (CFR) of the top 11 countries with the most cases including China were calculated, and the equivalent-mortality lines were plotted based on population size. As shown in Figure 1, Italy had the highest cumulative incidence

rate and crude CFR and was located in Zone 4 (10–15 deaths/100,000), and Spain was located in Zone 3 (5–10 deaths/100,000). Iran, France, and the Netherlands were located in Zone 2 (1–5 deaths/100,000) due to high CFR, while Switzerland located at the same zone due to high incidence. China and USA were located in Zone 1 (0–1 deaths/100,000) as a result of large populations and low crude CFRs, and the UK, the Republic of Korea, and Austria were also at this zone.

Transmission Rate Prediction

Transmission rates in severely affected countries over the next week. Based on the numbers of case issued on the official websites of WHO and/or individual governments on March 24, 2020, the countries with cumulative case numbers exceeding 5,000 were selected, and their effective reproduction numbers (R_t) were calculated using SEIR mathematic modeling of infectious diseases. Germany, France, the Netherlands, the USA, Switzerland, Spain, Italy, the UK, the Republic of Korea, and Iran were included. The R_t values of all 10 selected countries were predicted to be between 0.8 and 5.0 over the next week. Among them, the R_t value of the USA is projected to be the highest (4.63), followed by the UK (3.08), Spain (2.78) and Netherlands (2.54) (Figure 2A). Combined with the large numbers of existing cases in those countries, more new cases will be expected over the next week, particularly in the USA.

Transmission rates in the global climatic zones. Based on latitude and type of climate, the world can be roughly divided into five zones that are tropical, subtropical, temperate, subfrigid, and frigid. Until now, there were no COVID-19 cases reported in the frigid zone. According to geographical location, the numbers of COVID-19 cases worldwide, excluding China, were correlated with the climatic zones by country. If the country spans more than one climatic zone, the climatic zone occupying the most area was

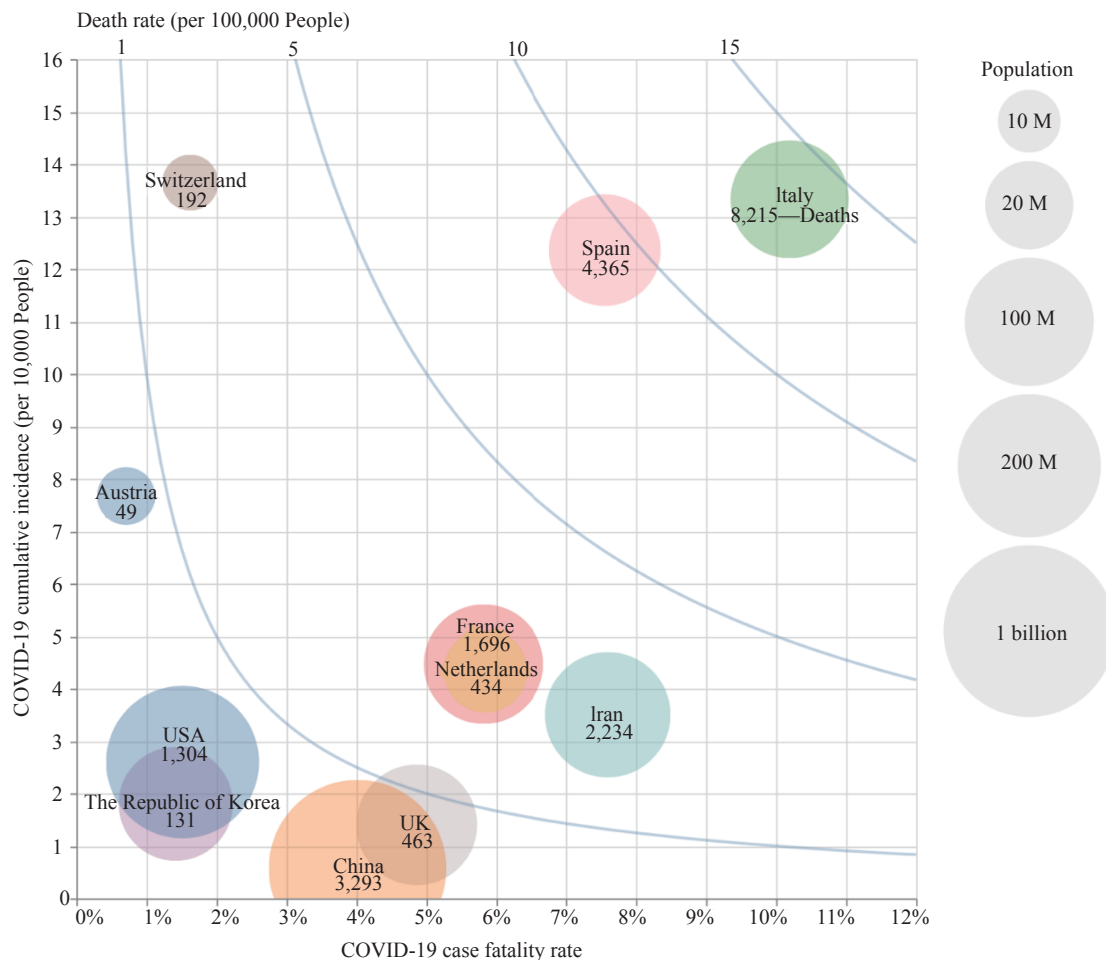


FIGURE 1. Comparison of the crude case fatality ratio (CFR), cumulative incidence (CI), and mortality of COVID-19 among the top 11 countries according to the real-time reported cases and deaths up to March 25, 2020. The crude CFR is displayed on the X-axis and the CI (1/10,000) on the Y-axis. The population mortality (1/100,000) is shown by the blue lines. The size of solid circle represents the population size of each country with legends on the right. The number of deaths in each country is labeled inside the circle. M=million.

selected. The reported cumulative incidence and crude fatality rate of each zone were calculated and showed that subtropical zone had higher rates than other climatic zones recently. Furthermore, the R_t values of those four climatic zones from January 7 to March 23 were calculated by SEIR mathematic modeling. As shown in Figure 2B, the R_t value of tropical zone was the highest (2.96), followed by temperate (2.68), subfrigid (1.84), and subtropical (2.14) zones. Due to the relatively fewer numbers of COVID-19 cases and lower morbidity currently in the tropical zone, the exact impact of climate on the spreading of disease still remains unclear and deserves further observation.

Laboratory Testing for 2019-nCoV in Four Severely Affected Countries

Comparison of the recommendations and criteria for

performing viral laboratory testing. To understand the laboratory testing performance for 2019-nCoV, the national recommendations and criteria for performing viral testing in four countries, including the USA, the UK, Italy, and the Republic of Korea, were reviewed and summarized in Table 1. Currently, the criteria for COVID-19 testing in Italy seemed to be the most accessible, followed by the Republic of Korea and the USA. The UK appeared to have relatively strict standards mainly focusing on patients with relatively severe respiratory symptoms.

Comparison of the numbers of the confirmed cases and the tested people. The cumulative numbers of confirmed cases and tested people at different times in those four countries were collected from relevant websites until March 24, 2020. The cumulative number of confirmed cases at each point in time for each country was illustrated according to the

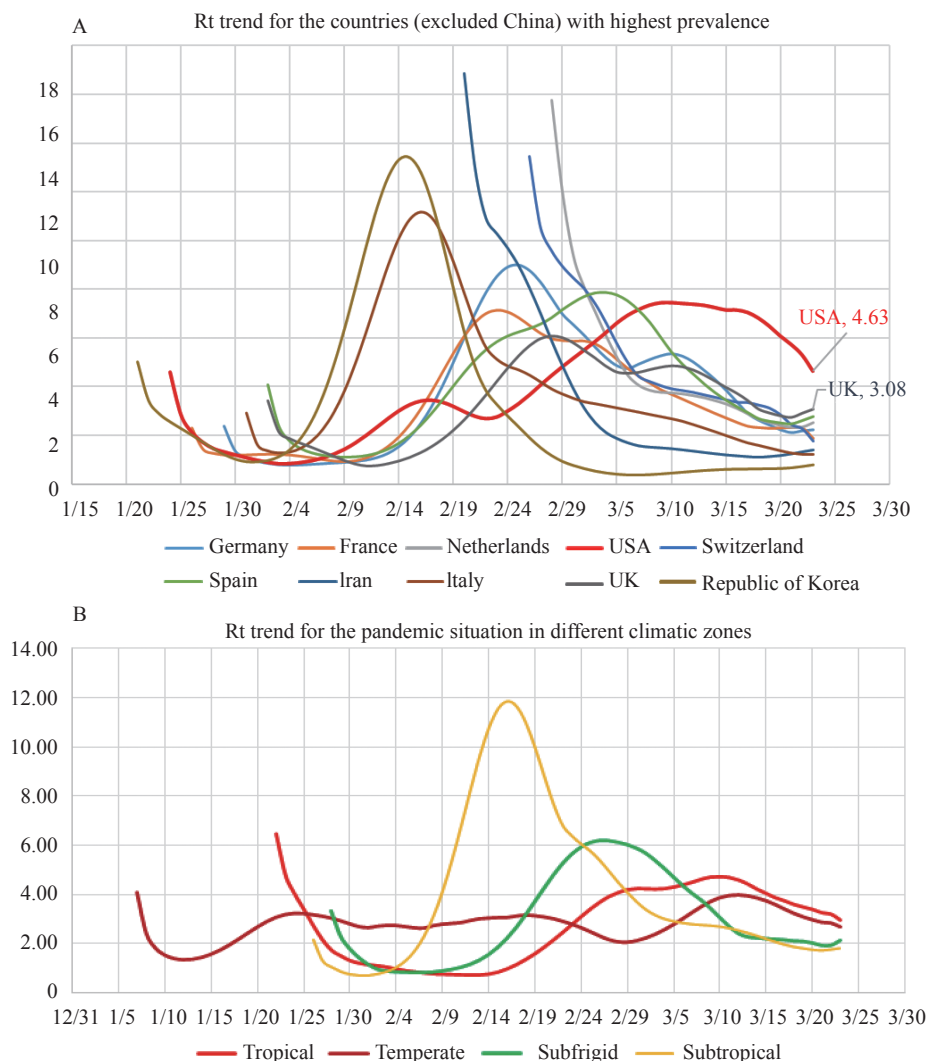


FIGURE 2. Calculation of the R_t trends and values of different countries and climatic zones. (A) The R_t trends and values of 10 countries with more than 5,000 total confirmed cases up to March 25, 2020. (B) The R_t trends and values of 4 climatic zones globally up to March 23, 2020.

TABLE 1. COVID-19 testing criteria in four severely affected countries.

Country	Key points of COVID-19 testing criteria
USA	<ol style="list-style-type: none"> 1. Hospitalized patients or healthcare facility workers with symptoms; 2. Patients with mild symptoms in communities experiencing high numbers of COVID-19 hospitalization; 3. Patients 65 years of age and older with symptoms or patients with underlying conditions with symptoms; 4. Patients with severe clinical symptoms who require hospitalization.
UK	<ol style="list-style-type: none"> 1. A person who has either clinical or radiological evidence of pneumonia; 2. Who has acute respiratory distress syndrome; 3. Who has influenza-like illness of acute onset
Italy	<ol style="list-style-type: none"> 1. Close contact with confirmed patients; 2. Or has travel history to high-risk epidemic areas or visits to hospitals or other high-risk areas; 3. Or is developing clinical symptoms.
The Republic of Korea	<ol style="list-style-type: none"> 1. Suspected Case: A person who develops clinical symptoms within 14 days of coming into contact with a confirmed patient while the patient was showing symptoms; 2. A person who is suspected of having the COVID-19 virus as per doctor's diagnosis due to pneumonia of unknown causes; 3. A person who develops clinical symptoms within 14 days of travelling to a country with local transmission of COVID-19; 4. A person with an epidemiologic link to the local COVID-19 outbreak and develops clinical symptoms within 14 days.

cumulative number of the tested people in a double logarithmic (log-log) chart, generating curves for those

four countries (Figure 3). The curve of Korea was quite flat at early stages before the outbreak of a cluster at a

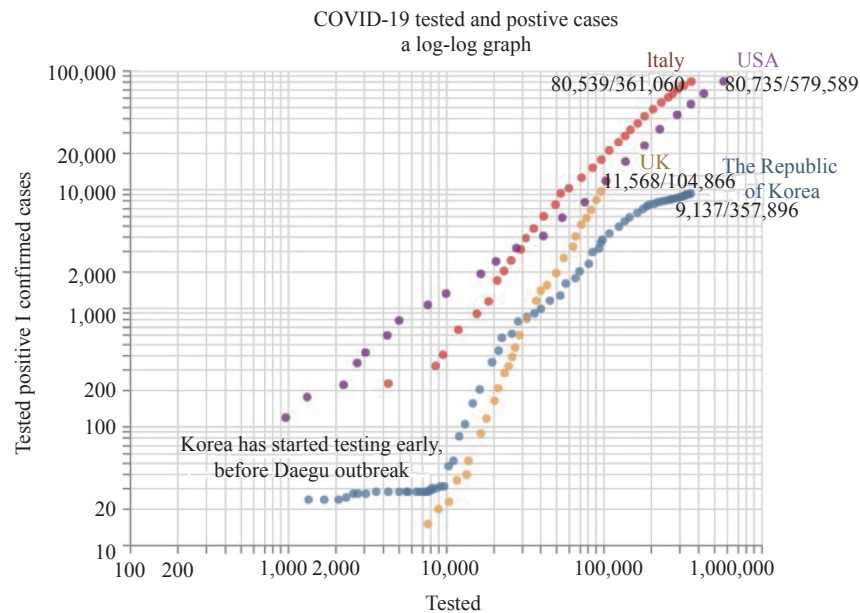


FIGURE 3. Comparison of the increase of the confirmed cases and the tested population in Republic of Korea, Italy, the USA, and the UK. The cumulative number of confirmed case in log scale are indicated on the Y-axis and the cumulative number of population tested in log scale are showed on the X-axis. The latest number of total confirmed cases and population tested are labeled at the end of each curve.

church in Daegu. Despite the cumulative case numbers remaining less than 30 for dozens of days, the amount tested expanded from roughly 1,500 to more than 10,000 individuals. The curve became more steep in the following 9 points in time after the outbreak in Daegu, which coincided well with the number of cases rapidly increasing from roughly 30 to 600 (roughly a 20-fold increase) but the number of people tested expanding only from 10,000 to about 22,000 (2.2-fold increase). The steep curve turned to be slightly flat in the following 15 points in time, in which the case numbers increased to approximately 4,000 (6.7-fold increase) along with the increase of testing numbers to 100,000 (4.5-fold increase). The curve was obviously flat in the latest dozen points in time and the cumulative positive rate was 2.55% (9,137/357,896).

On the contrary, the curves of Italy, the UK, and the USA maintained steep increases since the beginning, especially the UK (Figure 3). The population testing in these three countries expanded with the spread of the epidemic, but the curves still showed steeply rising trends. According to the latest issued data, the cumulative rates of the identified positive cases among the population tested in the Republic of Korea, Italy, the USA, and the UK were 2.55%, 22.3%, 13.9%, and 11.0%, respectively, highlighting a much higher testing ratio among the Korean population. Furthermore, we calculated the levels of increase in confirmed cases starting from 200 to the latest ones and the levels of

increase of the number tested from the point in time of reaching 200 confirmed cases to the newest count. The levels of increase of confirmed cases and that of the population tested in Korea, Italy, the USA, and the UK were approximately 45- and 27-fold, 366- and 16-fold, 367- and 263-fold, 53- and 9-fold, respectively. The capacity to expand virus testing in Italy and the UK lag behind the increases in confirmed cases.

Control Measures for COVID-19 in Five Severely Affected Countries

Although the strategies and methods of implementation varied among the countries, three major measures were conducted including school closures, city lockdowns, and gathering bans (Table 2). The cumulative deaths of the USA, the UK, Italy, Spain, and the Republic of Korea were correlated with the time (days) from the date of the first fatal case emerging and the implementation time of the three measures were indicated. As shown in Figure 4, the Republic of Korea conducted the interventions at a relatively early stage (within 7 days after the 1st fatal case reported) with about 10 cumulative deaths, which seemed to be associated with the relatively slow increasing curve. On the contrary, the other four countries implemented those measure relatively slowly, particularly the city lockdown that was conducted on the 10th (Spain) to 15th (USA, UK, and Italy) day after

TABLE 2. Interventions in five severely affected countries.

Country	School closure	Ban gatherings	Lockdown
USA	March 20 th , schools announced to be closed nationwide.	March 16 th , numerous theater chains temporarily closed across the country, and most professional sports leagues announced the suspension of their events.	March 20 th , the New York States, where has the worst pandemic situation, announced "lockdown".
Italy	March 4 th , the government announced to close all the schools across the country.	March 8 th , gatherings were banned across the country.	March 9 th , the government announced to extend the "lockdown" area across the country.
UK	March 18 th , most schools across the country announced to be closed	March 23 rd , Gatherings are banned across the country	March 23 rd , the government announced "lockdown", people were restricted from going out randomly.
The Republic of Korea	February 23 rd , suspension for classes were implemented.	February 25 th , Daegu and Gyeongbuk, where have the serious outbreak situation, lockdown.	February 27 th , a wide range of gatherings were banned.
Spain	March 12 th , schools across all the autonomous communities closed.	March 15 th , gatherings were banned nationwide.	March 16 th , the government announced "lockdown" nationwide.

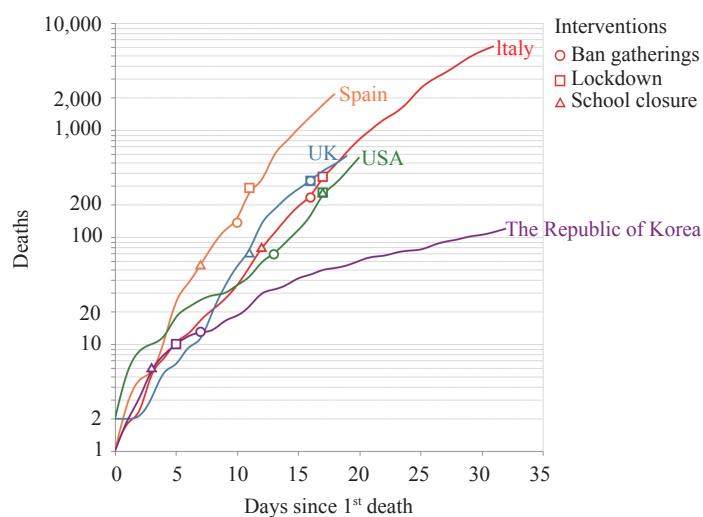


FIGURE 4. The increasing trends of deaths after the first fatal case reported in the Republic of Korea, Italy, Spain, the USA, and the UK. The implementation time of three major control measures are indicated on the curves. The cumulative numbers of deaths are shown in log scale on the Y-Axis and the time (days) after the first fatal case reported are shown on the X-axis.

the 1st fatal cases reported with 250 to 350 cumulative deaths. The exact association of the time of the measure implementation with the increase of death needs further evaluation.

Sources and Destinations of Imported Cases

According to civil flight information, the average daily number of entry flights from abroad to Mainland China was 165 in the week of March 19 to 25. Among these, flights from Asian countries accounted for 73%, Europe 9%, North America 7%, Oceania 4%, and Africa 2%.

Up to March 24, 2020, imported COVID-19 confirmed cases came from 34 different countries and were distributed in 16 provincial-level administrative

divisions (PLADs) (Figure 5). The top eight countries were the UK, Spain, the USA, Iran, Italy, the Philippines, France, and Pakistan, accounting for 76.7% imported cases. The main terminal locations of imported cases were Beijing, Guangdong, Shanghai, Gansu, Fujian, and Zhejiang. Imported cases from the UK mainly arrived in Beijing, Guangdong, and Shanghai. Most cases from Spain arrived in Beijing and relatively small portions went to Shanghai and Zhejiang. Cases from the USA had markedly more destinations, but Beijing and Shanghai still had a higher proportion.

DISCUSSION

From March 19 to 25, Europe was still the epicenter

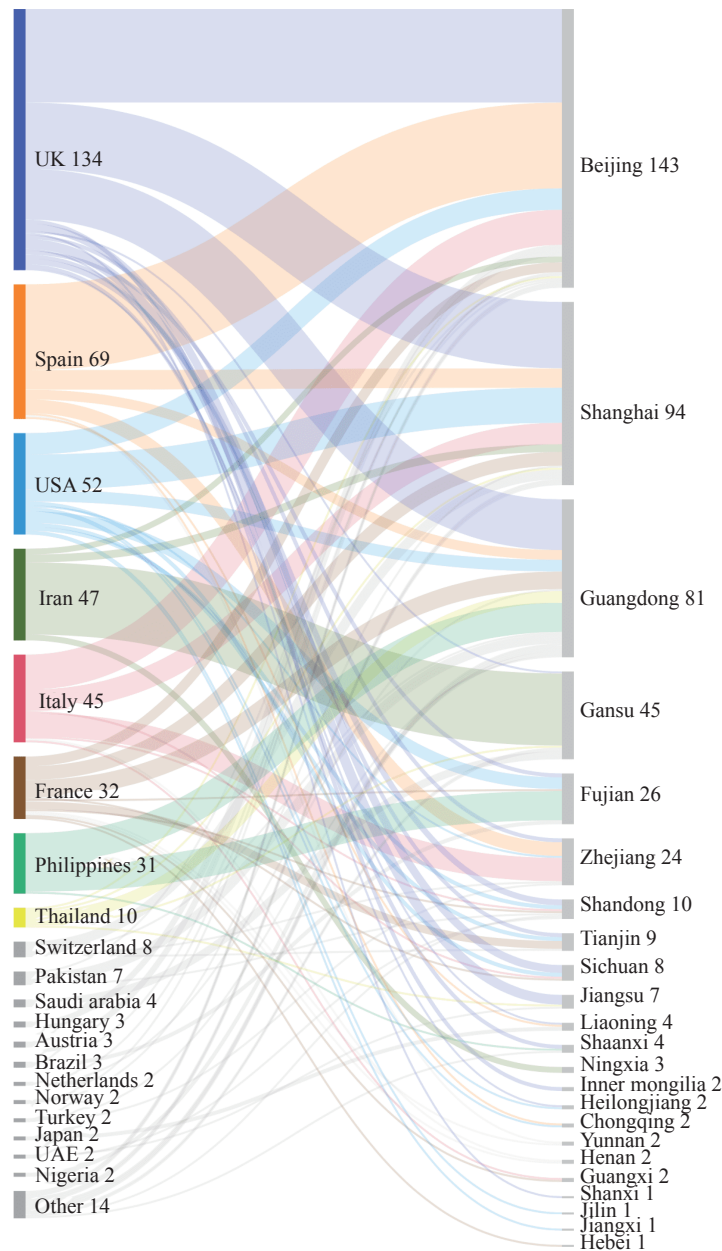


FIGURE 5. The sources and destinations of the imported confirmed cases in China up to March 24, 2020. The sources (countries) are illustrated on the left sorted by the imported case numbers. The destinations (provincial-level administrative divisions) are illustrated on the right and sorted by case numbers. The width of curve represents the proportion of the cases.

of the COVID-19 pandemic. The rapid increase of confirmed cases in the USA has made it the second epicenter. More importantly, the increasing trends of new cases in European countries and the USA do not show any sign of slowing. The number of newly diagnosed cases per day in the USA exceeded 10,000 in the past two days. Large quantities of COVID-19 cases in those epicenters will definitely produce great impact on the disease spreading not only for China but also for the rest of the world.

Our data here illustrate that the current R_t values of

COVID-19 in all four climatic zones are still higher than or close to 2.0 despite declines compared with that of previous weeks, highlighting that the transmissibility of COVID-19 worldwide is still very strong. The R_t value in the temperate zone has fluctuated between 2.0 to 4.0 since January 20, indicating a fairly stable transmissibility in this region that includes most of the severely affected countries such as China, Western European countries and the USA. It should be pointed out that although the current R_t value in the tropical zone is high, it may not

exactly reflect the real situation as case numbers of the most countries are still very limited, especially in a majority of African countries that contain a small number of imported cases. The influence of weather on the transmission of COVID-19 needs long-term observation.

Prompt and strict containment measures implemented in other PLADs of China besides Hubei Province have successfully interrupted disease transmission and ensured a lower morbidity and mortality. Our analysis here has also revealed that earlier implementation of control measures seems to help reduce the fatality rate, as evidenced in the Republic of Korea. Virus testing does not directly influence disease transmission. However, large-scale virus testing definitely benefits early detection and reporting, which subsequently increases early isolation and treatment and can lead to the eventual control and even elimination of the disease.

Our assessment here indicates that the COVID-19 pandemic is still rising and rapidly spreading worldwide, and such rising trends will probably persist in the next few weeks. Therefore, the impact of having more imported cases in China is still huge. Tailored control measures at varied risk levels and persistent and timely assessments of the COVID-19 pandemic trends and for the risk of imported cases to China are necessary.

The data collected and presented in this report are mainly extracted from public information on the websites of governments, mainstream media, relevant

professional websites, and official published research literature. The accuracy and real-time performance are limited not only by the data providers but also our search capacity. Because the number of cases by climatic zone is counted by country, partial misclassification still exists. The results of mathematic modeling are affected by unknown numbers of the actual infected population in a special region, the authenticity of reported data, the governmental efforts for control measure implementation, etc. Thus, deviations of the prediction from reality are likely inevitable.

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Perspectives

A Public Health Perspective on Preventing and Controlling the Spread of Coronavirus Disease 2019

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On March 11, 2020, the World Health Organization (WHO) formally declared coronavirus disease 2019 (COVID-19) a worldwide pandemic as the virus spreads rapidly with new cases and deaths rising exponentially in many countries. As of March 12, there were 125,048 confirmed cases and 4,613 deaths, and the numbers are still surging affecting 118 countries (1). Now we know that regional efforts to contain individual outbreaks have failed. The next phase of epidemic control is mitigation, and China has implemented multiple effective measurements such as mandatory citywide lockdowns to isolate and block the spread since January 2020. Recent data has shown evidence of controlling the epidemic (2).

How did the COVID-19 epidemic start?

The exact origin of COVID-19 in humans has not been identified. This infectious disease is reported to have started in December 2019 from the Huanan Seafood Wholesale Market in Wuhan, Hubei Province of China. By December 31, 2019, officials in Wuhan confirmed dozens of pneumonia cases of unknown etiology. Epidemiologists and infectious disease experts from China CDC investigated the seafood market in the early days of January 2020 but the market had already been closed and cleaned. Due to the possibility of asymptomatic transmission of the virus, identifying patient zero is incredibly difficult. However, Chinese scientists quickly and successfully identified the genetic sequence of COVID-19 and reported the sequence on January 7, 2020 (3).

Containing the spread of COVID-19 in China — lessons learned from Zhejiang Province and Hangzhou City

A couple of days after the lockdown of Wuhan, the epicenter, on January 23, 2020, Zhejiang Province was

the first provincial-level administrative division (PLAD) in the nation to raise the risk management response to the highest level. Hangzhou, the capital city of this province with a population of 11 million, started implementing extreme measures known as social distancing to contain the spread of COVID-19. From an epidemiological perspective, the benefits of stringent interventions are maximized if they are implemented early and maintained. Hangzhou has proven to be a perfect example of controlling the COVID-19 epidemic in a large metropolitan area (4). In controlling the COVID-19 outbreak in the early days of its emergence, the local officials often face significant challenges in making unprecedented decisions that will dramatically impact the economy and the social lives of millions of citizens. Timing also plays a key role in this decision-making process. The provincial and city authorities and experts from Hangzhou CDC worked closely to implement a series of actions (4):

Establishing a city-wide communication system to engage every individual to participate in implementing the city guidelines through apartments, communities, business, organizations, schools, and public facilities. This participation was major as it allowed the city, with the help of all involved, to successfully implement this mandatory lockdown for over a month. Strict entrance and exit control by local officials across the city were continuously maintained. Many citizens also monitored their neighbors. Sanitization measures were applied from every doorknob to every elevator keypad.

Maintaining food and supply flow through organized and government-controlled arrangements. Through online ordering and designated delivery groups, the sustained flow of fresh food and supplies were managed and maintained by district areas.

Reserving and designating infectious disease care and management hospital facilities to isolate, monitor, and treat COVID-19 positive patients. There are 22 hospitals in Hangzhou. The city designated two for COVID-19 patients and an additional 168 designated

facilities (i.e., hotels) to isolate and monitor COVID-19 positive but clinically mild symptom patients. In addition, there were 2,018 doctors and nurses from Zhejiang deployed to Wuhan to aid the response to the disease, among them, 318 were from Hangzhou city level hospitals and 525 were from affiliated hospitals of Zhejiang University.

Establishing electronic recording and tracking systems, and local response teams to continuously handle identified cases. Hangzhou implemented a big data analytics system and information technology that was named “one map, one QR code, and one index”. The health QR codes are established for everyone in the city and those who enter the city. Green codes allow one to move freely in the city, yellow codes require 7-day self-quarantine, and red codes require 14-day self-quarantine. Yellow and red codes can turn green after completion of the quarantine periods. The health surveillance system also tracks self-monitored temperature data that is recorded twice a day. Hangzhou’s CDC monitors the data.

As of March 12, 2020, there have been no new COVID-19 cases in Hangzhou for 22 days, and all 169 previously confirmed patients have been cured and discharged. The city is still under tight controls but started to allow workers to come back in phases based on priority with close monitoring and strict guidelines in place.

At the national level, the disease control and prevention measures were also implemented for most PLADs and cities. From a public health perspective, the national and local control strategies and measures have the following characteristics: mobilizing the whole nation at multiple levels from central government to individual families, responding (i.e., identification and detection of the virus) and implementing measures quickly; systematic and proactive risk management based on collaborations between government officials and health experts; the implementation of big data and information technology; and keeping the public well informed.

Role of the public health system in controlling the COVID-19 epidemic

China CDC is a governmental and national-level technical organization specialized in disease control and prevention. Under the leadership of the National Health Commission (NHC), China CDC exerts its function by providing technical guidance and support

of public health. Unlike the US CDC which is part of a governmental agency, China CDC does not have executive authority to implement a wide range of measures in case of an emergency. Its role only allows the organization to report an epidemic and/or emergency to the government and participate in the preparation and response of public health emergencies as technical and scientific resources.

Following the SARS outbreak in 2003, China enacted two laws: *The Regulation on Public Health Emergency* and *The Measures for the Administration of Information Reporting on Monitoring Public Health Emergencies and Epidemic Situation of Infectious Diseases* (5–6). The government established a management system for public health emergencies and detailed the principal rules for the prevention and control of infectious disease (i.e., infection source control, interruption of route of transmission, and susceptible person’s protection). Both central and local governments are in place to provide public health emergency responses (e.g., techniques, personnel, materials, and management preparedness), and an emergency information dissemination system that provides quick (within 2 hours), accurate, and comprehensive release of information. The public health management system reform led to better handling of an epidemic of infectious diseases. For example, the Chinese Ministry of Health (CMH, the precursor to the NHC) issued a swine flu prevention guide on April 29, 2009, 12 days before the first reported H1N1 case in China (7). On April 3, 2013, 4 days after the first H7N9 confirmed case, the CMH also issued a nosocomial H7N9-infection prevention guide (8).

It is worth noting that China’s public health response and management system contributed significantly to handling the COVID-19 crisis after the outbreak. For example, the rapid publication of COVID-19 genetic sequence information allowed scientists across the globe to immediately start developing vaccines; peer-reviewed publications of epidemiological and clinical case analysis provided first-hand information for healthcare workers on how to detect, isolate, and treat the disease caused by COVID-19; and multiple guideline publications and case tracking information on COVID-19 greatly promoted public awareness of this disease. The COVID-19 epidemic in China showed a clear picture of what would happen if a potential human-to-human transmissible infectious source was left unattended in

the community. However, other parts of China appeared to effectively mitigate the spread of the disease and many have shown significant improvements recently. Therefore, there is a need for the continuous improvement of the current public health management system. Specific strategies include the following:

To have more involvement of multidisciplinary experts (epidemiology, infectious disease, microbiology, clinical medicine, etc.) from CDCs, hospitals, and universities in the local and central government decision-making process.

To improve the emergency medical supply management system and plans to ensure clear pathways to follow in case of an epidemic emergency.

To establish a big data platform for disease control and prevention. On the premise of ensuring information security, colleges and universities cooperate with CDC to integrate basic population information, population movement information, patient information, medical insurance information, medical treatment information, and CDC data to establish a big data platform. This platform can realize the real-time, automatic, and quantitative reporting of new infectious diseases, and establish a system for prediction, early warning, and emergency response mechanisms to prevent the delayed detection and response to public health emergencies.

Building a strong public health team to safeguard people's health

In 2018, hospitals in China received a total budget of 269.7 billion RMB while CDC only received 51.1 billion (9). This is a clear reflection of the government's primary focus on treatment versus the prevention of diseases. In general, our public health talent cannot meet the needs of the "Healthy China 2030" in terms of quantity and quality. As of 2018, there are 187,826 employees at all levels of CDCs in China and that is only 1.35 CDC employees per 10,000 population, which is about one-fifth that of the United States (10). The overall quality of CDC employees is also a concern. Statistics show that only 44.2% of CDC health technicians have a bachelor's degree or higher. In addition, the lack of practical skills and knowledge of grassroots public health personnel needs to be improved. All of those are directly and indirectly linked to the current public health education system in China. Despite notable improvements in the higher

education field, public health is still largely functioning as an auxiliary branch of a medical school. Significant reforms in our higher education system are the key to future success in building "Healthy China 2030":

Increasing the scale of training and scientific levels of public health: building public health colleges and universities; establishing key national public health research centers focusing on both major communicable and non-communicable diseases; and increasing governmental funds supporting schools and colleges of public health across the nation.

Optimizing the public health personnel training system: First, building a rigorous system to train leaders with high-level doctoral public health degrees. Second is to train multidisciplinary professionals of public health and general medicine. Establish a "4+3" training mechanism, where a student studies medicine and public health courses in the first 4 years and continues with general medical practical training in the following 3 years. Preventive medicine students should also be trained in general medicine and be allowed to practice clinically after graduation.

Enhancing hands-on training in the public health professional curriculum: enhance practical trainings in various public health facilities for undergraduate and graduate students; increasing practical-skills-oriented courses for emerging infectious diseases in the undergraduate curriculum; improving practical skills training; strengthening the teaching of social practices with respect to emerging infectious diseases, and increasing training for public policy management and emergency responses.

Expanding the coverage of public health education: establishing a public health knowledge rotation training system for medical professionals; and regularly evaluate public health knowledge and practices of healthcare professionals and managers.

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