Report 30: The COVID-19 epidemic trends and control measures in mainland China

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Summary

Hubei and other provinces in China were the first to experience COVID-19 transmission between January and March 2020. Transmission was mostly contained following the implementation of several control measures. To understand the epidemic trends of COVID-19 in China, we carried out data collation and descriptive analysis in 31 provinces and municipalities, with a focus on the six most affected. An overview of control measures at the subnational level revealed that school closures, travel restrictions, community-level lockdown (closed-off management) and contact tracing were introduced concurrently around late January. The impact of these measures was different across provinces. Compared to Hubei province, the origin of the COVID-19 outbreak, the other five most-affected provinces reported a lower crude case fatality ratio and proportion of severe hospitalised cases over time. In Hubei, there were fewer contacts traced per case, consistent with the contact frequency observed during the lockdown period. From March 2020, the first wave driven by local transmission declined, while the burden of imported cases increased. The focus of control measures to continue the suppression of transmission was therefore shifted towards testing and quarantine of inbound travellers. The description of the course of the epidemic and the timing of interventions is consistent with the interpretation that early implementation and timely adjustment of control measures could be important in containing transmission and minimising adverse outcomes of COVID-19. However, further investigation will be needed to disentangle the effectiveness of different control measures. By making the collated data publicly available, we also provide an additional source for research and policy planning in other settings with an ongoing epidemic.

1. Introduction

The COVID-19 outbreak was first reported in Wuhan City of Hubei Province, China in late December 2019 [1]. From late January 2020, many provinces in China began to report confirmed COVID-19 cases. To control the epidemic, stringent social distancing, travel restrictions, contact tracing, environmental disinfection and other strategies were implemented. While other countries reported rising numbers of infection, a declining epidemic trend was observed in China from late February 2020. Considering the global spread of the pathogen, the World Health Organization declared COVID-19 a pandemic on 11 March 2020 [2]. Although the number of reported confirmed cases has increased since June 2020, the epidemic size remains small in mainland China.

The Imperial College London COVID-19 Response Team initiated activities of data collation in mid-January, to understand the COVID-19 epidemic in China and its potential impact on other countries. The Imperial Team, together with volunteers, made considerable efforts to collate aggregated data as well as individual patient information from publicly available, national and local situation reports published by health authorities in China. Part of these collated data have been used to inform transmission dynamics and epidemiology of COIVD-19 in several studies of the Team, including disease severity and fatality [3], phylodynamics in Shandong [4], and the association between inner-city movement and transmission [5]. We additionally reviewed control measures, school reopening, and work resumption that may relate to the trends across provinces in China. Builing on other existing data collation activities [6, 7], the data we extracted from the Chinese official reports can also be useful for the wider research community. In this report, we publish the collated data and conduct a descriptive analysis of the subnational epidemic trends and interventions. Drawing on epidemic progression and response measures in Chinese provinces affected by COVID-19 early on may provide insights for policy planning in other countries.

2. Methods

2.1 Data collation

Situation reports of the COVID-19 epidemic from mid-January up to 31 March 2020 in 31 provinces/municipalities (with equivalent levels of administration) of mainland China were extracted. We downloaded these reports from websites of local health commissions and used Google translate to obtain English versions for each province/municipality. In addition, reports from the National Health Commission and Wuhan City Health Commission websites were included. We extracted aggregated numbers of cases, deaths, recoveries, contacts, stratification of disease severity and case importation, from official reports released each day (Table 1). These quantitative results were included in a spreadsheet, grouped by province/municipality. Each record entry was checked and compared with the original situation report by a second researcher. Both the spreadsheet and original situation reports are available on Github: https://github.com/mrc-ide/covid19_mainland_China_report.

Table 1. Aggregated numbers extracted from provincial/municipal reports in mainland China

Variables[1]	Definition/description[2]
Cumulative cases	Number of total confirmed cases by the end of the reporting date
Cumulative imported cases	Number of total confirmed cases that are imported from other countries by the end of the reporting date
Cumulative recoveries	Number of total cases discharged after recovery by the end of the reporting date
Cumulative deaths	Number of total deaths by the end of the reporting date
Cumulative close contacts	Number of total close contacts by the end of the reporting date
Cumulative close contacts completing quarantine	Number of total close contacts completing 14-day quarantine by the end of the reporting date
Current cases	Number of confirmed cases that are currently hospitalised on the reporting date
Current critical and severe cases	Number of critical and severe cases that are currently hospitalised on the reporting date
Current close contacts under quarantine	Number of contacts currently under quarantine (medical observation) on the reporting date

[1]Only variables used in this descriptive analysis are listed. A full list of extracted variables can be found in the data dictionary at the GitHub repository mentioned earlier. Newly reported numbers can be derived by taking the difference of cumulative numbers between two consecutive reporting dates. [2]Case definitions and clinical severity from the guideline of the National Health Commission were used [8].

We reviewed the timing of implementation and subsequent lifting of the following control measures: i) cancellation of cross-province public transportation; ii) temperature checks for inbound travellers at provincial borders; and iii) community-level lockdown (so called closed-off management, including measures such as shop closure and ban of non-resident entry [9]). We searched official notices and announcements published by the national and provincial/municipal governments as well as local news for information on these non-pharmaceutical interventions. Closure and reopening dates of primary-, middle-, and high-schools, as well as universities were also extracted. Additionally, we monitored the progress of economic activity resumption through the reopening of ‘designated enterprises’, which contain registered companies with an annual revenue exceeding 2.8 million United States Dollars (20 million Chinese Yuans) [10].

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2.2 Descriptive analysis of epidemic trends

Based on the aggregated data collated for each province/municipality, we conducted a descriptive analysis to understand the epidemic trends and their possible association with the interventions implemented. We focused on the six provinces (Hubei, Guangdong, Henan, Zhejiang, Hunan, and Anhui) reporting the highest numbers of confirmed cases up to the end of March 2020. These provinces/municipalities together accounted for 90% of the total COVID-19 cases in mainland China. Hubei alone accounted for 80% of the total number of reported cases. (Figure 1).

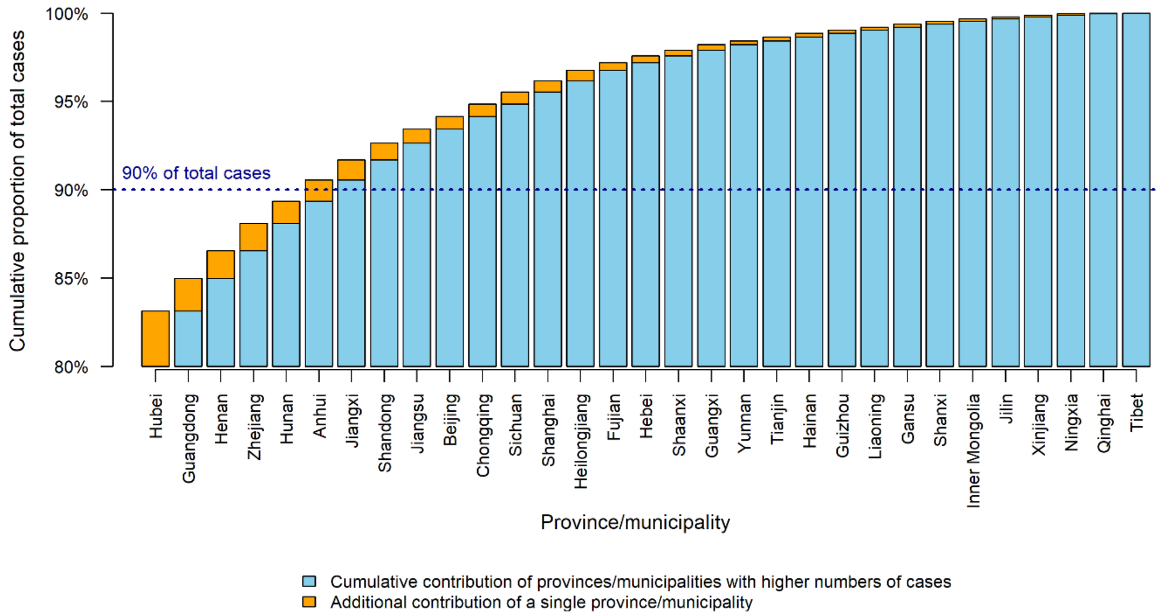

Figure 1. Cumulative proportions of total cases contributed by province/municipality up to 31 March 2020
Thirty-one provinces/municipalities in China are ranked in descending order (left to right) of total confirmed cases up to 31 March. Yellow bars represent the proportion of national confirmed cases contributed by a single province/municipality, while blue bars are the cumulative contributions from provinces/municipalities with higher numbers of cases reported.

We first calculated the crude case-fatality ratio (cCFR) by 31 March in different provinces, using the cumulative numbers of deaths and recoveries, as:

$$cCFR = \frac{number\ of\ cumulative\ confirmed\ deaths}{number\ of\ cumulative\ confirmed\ deaths\ and\ recoveries} \times 100\%.$$

Confidence intervals (CI) of the cCFRs were obtained by assuming binomial distributions. The cCFR estimates based on the aggregated notification data may be biased due to censoring, but the true disease fatality can be approximated when most cases have a resolved outcome near the end of an epidemic. From 15 January to 31 March, we calculated the proportion of recoveries by:

$$Proportion\ of\ recoveries = \frac{number\ of\ cumulative\ recoveries}{number\ of\ cumulative\ confirmed\ cases} \times 100\%.$$

Note that almost all confirmed cases were hospitalised for isolation and medical care in mainland China and hospitals are responsible for reporting cases to the surveillance system. Recoveries in such setting were defined as hospitalised cases who meet criteria of discharge, including symptom relief and negative test results [8]. In addition, severe and critical cases were defined as those who present shortness of breath or a low blood oxygen level, or require a mechanical ventilator or intensive care [8]. We captured varying need for critical care over time using the distribution of case severity among currently hospitalised cases:

$$Proportion\ of\ critical\ or\ severe\ cases = \frac{number\ of\ critical\ or\ severe\ hospitalised\ cases}{number\ of\ total\ hospitalised\ cases} \times 100\%.$$

According to the guideline for contact investigation published by the Chinese Center for Disease Control and Prevention, those who have close contact with a confirmed case of COVID-19, up to two days prior to their symptom onset, should be quarantined at home or a specific facility for 14 days [11]. To demonstrate the scale and effort involved in contact tracing across provinces, we calculated the ratios of contact-to-case by:

$$Contact - to - case\ ratio = \frac{number\ of\ contacts}{number\ of\ confirmed\ cases}.$$

In this analysis, the calculation of contact-to-case ratio was first conducted based on cumulative numbers up to 31 March for each of the six provinces. We then derived the same ratio by taking the newly reported numbers at the national level over the observation period. As it is recommended that epidemiological surveys into the contact history of new cases are completed within 24 hours from case confirmation [11], we considered an alternative assumption of 1 day lag between case confirmation and contact tracing.

3. Results

3.1 Overview of COVID-19 control measures

On 26 January 2020, the State Council of the People's Republic of China announced the extension of the school winter vacation for the purpose of COVID-19 control. Schools had been closed since 24 January or earlier for the Chinese New Year [12]. As the epidemic continued, the reopening of schools was postponed multiple times [13] in order to comply with the Ministry of Education's guidance taking into consideration disease control and prevention preparedness of the schools before reopening. [14]. From mid-March, some local governments, mostly in provinces less affected by COVID-19, reopened schools, particularly for senior-year students in middle and high schools (Figure 2). Most of the other provinces/municipalities kept schools closed until late April and May. As a result of interruption of studies, the National College Entrance Examination in China was postponed by one month to July 2020 [15]. Reopening of universities was generally further delayed, likely because it generates large-scale, cross-province movement of population [13].

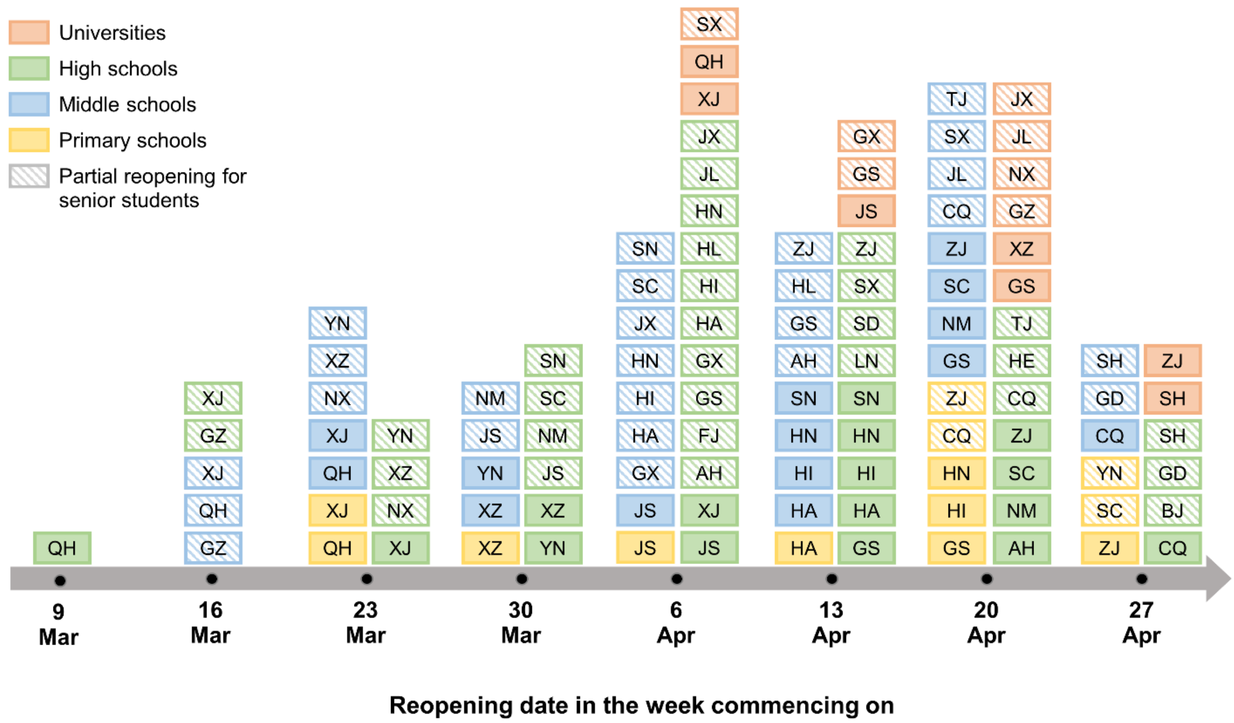

Figure 2. Reopening dates for primary, middle, and high schools, and universities
Dates of school reopening are aggregated to units of weeks in March and April 2020. Each rectangle indicates the reopening of a specific level of school (denoted by colours) in a province/municipality (denoted by text abbreviations). Rectangles fully filled with colour represent reopening at full scale, while those filled with diagonal lines represent partial reopening for senior-year or research students. Reopening dates were extracted from official announcements and local news (available at Github: https://github.com/mrc-ide/covid19_mainland_China_report). Abbreviations of provinces/municipalities: AH – Anhui, BJ – Beijing, CQ – Chongqing, FJ – Fujian, GD – Guangdong, GS – Gansu, GZ – Guizhou, GX – Guangxi, HA – Henan, HE – Hebei, HI – Hainan, HL – Heilongjiang, HN – Hunan, JS – Jiangsu, JL – Jilin, JX – Jiangxi, LN – Liaoning, NM – Inner Mongolia, NX – Ningxia, QH – Qinghai, SC – Sichuan, SD – Shandong, SH – Shanghai, SN – Shaanxi, SX – Shanxi, TJ – Tianjin, XJ – Xinjiang, XZ – Tibet, YN – Yunan, and ZJ – Zhejiang.

In addition to school closures, the State Council also extended the end of the national Spring holiday (Chinese New Year holiday) from 30 January to 2 February 2020 [12]. In response to the COVID-19 epidemic, Beijing, Shanghai, and several local governments further delayed resumption of work resumption to 10 February [16]. In Hubei province, the most affected province in China, the date of returning to work was first postponed to 14 February [16] and then further to 11 March [17]. In Wuhan City, general industries (except for the essential service providers and key global enterprises), resumed operation from 21 March [18]. Concordant with the national guideline to prioritise industries which provide essential products and services [19], production and transportation have been restored in stages. Up to the end of March, most of the provinces/municipalities in China reported a high degree of recovery in economic activities, with more than 90% of 'designated enterprises' returning to business (Figure 3). Although Hubei resumed work activities much later than other provinces/municipalities, it was reported that as 85% of the local 'designated enterprises' had resumed operation by 23 March [18].

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3.2 Descriptive analysis of COVID-19 epidemics in the six provinces with the highest total caseload

Juxtaposed with keys dates for initiating and lifting three most common control measures, Figure 3 shows daily confirmed cases over time in the top six provinces in China. Measures related to provincial border control – cancellation of cross-province public transportation (CC), and temperature checks for inbound travellers at provincial borders (TC) – were mostly imposed in late January, around the same time lockdown was implemented in Wuhan. The implementation of community-level closed-off management (CM) was generally introduced during the peak of the local epidemic. Relaxation of these measures varied by province, depending on the epidemic trend –when the number of daily confirmed cases was low and declining. Except for Hubei, the local epidemic in the other five provinces was mostly suppressed in late February. Zhejiang and Guangdong provinces, where international airports are located, reported a second wave of COVID-19 driven by incoming travellers from the beginning of March. However, the caseload caused by this second wave was much smaller than the first one, as measures to stop secondary transmission were put in place at the border for inbound passengers [20].

There is a wide variation in cCFRs by 31 March 2020 reported in each province. , Where most provinces show a cCFR less than 1%, Hubei had a cCFR of 4.80% (95%CI 4.64%-4.97%) (Table 2). In addition, Henan province had the second-highest cCFR (1.73%, 95% CI 1.14%-2.60%) among the six most affected provinces analysed. The most affected areas in Henan province — Xinyang City, Nanyang City, and Zhumadian City — are adjacent to Hubei province and many workers returned from Wuhan before the lockdown due to the Chinese New Year holiday [21]. Both the geographical and social connections with Hubei may thus lead to a stronger impact of the COVID-19 epidemic in Henan.

Table 2. Crude case-fatality ratios up to 31 March by province

Province	Total cases	Total deaths	Total recoveries	% of cases without a resolved outcome	Crude CFR[1] (95%CI)
National	81,554	3,312	76,238	2.46%	4.16% (4.03%, 4.30%)
Hubei	67,802	3,193	63,326	1.89%	4.80% (4.64%, 4.97%)
Guangdong	1,501	8	1,357	9.06%	0.59% (0.30%, 1.15%)
Henan	1,273	22	1,250	0.08%	1.73% (1.14%, 2.60%)
Zhejiang	1,257	1	1,226	2.39%	0.08% (0.004%, 0.46%)
Hunan	1,018	4	1,014	0%	0.39% (0.15%, 1.01%)
Anhui	990	6	984	0%	0.61% (0.28%, 1.32%)

[1]Crude case-fatality ratios (CFRs) were calculated using confirmed cases with a resolved outcome and their 95% confidence intervals (CIs) were obtained based on an assumption of binomial distribution.

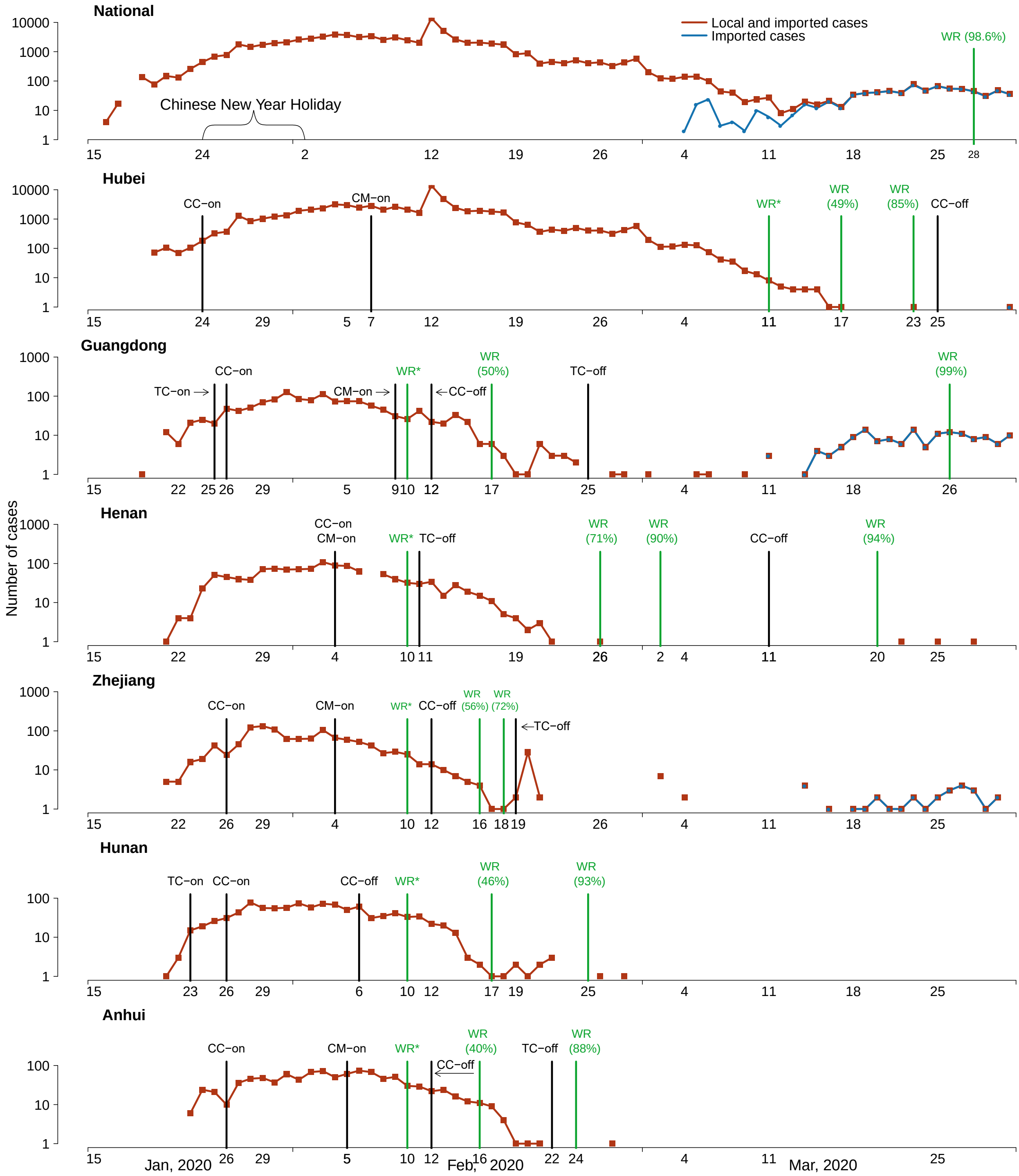

Figure 3. Newly confirmed cases and timings of control measures by province
Number of confirmed cases at national and provincial levels are shown on the log scale. Vertical lines mark the timings of implementing and relaxing control measures (black) and related work resumption statistics (green). The asterisks (*) mark the initiation date of work resumption. Abbreviations for control measures: CC – cancellation of cross-border public transportation, TC - temperature checks at provincial borders, and CM – closed-off management at community level.

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We explored the association between the epidemic trend and healthcare burden by the proportion of total confirmed cases who recovered (Figure 4). Most provinces reported 50% recovery for cases by mid-February, 2~3 weeks after the peak of daily confirmed cases seen in late January or early February. The national trend was delayed for approximate 10 days by the severe epidemic in Hubei, where the peak of daily cases and 50% of recovery occurred on 12 and 29 February respectively. Moreover, the duration for provinces to progress from 50% to 90% of recovery varied. In Guangdong, it took a longer time for the numbers having recovered to reach a value equivalent to 90% of the cumulative number of total confirmed cases, which declined at a slower rate in late February. The duration is also long in Hubei, as there were still more than 100 daily new cases reported in early March.

Next, we investigated the disease severity among hospitalised cases (Figure 5) and found Hubei reported a particularly high proportion of critical and severe cases (20-30%) compared to other provinces. Across the six provinces, the proportion of critical or severe cases was high in early February (Figure 5A). In March, the proportion of critical or severe cases increased again while the total numbers of hospitalised cases declined, reflecting a longer period of hospitalisation of severe cases compared to mild cases. However, a distinct trend was seen in Guangdong from mid-March, showing a decline in the proportion of critical or severe cases. This decline coincided with the increase of cases imported from foreign countries, who tended to have mild symptoms compared to locally transmitted cases (Figure 5B).

Finally, we investigated the scale of contact tracing involved in infection control at national and provincial levels, using the ratio of total contacts to total cases by the end of March (Table 3). On average, 20-40 close contacts were traced per confirmed case. Hubei province reported a particularly low contact-to-case ratio compared to other provinces. To further explore the change in the number of contacts traced over the epidemic, we calculated the contact-to-case ratio again with the daily numbers of confirmed cases and reported contacts (Figure 6). There were less than 20 contacts traced for each new case over most of January and February, however, the contact-to-case ratio increased in March. This increase in the ratio was caused by an increase in the number of total contacts reported in provinces outside Hubei, likely due to imported cases. In the exploratory scenario to address the 1-day delay of contact tracing following case confirmation, the general trend of the contact-to-case ratio over time was consistent with the scenario without the consideration of delay.

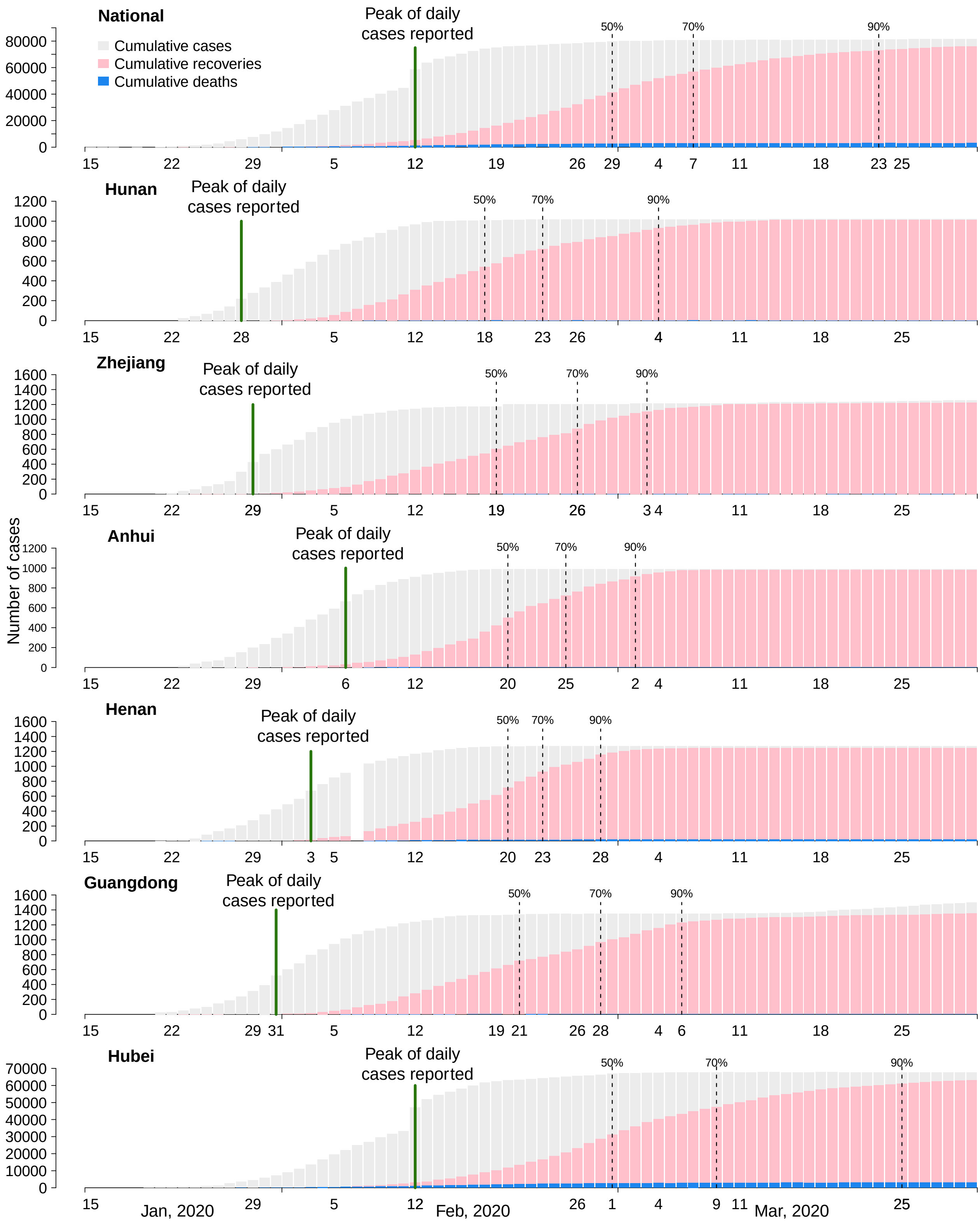

Figure 4. Cumulative cases, deaths, and recoveries by province

Bars represent the cumulative numbers of cases (grey), recoveries (pink), and deaths (blue). Black vertical dashed lines show the dates when 50%, 70%, and 90% of recoveries among all cases was reached. Green vertical solid lines show the dates when the peak number of the daily confirmed case occurred. The top six provinces were ranked from top to down by the date that 50% of recovery was achieved. Note the range of y-axis is different by province, to fit the magnitude of cases.

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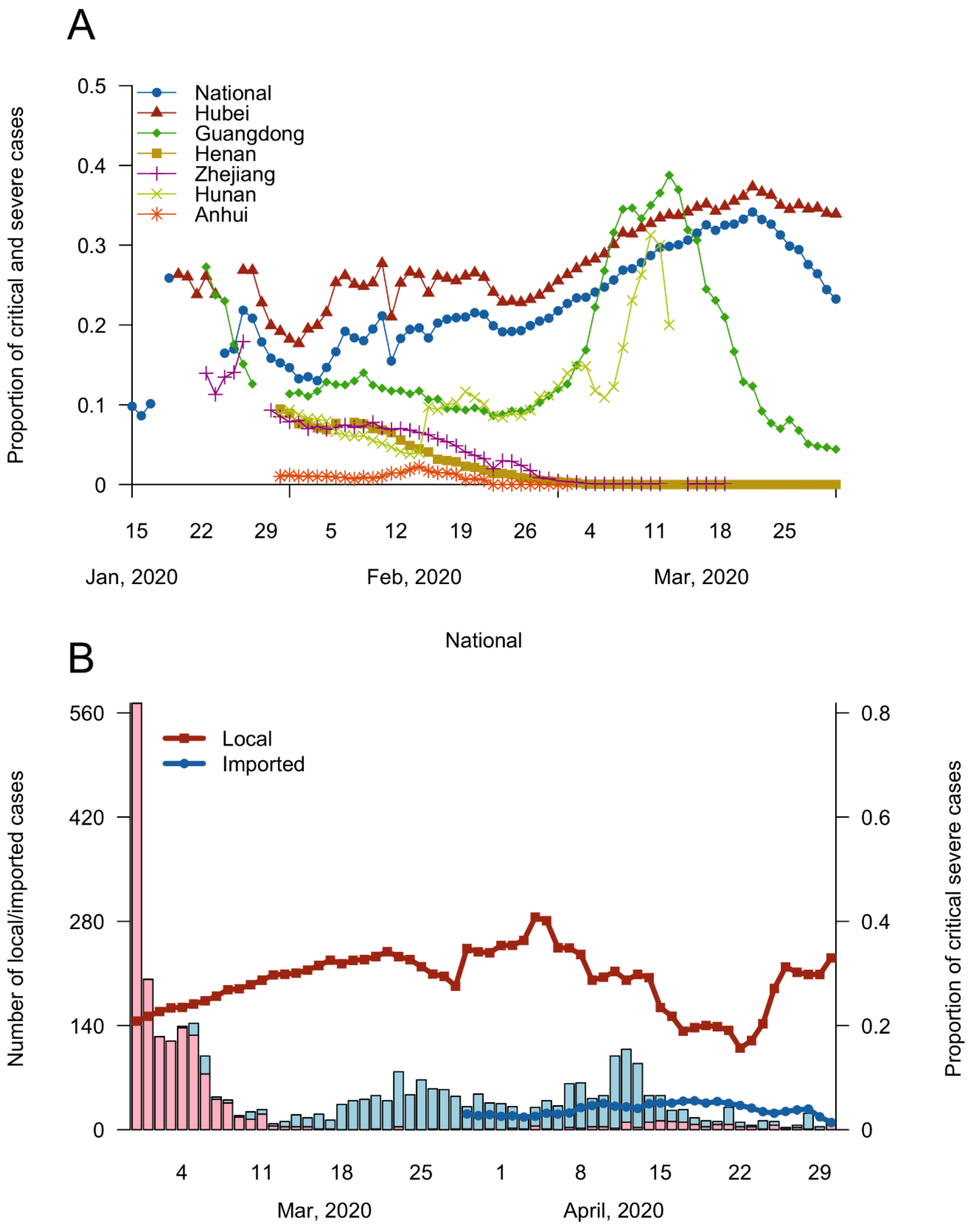

Figure 5. Severity of COVID-19 among current cases (A) by province and (B) by locally transmitted and imported cases

Proportions of critical and severe cases among all current cases are presented in the upper panel (A), by national and six provinces with the highest caseload, from 15 January to 31 March. In the lower panel (B), from 1 March to 30 April, disease severity is shown by locally transmitted (red) and imported (blue) cases. Solid lines represent the proportions of critical and severe cases at a level corresponding to the right y-axis, and bars show absolute numbers of total cases with a scale denoted in the left y-axis.

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Table 3. Average number of contacts traced per confirmed cases by province

Province	Total contacts	Total cases	Contact-to-case ratios[1]
National	707,913	81,554	8.68
Hubei	278,179	67,802	4.10
Guangdong[2]	--	1,501	--
Henan	40,019	1,273	31.44
Zhejiang	46,764	1,257	37.20
Hunan	27,331	1,018	26.85
Anhui	28,981	990	29.27

[1]Cumulative numbers of confirmed cases and contacts reported by 31 March 2020 were used to calculate contact-to-case ratios. [2]Number of total contacts were not reported in Guangdong and thus the contact-to-case ratio is not applicable.

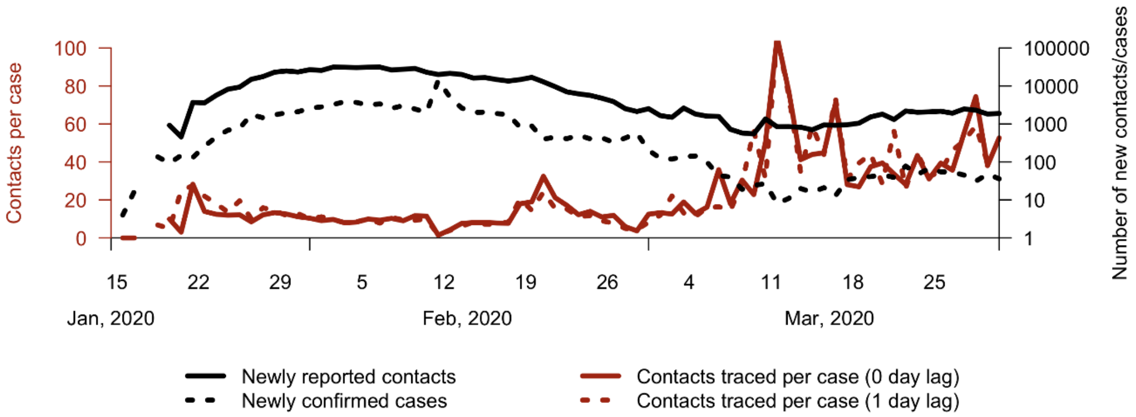

Figure 6. Contacts traced per newly confirmed case

The trends of contacts traced per newly confirmed case are presented by assuming 0 (red solid line) and 1 day lag (red dashed line), based on the y-axis showing on the left-hand side. Numbers of daily contacts and cases are shown on the log scale in black solid and black dashed lines, respectively, corresponding to the y-axis of the right-hand side.

4. Discussion

We carried out data collation and descriptive analysis of the COVID-19 epidemic trends and control measures in mainland China, between mid-January and March 2020. In most provinces, the local epidemics peaked in early February and declined in early March but were not completely eliminated as the number of imported cases increased. School closures, travel restrictions, contact tracing, and other control measures were enforced at a similar time from late January across provinces. However, in Hubei, where the origin of the COVID-19 pandemic was reported, an increased level of case fatality and severity was reported, compared to the other five most affected provinces analysed. The description of the epidemic trends and timing of intervention is consistent with the interpretation that early implementation and timely adjustment of control strategies could be crucial in containing the COVID-19 epidemic in mainland China. These collated data are made available and should be useful for further research on epidemic control and policy planning.

Domestic travel restrictions were implemented at similar times across provinces in China (Figure 4), although the epidemic situation in each province differed. For provinces apart from Hubei, these restrictions were introduced when there were few cases reported and thus may have been more effective in limiting and averting transmission. Lifting of the travel restrictions not only depended on the control of local epidemics but also the risk of case importation and transmission. For example, on 11 March, Henan province restored both cross-province and inner-province public transportation except for routes connected with adjacent Hubei [22]. For case-based measures such as community-level lockdown (closed-off community management) and contact tracing, implementation was initiated at the notification of confirmed cases and detection of outbreak clusters in each province.

While the timing of schools reopening in China depended on the local epidemic situation [14], the general strategy was shared across multiple provinces (Figure 3). Staged reopening was widely observed, where senior students in middle and high schools are suggested to return first. Junior students and elementary schools were to follow a week later. In terms of returning to work, most provinces demonstrated rapid resumption of business activity after constraints on travel and commuting were relaxed (Figure 4). However, this rapid resumption was found in the reoperation of 'designated enterprises', which excluded enterprises not in key industries or smaller scale enterprises. Additional surveys on detailed indicators of resumption, such as production capacity and attendance of employees, and resumption in other aspects of economic activities will be useful in fully understanding the progress of restoration and inequality of the COVID-19 impact.

Among the six most affected provinces by COVID-19 in China, disease fatality and severity of hospitalised patients showed heterogeneities (Table 2 & Figure 4). In Hubei, both the cCFR and proportion of critical and severe cases remained high over the past few months. This is potentially driven by the explosive increase of cases that overwhelmed local healthcare services during the peak of the epidemic. Henan province reported a moderate cCFR but a low proportion of severe cases, whereas Guangdong province presented an opposite trend of case fatality and severity. However, the interpretation of this difference is challenging, as these indicators, together with the proportion of cases recovering (Figure 5), reflect the combined effects of different epidemic burden and local health systems. Meanwhile, the reporting quality by province can also affect these indicators. For example, the Hubei Health Commission announced the corrections to the numbers of deaths and recoveries during the epidemic on 17 April [23], which resulted in a further increase of the national cCFR from 4.80% to 5.63% (95%CI 5.48%-5.79%) by the end of April. The interpretation of COVID-19 fatality and severity could also be affected by the varying capacity of case detection over time, as implied by the higher proportions of critical and severe cases observed at the beginning of the epidemic. Further data collection and assessment of hospital capacities of testing, caring, and reporting in different settings will be essential in understanding the COVID-19 characteristics.

Contact tracing was implemented nationally since the beginning of the epidemic. We found for every confirmed case, an average of 4 contacts were traced in Hubei, where over 20 contacts per case were traced in other provinces (Table 3). These numbers of contacts are consistent with the average number of daily contacts from diary-based contact surveys in Wuhan City and Shanghai. These cities reported approximate 2 and 17 daily contacts per citizen during the lockdown and before the COVID-19 epidemic, respectively [24]. Stringent social distancing policies could modify the contact patterns and reduce the number of contacts. The overall case burden in each province may also affect the number of contacts which can be traced by the local public health authority. From early March, there was an increase in the number of contacts traced per case, which may be due to large clusters of contacts who shared the same flights and trains with imported cases travelling from foreign countries. However, we cannot exclude the possibility that the increase in the contact-to-case ratio was due to increased investment in both personnel training and establishment of proper management systems for contact tracing. Such resources could be gradually released from other control measures with the relief of epidemic burden. It is uncertain how many contacts were eventually confirmed as cases in most provinces. Further data collation and investigation will enable the assessment of the effectiveness of contact tracing in reducing COVID-19 transmission.

A major limitation of our descriptive analysis is the use of aggregate data of cases, deaths, recoveries, and contacts. Whilst these indicators are convenient for monitoring and comparing the epidemic trends by province, further inference of risk factors on transmission dynamics is not possible. Patient characteristics such as age and comorbidities are essential in understanding the heterogeneity in disease severity. Estimating setting-specific incubation period, reporting delay, and disease progress also relies on the date of symptom onset and care-seeking pathways of individual cases [7]. Another limitation lies in validating, quantifying, and distinguishing the impact of different control measures. Through comparisons across provinces, we could only investigate the temporal associations between interventions and epidemic trends. Applying dynamic modelling techniques and knowledge of COVID-19 epidemiology to the surveillance data may advance our understanding of the contributions of different interventions in the epidemic course [25].

Many containment measures have been implemented in different provinces of China since the beginning of the COVID-19 outbreak in Wuhan City, Hubei Province. Similar control measures were introduced in other countries such as Singapore and South Korea despite variation in practical implementation [26]. These measures of social distancing and contact tracing are likely to contribute to the reduction of COVID-19 transmission as the reported epidemic size was relatively small-scale in these countries and in the Chinese provinces where the measures were implemented early in the epidemic. Following the decline in the first wave of the epidemic, the driving force of the COVID-19 epidemic in mainland China has shifted from local transmission to importation from other affected countries. In responding to this shift, there have been modifications in the focus of control strategies, such as compulsory testing and quarantine for all incoming travellers [27] and close monitoring of asymptomatic infections [28]. A low caseload has been maintained over time in China, reiterating the importance of timely adjustment of control strategies based on surveillance in the sustained control of COVID-19.

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