Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Economic burden of public health care and hospitalisation associated with COVID-19 in China

X. An a,e, L. Xiao b,e, X. Yang c, X. Tang a, F. Lai d, Xiao-Hua Liang a,*

a Department of Clinical Epidemiology and Biostatistics, Children's Hospital of Chongqing Medical University, National Clinical Research Center for Child Health and Disorders, Ministry of Education Key Laboratory of Child Development and Disorders, Chongqing Key Laboratory of Pediatrics, Chongqing, China
b Disease Control and Prevention Center of Jiulongpo District, Chongqing, China
c Tianjin Key Laboratory of Environment, Nutrition and Public Health, Department of Occupational and Environmental Health, School of Public Health, Tianjin Medical University, Tianjin, China
d Department of Pediatrics, Renmin Hospital of Wuhan University, Wuhan, China

Article info

Article history:
Received 20 September 2021
Received in revised form 10 November 2021
Accepted 1 December 2021
Available online 13 January 2022

Keywords:
Socio-economic burden
COVID-19
Public health care
Hospitalisation
Treatment

Abstract

Objectives: This study aimed to evaluate the socio-economic burden imposed on the Chinese healthcare system during the coronavirus disease 2019 (COVID-19) pandemic.

Study design: A cross-sectional study was used to investigate how COVID-19 impacted health and medical costs in China. Data were derived from a subdivision of the Centers for Disease control and Prevention of China.

Methods: We prospectively collected information from the Centers for Disease Control and Prevention and the designated hospitals to determine the cost of public health care and hospitalisation due to COVID-19. We estimated the resource use and direct medical costs associated with public health.

Results: The average costs, per case, for specimen collection and nucleic acid testing (NAT [specifically, polymerase chain reaction (PCR)]) in low-risk populations were $29.49 and $53.44, respectively; however, the average cost of NAT in high-risk populations was $297.94 per capita. The average costs per 1000 population for epidemiological surveys, disinfectant, health education and centralised isolation were $49.54, $247.01, $90.22 and $543.72, respectively. A single hospitalisation for COVID-19 in China cost a median of $2158.06 ($1961.13-$2325.65) in direct medical costs incurred only during hospitalisation, whereas the total costs associated with hospitalisation of patients with COVID-19 were estimated to have reached nearly $373.20 million in China as of 20, May, 2020. The cost of public health care associated with COVID-19 as of 20, May, 2020 ($6.83 billion) was 18.31 times that of hospitalisation.

Conclusions: This study highlights the magnitude of resources needed to treat patients with COVID-19 and control the COVID-19 pandemic. Public health measures implemented by the Chinese government have been valuable in reducing the infection rate and may be cost-effective ways to control emerging infectious diseases.

© 2021 The Royal Society for Public Health. Published by Elsevier Ltd. All rights reserved.

Introduction

During the coronavirus disease 2019 (COVID-19) pandemic, there has been a substantial impact on global health care and medical systems. By 9, June, 2020, a total of 7,085,894 cases had been confirmed worldwide and 405,168 deaths had been reported. The case fatality rate of COVID-19 (5.70%) is gradually approaching that of severe acute respiratory syndrome (SARS; 9.6%). As of 20, May, 2020, there were 82,967 confirmed cases, 740,967 close contacts and 4634 deaths in China. Faced with an enormous number of cases within a short period of time, the government, healthcare professionals and healthcare systems voiced concern that demand would exceed the existing capacity, and they requested the urgent provision of additional resources and financial support. An effective method of mitigating the impact of the pandemic on the healthcare system is to reduce the percentage of the population who become infected by implementing preventive measures mediated by public health officials. Therefore, the government, healthcare system and medical insurance system had...
to provide sufficient public health resources and hospital accommodation to quickly curb the spread of COVID-19.

The COVID-19 pandemic was brought under control in China within a relatively short period of time; therefore, it is useful to evaluate the costs of public health measures and hospitalisation due to COVID-19 in China. Such information is critical for efficiently developing strategies to mitigate the impacts of potential outbreaks of new infectious diseases in the future.

In China, the healthcare system is composed of two sections: (i) medical institutions (e.g. hospitals, primary medical and health centres, such as township hospitals or community health centres); and (ii) public health organisations, such as the Centers of Disease Control and Prevention (CDC) and Centres of Health Supervision (these medical organisations are stratified into five levels: state, province, city, county/district and town). After the outbreak of the COVID-19 pandemic, the Chinese government released pandemic control policies called a ‘unanimous nationwide system’ to form a joint defence and control programme with multiple departments. All hospitals and primary medical centres were administrated by the Health Commissions (HCS) and CDCs at each level. The HCs and CDCs at each level planned the supplies and human resources for the hospitals and primary medical centres in their areas.

However, limited studies have reported the costs of emerging infectious diseases. Bartsch et al. used a mathematical model to quantify the cost of Ebola virus disease (EVD) from the perspectives of providers and society in Guinea, Liberia and Sierra Leone. In addition, two studies developed computational models to forecast the potential economic burden and the cost-effectiveness of measures addressing Zika in the US. Bartsch et al. also developed a computational model to estimate the potential resource use and direct medical costs of COVID-19 in the US under various conditions. Previous cost studies primarily used a proxy disease to obtain estimates of the clinical costs of an emerging infectious disease and used a mathematical model to forecast the medical costs associated with the target infectious disease; these studies have lacked a clear scientific source of the estimated costs. A few studies have estimated healthcare utilisation and cost using structured interview methods, but a review of the literature reveals that, to date, there are no studies determining the costs of both public health and hospitalisation associated with COVID-19.

In this study, we investigate the actual expenses associated with public healthcare resources and hospitalisation from COVID-19. From these figures, we estimate the healthcare costs of COVID-19 control in China during the initial outbreak period of the pandemic. This study estimates the potential financial cost to control the outbreak of an infectious disease, without health insurance support, in an emergency situation. Results from this study will help governments worldwide in the management of infectious disease outbreaks.

Methods

Study design

A cross-sectional study was used to investigate how COVID-19 impacted health and medical costs in China. Data were derived from a subdivision of the CDC of China.

Data sources for the COVID-19 epidemic in China

This study used COVID-19 data from the official website of the National Health Commission of the People’s Republic of China from 20 January, 2020, to 20 May, 2020. The epidemiological data included the daily numbers of total confirmed cases, suspected cases, close contacts, people under medical observation, inpatient cases, severe cases, deaths and discharged cases.

Definition of medical costs

Medical expenses associated with COVID-19 are composed of the costs of public health care and treatment during hospitalisation (see supplementary figure S2). Public healthcare costs included nucleic acid testing (NAT [specifically, polymerase chain reaction (PCR)]) (including NAT for both people and the environment), epidemiological surveys, centralised quarantine (see supplementary figure S2), disinfection and health education. The costs associated with public health care had two dimensions, namely, financing resources (e.g. protective equipment, medical materials, medical equipment and ambulances) and human resources (i.e. medical staff participating in the prevention of COVID-19). The hospitalisation costs include the direct cost of acute hospitalisation according to the discharge settlement amount.

Data collection

To accurately estimate the costs of pandemic control, including both public health care and hospitalisation, three criteria were taken into consideration when selecting the study district, as follows: first, there must be sufficient resident and COVID-19 cases in this district; second, the chosen district should contain both urban and rural areas so that urban-rural differences could be eliminated; and finally, the district must have hospitals with sufficient funds to cover total medication costs for patients with COVID-19 and isolation expenses for residents.

The Jiulongpo District was selected as the study area. In total, 1.2 million people permanently resided in Jiulongpo District and there were >20 reported cases of COVID-19. Jiulongpo District is located to the west of the Chongqing metropolitan region, with both semirural and urban areas, including nine urban streets and four rural towns. Furthermore, in this district, there are sufficient hospitals, including every grade of hospital in China, which formed a loop, so that the centralised isolation and treatment of patients with COVID-19 could be carried out locally to make the cost data transparent. Therefore, in Chongqing, the Jiulongpo District met all the three selection criteria and thus provides a suitable study area resulting in good representation for the costs associated with COVID-19 in China.

Data on medical costs related to the treatment of COVID-19 were collected using a micro-cost survey approach. The total public healthcare costs in Jiulongpo District were collected. The urban area in Jiulongpo District is very prosperous, and it could represent the typical costs of COVID-19 in the urban areas of Chongqing or other metropolitan cities. In addition, the four rural towns in Jiulongpo District can represent rural areas of Chongqing. The survey was administered to one CDC, seven secondary or tertiary medical institutions, 15 community health centres and 10 township hospitals or temporary medical institutions in Jiulongpo District, which includes all subdistricts and towns (in the countryside), with 1.2 million permanent residents.

Medical cost data were collected by conducting a series of key information interviews at the CDC and designated medical institutions. The questionnaire survey of local survey data was collected from the CDC and hospitals and health insurance system. All relevant medical centres at all levels in Jiulongpo District were investigated, and the CDC of Jiulongpo District provided support for all the surveys. The detailed method of quantitative cost collection is provided in Supplementary Method 1.

Method of cost calculation

The average exchange rate of RMB to US$ equivalent during the period of the survey was 1 RMB = 0.1402 USS. The detailed method of cost calculation is provided in Supplementary Method 2.
Statistical analyses

The Wilcoxon test was used to compare the differences in various hospitalisation expenses, payment methods (e.g. paid by medical insurance, medical insurance subsides for official staff, medical insurance claims for large expenses, social assistance, the hospital and the patient) and duration of hospitalisation in different subgroups. The 95% confidence interval (CI) of the median or mean cost was calculated by the bootstrap method with 1000 iterations. In addition, a generalised linear regression model (GLM) was used to estimate the factors impacting the hospitalisation costs, which were log-transformed to ensure a normal distribution.

Data analyses for this study were conducted using SAS, version 9.4, software (Copyright © 2016 SAS Institute Inc. Cary, NC, USA). A significant difference was defined by an α level of 0.05 with a two-sided test.

Results

The cost of public health care

The per sample cost of obtaining samples for NAT at the CDC, secondary or tertiary hospitals, community healthcare centres and township hospitals or temporary hospitals were $8.81, $42.10, $23.94 and $23.76, respectively (Table 1). Moreover, single-use personal protective equipment (PPE) cost approximately $50.95 (see Supplementary Table S1). The average per sample cost of NAT among different medical institutes was $29.49, and the human resources used were the equivalent of 0.38 days. There were significantly different detection times and costs for NAT between low-risk (those who did not closely contact with confirmed cases) and high-risk (close contacts) populations (Supplementary Table S2). The costs of NAT and diagnostic examinations for the first time and the last time tests for people before diagnosed as suspected cases was $154.41 per capita, including $124.92 for test material cost and $29.49 of NAT cost. And NATs of people after diagnosed as suspected cases for the first time and for the last time NATs was $77.86. Moreover, the costs of NATs for predischarge and postdischarge of confirmed cases were $119.64 and $147.54, respectively (in Supplementary Table S3).

The CDC completed 156 epidemiological surveys (on-site investigations or telephone follow-ups), including 3629 individuals in high-risk populations, and the direct costs (labour costs, PPE and ambulance costs) were calculated (Table 2). The average epidemiological costs for people in centralised isolation, home isolation and jail were $4.57, $10.59 and $2.36 per case, respectively. Moreover, the average epidemiological costs of antibody-positive individuals, close contacts of people with confirmed cases, people who retested positive after recovery and individuals with suspected cases were $10.52, $14.78, $389.84, $214.42, $136.70 and $243.50 per case, respectively. The average epidemiological cost associated with the inspection of hospital fever clinics by the CDC was $214.42 per incident. The total

### Table 1

The cost of obtaining sample specimens for NAT in different medical institutes.

| Items                                      | Number of samples | Labour resource of medical staff, days | Price, $ | Cost per sample, $ | Human resource, days/per sample |
|--------------------------------------------|-------------------|----------------------------------------|----------|--------------------|---------------------------------|
| **In CDC**                                 |                   |                                        |          |                    |                                 |
| Labour to obtain specimen                  | 4267              | 214                                    | 42.06    | 2.11               | 0.05                            |
| Community policeman                        | 4267              | 81                                     | 28.04    | 0.53               | 0.019                           |
| Labour to deliver specimen                 | 4267              | 252                                    | 28.04    | 1.66               | 0.029                           |
| Ambulance                                  | 4267              | 252                                    | 16.82    | 0.99               |                                 |
| PPE                                        | 4267              | 295                                    | 50.95    | 3.52               |                                 |
| **Total average cost**                     |                   |                                        |          | **8.81**           | **0.128**                       |
| **In secondary or tertiary hospitals**     |                   |                                        |          |                    |                                 |
| Labour to obtain specimen                  | 9547              | 3760                                   | 42.06    | 16.56              | 0.394                           |
| Community policeman                        | 9547              | 1164                                   | 28.04    | 3.42               | 0.122                           |
| Labour to deliver specimen                 | 9547              | 1164                                   | 16.82    | 2.05               |                                 |
| Ambulance                                  | 9547              | 3760                                   | 50.95    | 20.07              |                                 |
| **Total average cost**                     |                   |                                        |          | **42.1**           | **0.516**                       |
| **Community healthcare centre**            |                   |                                        |          |                    |                                 |
| Labour to obtain specimen                  | 4850              | 939                                    | 42.06    | 8.14               | 0.194                           |
| Labour to deliver specimen                 | 4850              | 642                                    | 28.04    | 3.71               | 0.132                           |
| Ambulance                                  | 4850              | 642                                    | 16.82    | 2.23               |                                 |
| PPE                                        | 4850              | 939                                    | 50.95    | 9.86               |                                 |
| **Total average cost**                     |                   |                                        |          | **23.94**          | **0.326**                       |
| **Township hospitals or temporary participating institutions** |                   |                                        |          |                    |                                 |
| Labour to obtain specimen                  | 192               | 23                                     | 42.06    | 5.04               | 0.12                            |
| Labour to deliver specimen                 | 192               | 54                                     | 28.04    | 7.89               | 0.281                           |
| Ambulance                                  | 192               | 54                                     | 16.82    | 4.73               |                                 |
| PPE                                        | 192               | 23                                     | 50.95    | 6.1                |                                 |
| **Total average cost**                     |                   |                                        |          | **23.76**          | **0.401**                       |
| **Total cost in all medical institutes**   |                   |                                        |          |                    |                                 |
| Labour to obtain specimen                  | 18,856            | 4936                                   | 42.06    | 11.01              | 0.262                           |
| Community policeman                        | 18,856            | 81                                     | 28.04    | 0.12               | 0.004                           |
| Labour to deliver specimen                 | 18,856            | 2112                                   | 28.04    | 3.14               | 0.112                           |
| Ambulance                                  | 18,856            | 2112                                   | 16.82    | 1.88               |                                 |
| PPE                                        | 18,856            | 4936                                   | 50.95    | 13.34              |                                 |
| **Total average cost**                     |                   |                                        |          | **29.49**          | **0.378**                       |

CDC: Centers for Disease Control and Prevention; PPE: personal protective equipment; NAT: nucleic acid testing.

*The per sample cost in bold, was calculated by adding the cost of subgroups, such as 8.81+2.11+0.53+1.66+0.99+3.52. The human resource (days per sample) in bold, was calculated by adding the human resource of subgroups, such as 0.128+0.05+0.019+0.059.

Note: The typical exchange rate of RMB to US$ equivalent in the period of this survey is 1 RMB — 0.1402 US$.
### Table 2

| Type of cases | Survey administrations | Cases | Survey cost of CDC | Total labour costs | Total labour costs per administration | Cost per case or per administration, $ | PPE cost, $ | Survey cost, $ |
|---------------|------------------------|-------|-------------------|--------------------|--------------------------------------|----------------------------------------|------------|-------------|
| **Centralised quarantine locations** |                        |       |                   |                    |                                     |                                        |            |             |
| Home quarantine | 2                     | 66    | 2                 | 4                  | 407.56                | 575.80                                | 407.56    | 575.80      |
| Antibody-positive individuals | 1                     | 18    | 3                 | 2                  | 189.27                | 189.27                                | 189.27    | 189.27      |
| Close contacts of cases | 8                     | 872   | 280               | 1                  | 764.23                | 12,583                                | 764.23    | 12,583      |
| **Patients with confirmed cases** |                        |       |                   |                    |                                     |                                        |            |             |
| Fever clinics | 5                     | 15    | 6                 | 3                  | 560.38                | 917.89                                | 560.38    | 917.89      |
| Patients who retested as positive after recovery | 2                     | 2     | 3                 | 4                  | 273.39                | 273.39                                | 273.39    | 273.39      |
| Individuals with suspected cases | 26                    | 124   | 323               | 391                | 30,193                | 30,193                                | 30,193    | 30,193      |

**Note:**
- CDC: Centers for Disease Control and Prevention; PPE: personal protective equipment.
- The median hospitalisation costs associated with COVID-19 were analysed based on the hospitalisation costs of 220 inpatients with COVID-19 (Table 4 and Supplementary Table S4). A single SARS-CoV-2 infection cost a median of $2158.06 (95% CI = $1991.93–$2321.28) in direct medical costs, that is, only including the costs that were accrued during the course of hospitalisation. The median cost of hospitalisation in the negative-pressure isolation ward (NPIW) was higher than that in the general isolation ward ($3439.00 (95% CI = $2942.59–$4573.96) vs $1902.26 (95% CI = $1745.77–$2146.22); P < 0.001). Hospitalisation with non-invasive ventilation cost a median of $9278.05 (95% CI = $6990.72–$11,151.19), which was higher than the cost of hospitalisation without ventilation ($2017.16 (95% CI = $1837.62–$2224.99); P < 0.001). The median cost of hospitalisation in the intensive care unit (ICU) was significantly higher than that in general isolation wards ($11,144.88 (95% CI = $9278.05–$13,283.93) vs $2114.65 (95% CI = $1880.72–$2254.52); P < 0.001). In addition, the median cost of hospitalisation for severe and critical COVID-19 was markedly higher than that for mild and moderate COVID-19 ($3439.00 (95% CI = $3055.95–$4573.96) vs $1898.59 (95% CI = $1731.59–$2130.93); P < 0.001). Patients with two or more hospitalisations for COVID-19 had a higher hospitalisation cost than those with a single hospitalisation ($3437.72 (95% CI = $2432.65–$5828.88) vs $2120.00 (95% CI = $1898.59–$2257.09); P = 0.002). Also, the median cost of hospitalisation for patients from abroad was $4567.89 (95% CI = $2992.07–$5072.00), which was higher than for local patients ($2132.99 (95% CI = $1938.52–$2298.65); P = 0.01).

- The total direct hospitalisation medical expenses consist of drug fees ($364.16 (95% CI = $330.21–$390.17)), medical examination fees ($200.21 (95% CI = $200.21–$266.94)), laboratory fees ($513.24 (95% CI = $481.57–$543.49), consultation fees ($52.58 (95% CI = $47.67–$57.48), treatment fees ($182.45 (95% CI = $152.64–$232.66), nursing fees ($62.25 (95% CI = $57.20–$68.98), bed fees ($205.04 (95% CI = $177.70–$226.16), medical supply fees ($409.52 (95% CI = $357.55–$460.71), hospitalisation fees ($27.60 (95% CI = $25.41–$31.51), median of basic medical fees ($0.14 (95% CI = $0.08–$0.22), median of Chinese patent medicine fees ($28.49 (95% CI = $25.25–$34.36), median of surgery fees ($2.61 (95% CI = $0.88–$5.35) and median of Chinese herbal medicine fees ($6.77 (95% CI = $3.56–$10.07) (Table 4).

- The median and mean hospitalisation costs are compared in Table 4. Treatments in the NPIW with non-invasive ventilation or
in the ICU were associated with relatively higher hospitalisation costs (all $P < 0.05$). Severe and critical COVID-19 was associated with higher hospitalisation costs than mild and moderate COVID-19 ($P < 0.001$). Moreover, patients with two or more hospitalisations and patients from abroad had higher hospitalisation fees than their counterparts (all $P < 0.05$).

In addition, multivariable GLM analyses revealed that the factors impacting hospitalisation cost were age (45–59 years vs < 18 years; $P = 0.027$), duration of hospitalisation ($P < 0.001$), hospitalisation in the NPIW ($P < 0.001$), the use of non-invasive ventilation ($P < 0.001$), admission to the ICU ($P < 0.001$), the classification of COVID-19 as severe and critical ($P < 0.001$) and the number of hospitalisations ($P = 0.001$) (Table 5).

### Compensation methods for hospitalisation cost

The methods of paying for hospitalisation include basic medical insurance, medical insurance claims for large expenses, other assistance and out-of-pocket payments. The results (Table 4 and Supplementary Table S4) revealed that the mean hospitalisation costs for COVID-19 were mainly paid by medical insurance ($2531.85$ [95% CI = $1953.46–$3310.91]) and by the patients ($1134.45$ [95% CI = $610.75–$2084.81]). Compared with their counterparts, the compensation paid by medical insurance was higher for patients who were hospitalised in the NPIW ($5046.69$ [95% CI = $3033.67–$7605.15] vs $1610.27$ [95% CI = $1480.19–$1750.64]; $P = 0.003$), received non-invasive ventilation ($10,789.11$ [95% CI = $6362.94–$16,478.35] vs $1771.32$ [95% CI = $1480.90–$2218.23]; $P < 0.001$) and were hospitalised in the ICU ($16,940.65$ [95% CI = $8334.59–$26,511.06] vs $1773.50$ [95% CI = $1578.50–$1988.21]; $P < 0.001$). In addition, patients with severe and critical COVID-19 and those with two or more hospitalisations received more compensation from medical insurance than their counterparts (all $P < 0.001$). The government paid the medical expenses that should have been paid by patients with COVID-19 in China.

Furthermore, the results show that the expense percentages paid by basic medical insurance and medical insurance claims for large expenses were 51.92% and 16.48%, respectively, and that the expense percentages paid by medical insurance, the government and other forms of compensation were 68.40%, 30.65% and 0.95%, respectively (Supplementary Table S5). The government paid approximately $94.12 million for the hospitalisation of patients with confirmed COVID-19 in China until 20 May, 2020. Medical insurance covered $60.08–84.49% of the hospitalisation costs for COVID-19.
Table 4
The cost of hospitalisation for COVID-19, median (95% CI).a

| Variables                                           | Total                  | Negative-pressure isolation ward | Noninvasive ventilation |
|-----------------------------------------------------|------------------------|----------------------------------|-------------------------|
|                                                    | Total                   | No                               | Yes                     | P          | No                     | Yes                     | P          |
| Sample size, n                                      | 220                    | 161                              | 59                      | 200        | 191                    | 19                      | 201        |
| Duration of hospitalization, days                  | (17.00-20.00)          | (16.00-19.00)                    | (17.00-25.00)           | 0.053      | (16.00-19.00)          | (20.00-35.00)           | 0.001      |
| Drug fee, $                                         | 364.16                 | 353.63                           | 416.63                  | 0.446      | 338.3                  | 1522.11                 | <0.001     |
| Medical examination fee, $                          | (330.21-390.17)        | (329.04-381.36)                  | (294.02-496.55)         |            | (315.43-372.78)        | (1145.39-2466.65)       | <0.001     |
| Clinical laboratory fee, $                          | 200.21                 | 200.21                           | 201                     | 0.205      | 200.21                 | 467.15                  | <0.001     |
| Treatment fee, $                                     | (200.21-266.94)        | (200.21-215.35)                  | (200.21-333.68)         |            | (200.21-209.74)        | (400.41-492.94)         |           |
| Consultation fee, $                                  | 182.45                 | 152.27                           | 292.2                   | <0.001     | 134.98                 | 1757.9                   | <0.001     |
| Nursing fee, $                                       | (152.64-232.66)        | (119.55-185.62)                  | (213.97-500.54)         |            | (1383.51-2119.68)      |                         |           |
| Bed fee, $                                           | 62.25                  | 60.57                            | 67.97                   | 0.088      | 61.24                  | 92.53                   | <0.001     |
| (57.20-68.98)                                       | (55.52-65.61)          | (57.20-85.80)                    | (55.52-65.61)           |            | (57.20-85.80)          | (55.52-65.61)           |           |
| Medical supply fee, $                                | 205.04                 | 159.83                           | 514.53                  | <0.001     | 186.82                 | 817.02                   | <0.001     |
| (177.70-226.16)                                     | (150.36-181.56)        | (385.55-685.23)                  | (388.99-775.53)         | 0.018      | (168.24-216.96)        | (577.27-1280.38)        |           |
| Basic medical fee, $                                 | (357.55-460.71)        | (331.69-443.16)                  | (388.99-775.53)         |            | (323.94-426.39)        | (1008.86-1529.84)        |           |
| Chinese patent medicine fee, $                       | 0.14                   | 0.12                             | 0.13                    | 0.042      | 0.14                   | 0.21                    | 0.07       |
| Surgery fee, $                                       | (0.08-0.22)            | (0.08-0.14)                      | (0.10-0.23)             | <0.001     | (0.08-0.20)            | (0.14-0.32)             | <0.001     |
| (12.25-49.36)                                       | (11.29-40.32)          | (11.29-40.32)                    | (10.00-39.27)           |            | (11.29-40.32)          | (10.00-39.27)           |            |
| Chinese herbal medicine fee, $                       | 6.77                   | 4.13                             | 9.79                    | <0.001     | 6.77                   | 7.36                    | 0.175      |
| Other hospitalization fees, $                        | (3.36-10.07)           | (3.36-8.58)                      | (4.20-14.07)            |            | (3.44-10.07)           | (4.04-11.70)            |           |
| Total medical expenses, $                            | (25.41-31.51)          | (23.83-29.30)                    | (27.44-46.76)           | <0.001     | (24.54-29.30)          | (38.56-55.73)           | <0.001     |
| (2158.06-1902.26)                                   | (1902.26-1745.77)      | (2942.59-4573.96)                | (2017.16-2224.99)       | <0.001     | (1837.62-2224.99)      | (9278.05-11151.19)      |           |
| Compensation methods                                 |                        |                                  |                        |            |                        |                          |            |
| Paid by medical insurance, $                         | 1467.21                | 1415.33                          | 2176.95                 | 0.003      | 1415.33                | 5717.11                  | <0.001     |
| (1367.85-1700.27)                                   | (1294.50-1529.39)      | (1294.50-1529.39)                | (1471.08-2864.34)       |            | (1301.30-1525.23)      | (4795.72-6058.62)        |           |
| Paid by medical insurance claims for large expenses, $| 0                      | 0                                | 0                       | <0.001     | 0                      | 2023.71                  | <0.001     |
| (0.00-0.00)                                         | (0.00-0.00)            | (0.00-0.00)                      | (0.00-0.00)             |            | (0.00-0.00)            | (0.00-3706.92)           |           |
| Total general medical insurance, $                   | 1467.21                | 1415.33                          | 2176.95                 | 0.003      | 1415.33                | 8053.25                  | <0.001     |
| (1369.82-1700.27)                                   | (1294.50-1529.39)      | (1294.50-1529.39)                | (1471.08-2892.43)       |            | (1301.30-1525.23)      | (5320.54-10804.81)       |           |
| Paid by the patient, $                               | 406.35                 | 381.81                           | 554.89                  | 0.061      | 404.88                 | 902.85                   | 0.017      |
| (317.92-491.63)                                     | (292.35-476.83)        | (318.88-902.85)                  | (298.80-490.05)         |            | (298.80-490.05)        | (318.50-1688.98)         |           |
| Other assistance, $                                  | 0                      | 0                                | 0                       | 0.012      | 0                      | 0.21                    | <0.001     |
| (0.00-0.00)                                         | (0.00-0.00)            | (0.00-0.10)                      | (0.00-0.00)             |            | (0.00-0.00)            | (0.00-0.65)             |           |

CI, confidence interval.

Note: The typical exchange rate of RMB to US$ equivalent in the period of this survey is 1 RMB = 0.1402 US$.

a The 95% confidence interval of the median was based on 1000 bootstrap iterations (seed: 3045984).

b The fee that would ordinarily have been paid by the patients was covered by the government subsidies.
The estimated cost of COVID-19 in China

The cost of public health care associated with COVID-19 included the cost of centralised quarantine, NAT, epidemiological surveys, disinfectant and PPE (see Supplementary Table S6). The costs of centralised quarantine for high-risk individuals from abroad, close contacts and postdischarge patients were $1.11 million, $479.93 million and $101.37 million, respectively, totalling $582.41 million. The cost of centralised isolation was $761.24 million, based on the cost of centralised quarantine per 1000 population in Chongqing. This may reflect the true cost because some regions did not report the number of people in the high-risk population at the beginning of the pandemic. The cost of NAT was assessed for the high-risk population and for other populations. The costs of NAT for the high-risk population, including individuals from abroad, close contacts, individuals with suspected cases and individuals with confirmed cases were $0.13 million, $89.09 million, $21.18 million and $53.40 million, respectively. In addition, the costs of NAT for the low-risk population of people from Wuhan, from abroad, from Hubei outside of Wuhan, from Guangdong and from other regions were $599.22 million, $18.12 million, $159.24 million, $362.89 million and $1833.99 million, respectively. Based on the total population of 1.4005 billion in mainland China at the end of 2019, the costs of epidemiological surveys, disinfectant, PPE and health education were $69.36 million, $345.83 million, $1807.42 million and $126.31 million, respectively. Finally, the total cost of public health care as a result of COVID-19 was $6.83 billion.

As of 20, May, 2020, the total number of COVID-19 cases in China was 82,967, which included 1709 cases from abroad and 81,258 local cases; the estimated number of severe cases was 17,147, and there were 4634 deaths and 78,249 recoveries. According to the average hospitalisation cost of $3792.69 of all cases, the total direct cost of hospitalisation in China was $314.668 million. According to the source of cases, the hospitalisation cost was $314.43 million, and individuals from abroad and local individuals were $7.20 million and $307.23 million, respectively (see Supplementary Table S6). Moreover, 17,147 patients with severe COVID-19 cost $140.10 million, which was almost equal to the cost for 65,820 patients with mild and moderate COVID-19 ($144.04 million). In addition, the hospitalisation cost for 98,430 patients with suspected cases was $58.53 million, and the total hospitalisation cost for patients with confirmed and suspected cases was $373.20 million. The estimated total direct costs of public health care and hospitalisation were approximately $7.2 billion, and the components related to COVID-19 are shown in Supplementary Figure S3.

Discussion

This study found that the total direct medical costs for public health care as a result of COVID-19 were $6.83 billion, which is substantially higher than the hospitalisation cost of $0.37 billion (these sums only consider the increased direct costs during the pandemic period and not the costs due to lost productivity or the indirect costs of the efforts to control COVID-19). Our study estimates the public healthcare costs from six aspects, namely, the costs due to centralised quarantine, NAT, epidemiological surveys, disinfectants, PPE and health education. The estimation in our analysis revealed that the cost of NAT was enormous and that NAT has imposed a tremendous economic burden on the healthcare system. In addition, we also estimated the hospitalisation costs, and the results showed that the average cost of hospitalisation for severe COVID-19 was four times that of hospitalisation for non-severe COVID-19 ($9278.05 vs $2017.16).

Estimating the cost of public health interventions for COVID-19 will provide a reference for determining the financial budget of government policy-making departments. Public health measures play critical roles in preventing the spread of emerging novel infectious diseases, such as COVID-19.\textsuperscript{14–16} Such diseases require the government and the healthcare system to provide financial support and effective public health care. In addition to outpatient and inpatient treatment expenses, public health services should be paid for by the government. However, there are limited studies estimating the cost of public health care,\textsuperscript{17} and to date, no study has calculated the public healthcare cost due to COVID-19. This is the first study to document the public healthcare cost associated with COVID-19 (i.e. not including the cost of the traditional monitoring of the incidence of communicable diseases and performance of routine investigations).

The public health costs in our study were associated with efforts to control the COVID-19 outbreak and epidemiological investigations. Of the public health measures taken, NAT, when both sampling and testing costs were considered, imposed the largest burden.\textsuperscript{15–19} Our study found that the costs of obtaining samples in secondary or tertiary hospitals were five times and two times, respectively, more than the costs of obtaining samples at the CDC, community healthcare centres and township hospitals owing to the higher costs of labour and PPE; this agrees with the findings of a previous study.\textsuperscript{17} The average cost of NAT (such as PCR) and diagnostic testing in the high-risk population reached $297.94 per capita, which was six times that in the low-risk population owing to the fact that the number of tests per capita was far larger in the

| Variable                                      | Univariate GLM | Multivariate GLM\textsuperscript{a} |
|-----------------------------------------------|----------------|----------------------------------|
| Sex, female vs male                           |                |                                  |
| Age, ref. <18 years                           | 0.016          | 0.083                            |
| 18–44                                        | 0.345          | 0.189                            |
| 45–59                                        | 0.517          | 0.19                             |
| > 60                                         | 0.639          | 0.198                            |
| Duration of hospitalisation, days             | 0.054          | 0.003                            |
| Negative-pressure isolation ward, yes vs no   | 0.614          | 0.084                            |
| Non-invasive ventilation, yes vs no           | 1.434          | 0.114                            |
| ICU, yes vs no                               | 1.635          | 0.176                            |
| Severe and critical COVID-19, yes vs no       | 0.631          | 0.083                            |
| Frequency of hospitalisation, >2 vs. 1        | 0.43           | 0.206                            |
| Imported from abroad, yes vs no               | 0.555          | 0.25                             |

Note: The typical exchange rate of RMB to US$ equivalent in the period of this survey is 1 RMB = 0.1402 US$.

GJM: generalized linear regression model (dependent variable was logarithm of total medical expenses); ICU: intensive care unit; SE: standard error.

\textsuperscript{a} The variable of severe and critical COVID-19 was excluded because it had collinearity with hospitalization in the negative-pressure isolation ward.
high-risk population.\textsuperscript{20,21} The huge cost of NAT should be considered when deciding which population groups need to be tested and which medical institutions should perform priority NAT.

In addition to pathogen detection, epidemiological field investigations in high-risk populations are important to control COVID-19\textsuperscript{19} because they can reduce the spread of the pandemic. The main cost incurred by epidemiological investigation is that associated with labour.\textsuperscript{17} This study found that the average epidemiological survey costs were approximately $389.84 for confirmed cases and $243.50 for suspected cases, which is 20–30 times higher than costs for other populations. Moreover, our study revealed that epidemiological survey costs accounted for approximately 1.02% of the total increased medical costs associated with COVID-19; this may be significantly lower than the actual cost, as our study only included the subsidy for labour involved in the control of COVID-19 and did not include the general salaries of medical employees.

Another critical measure for preventing the spread of SARS-CoV-2 in China is to require the use of disinfectant\textsuperscript{23} and PPE.\textsuperscript{24} Based on the current estimation, the cost of the additional disinfectant accounted for more than 5% ($0.35 billion) of the public healthcare costs associated with COVID-19, primarily driven by the cost of the disinfectant solutions and the materials themselves. The cost of disinfection reported in our study is lower than the actual cost because the labour cost associated with the disinfection of hospital waste was not calculated. Wang et al.\textsuperscript{23} found that the disinfection of hospital waste and wastewater is very important for controlling the COVID-19 pandemic.

In addition to NAT, the cost of PPE accounted for 26.46% of the public healthcare costs in our study, in part due to the shortages in medical masks, gowns and protective suits at the beginning of the pandemic. There are debates about whether wearing masks is effective and who needs to wear masks;\textsuperscript{13,25,26} one study suggested wearing PPE in certain circumstances;\textsuperscript{25} and one study from Wuhan found that the use of PPE can protect healthcare professionals from COVID-19.\textsuperscript{27}

Moreover, the centralised quarantine of high-risk populations is another effective way to reduce transmission,\textsuperscript{28} minimising the spread of COVID-19 among family members and the community.\textsuperscript{29} In this study, we found that the cost of centralised quarantine accounted for 19.30% of the increased public healthcare costs associated with COVID-19, including the Chinese government’s reimbursements for medical expenses and the costs of the accommodation and meals provided during centralised quarantine (it is important to note that the provision of these items significantly improved compliance with centralised isolation and reduced the psychological stress of those in quarantine).

Health education is an essential measure that can increase people’s knowledge, attitudes and practices (KAP) towards COVID-19.\textsuperscript{30} Our study found that the making of videos and publicity materials by authorities and the healthcare system to increase public awareness of COVID-19 accounted for 1.85% of the public healthcare costs associated with COVID-19 and had a significant effect.\textsuperscript{31}

Isolation within hospitals is necessary for patients with confirmed and suspected cases of COVID-19,\textsuperscript{19,21} and the choice of treatment for patients was impacted by the method of compensation for hospitalisation expenses. To provide hospitalisation and treatment for every patient with a confirmed and suspected case, the Chinese government paid all medical expenses that would ordinarily have been paid by individuals, and our study found that the government provided 30.65% (nearly $0.11 billion) of the hospitalisation-associated costs for patients with confirmed cases (Supplementary Table S5). In contrast, out-of-pocket healthcare costs have placed an enormous burden on many patients with COVID-19 in some countries, preventing patients from receiving medical treatment\textsuperscript{31} and exacerbating the spread of COVID-19. The average cost is 2.58 times that of the average medical expenses for inpatient treatment in general ($1468.78 in medical costs in 2020 values)\textsuperscript{32} and 3.68 times that of the average medical expenses for bacterial pneumonia ($1039.71 in medical costs in 2020 values), which was similar to the results of Bartsch et al.\textsuperscript{12} The direct medical costs are higher for COVID-19 than for other common infectious diseases because inpatients with COVID-19 have a longer average hospital stay (18 days vs 8.5 days) and higher mortality than patients with seasonal influenza and other infectious diseases.\textsuperscript{12,32–34} Moreover, we found that the hospitalisation-associated costs for severe patients with COVID-19 (those treated in the NPIW, treated with non-invasive ventilation, treated in the ICU, and with two or more hospitalisations), patients from abroad and older patients were greater than those for their counterparts, which was in agreement with the findings of another published study.\textsuperscript{12} The hospitalisation-associated costs in our study included only the expenses incurred during hospitalisation and did not consider the potential continued medical costs after the acute infection had run its course, including the cost of caring for those who had survived with major complications, such as cardiovascular disease and diabetes.\textsuperscript{33} Furthermore, the costs of subsidies for emergency medical personnel (40,000 medical staff members supported the efforts to control COVID-19 in Wuhan), follow-up care and potential rehospitalisation are likely to be considerable because of the long-term effects of COVID-19,\textsuperscript{35} making patients more susceptible to other health problems. These costs will further increase the cost of hospitalisation. The compensation policy for out-of-pocket hospitalisation costs for COVID-19 in China and the average hospitalisation cost in our study will provide references for other countries coping with the pandemic.

The current study has several limitations. First, we focused on the increased direct medical costs associated with COVID-19. Therefore, we did not consider the potentially substantial indirect medical costs that may be associated with COVID-19, such as those related to reduced economic activity and lost productivity owing to absenteeism and premature mortality, as we cannot contact the patients during the pandemic. In addition, we can only get the hospitalisation cost from the medical insurance information systems. Second, the results in this study may underestimate the direct medical costs because we only used the situation in Chongqing to calculate the costs for China as a whole. For example, we did not include the additional costs of building the mobile cabin hospitals in Wuhan or the tent hospitals in other places. Third, we did not include the financing of emergency medical equipment used for the control of COVID-19. Fourth, costs for environmental NAT sampling were not included in this study, which may underestimate the cost of public health care of COVID-19. Fifth, our analysis included only the subsidies paid to medical staff during the COVID-19 pandemic and did not include their regular salaries, which may have resulted in a significantly underestimation of the labour costs. Finally, we did not test the external validity of this study because we did not obtain the cost data from other areas of China.

However, the data regarding COVID-19 were from the National Health Commission of People’s Republic of China (http://www.nhc.gov.cn), which collected information from patients in all of China. In addition, the Jiulongpo District, from which we collected the data from other areas of China. Further, and different to other countries, the health policies (especially the policies on COVID-19 medication and public health) were exactly the same throughout mainland China. The facilities, equipment, drugs and health services were uniformly priced by the
Chinese government, so that even the cost data from a small part of China, such as Jiulongpo district, can represent the data for the whole of mainland China, which results in our conclusions having good external validity.

In conclusion, this study found that the COVID-19 pandemic has resulted in the expenditure of $6.83 billion in public health care and $0.37 billion in direct medical costs associated with hospitalisation. As large numbers of people must be tested and treated to prevent hospitalisation and potential death, the public healthcare costs were far greater than the hospitalisation costs. This suggests that governments should plan to increase the financial investment both in emergency public health care and hospitalisation during infectious disease outbreaks to effectively contain the spread of disease. Our study also highlights the magnitude of the resources needed to prevent the spread of the COVID-19 pandemic and to treat patients with COVID-19. Even when considering only the costs during the most severe pandemic period, and not those associated with routine surveillance and treatment following an acute outbreak, the increased medical costs related to the COVID-19 pandemic are likely to be substantially higher than those reported in this study. Therefore, tremendous health resources are needed to control the outbreak of infectious disease pandemics. However, at the beginning of pandemics, the medication and public healthcare costs of infectious diseases (such as SARS or COVID-19), are often not covered by health insurance, which will be an obstacle for the quick control of the pandemic. The quick control of the COVID-19 pandemic in China has been described in our previous study.

The estimated cost of pandemic control, especially the financial resources required from government to cover the medication and public health demand, will be of great help in achieving the goal to prevent the ‘burst-out’ situation of an infectious disease public health emergency.

**Author statements**

**Acknowledgements**

The authors would like to acknowledge the laboratory support of the Ministry of Education Key Laboratory of Child Development and Disorders, and the data support of Chongqing Public Health Medical Center and Disease Control and Prevention Center of Jiulongpo District.

**Ethical approval**

The Institutional Review Board at the Children’s Hospital of Chongqing Medical University approved this study ((2020) No.59). Informed consent was provided by all patients.

**Funding**

This work was supported by Chongqing Medical University (Grant no. CQUMNCP0204), the Natural Science Foundation of Chongqing (Grant no. cstc2020syj-zzzysbA00075), Joint Medical Research Project of Chongqing Municipal Health Commission and Chongqing Municipal Science and Technology Bureau (2020FYX142) the Ministry of Science and Technology of the People’s Republic of China (Grant no. 2017YFC0211705), the National Natural Science Foundation of China (Grant no. 81502826), the Education Commission of Chongqing (Grant no. KJQN201900443) and the China Postdoctoral Science Foundation (Grant no. 2014M562289). The funders had no role in the study design, the data collection and analysis, the decision to publish or the preparation of the manuscript.

**Competing interests**

The authors declare that they have no competing interests.

**Author contributions**

An X and Xiao L conceived and designed the study; Yang X and Tang X participated in the acquisition and management of the data; An X analysed the data; Liang XH wrote the manuscript and all authors revised the manuscript. All authors took responsibility for the integrity of the data and the accuracy of the data analysis. All authors made critical revisions to the manuscript for important intellectual content and gave the final approval of the manuscript.

**Data statement**

Data are available on request owing to privacy/ethical restrictions.

**Appendix A. Supplementary data**

Supplementary data to this article can be found online at https://doi.org/10.1016/j.puhe.2021.12.001.

**References**

1. WHO. Coronavirus disease (covid-19) pandemic. 2020. Available from: https://www.who.int/emergencies/diseases/novel-coronavirus-2019.
2. Chan-Yeung M, Xu RH. SARS: epidemiology. Respirology (Carlton, Vic) 2003;8(Suppl):9–14.
3. National Health Commission of the People’s Republic of China. The latest situation of the COVID-19 epidemic situation as of 24:00 on May 20, 2020. Available from: http://www.nhc.gov.cn/xcs/yqtb2020/ 7be4e6b23c6c4941d0d93d66c60b1fa/ae.shtml
4. Wilder-Smith A, Freedman DO. Isolation, quarantine, social distancing and community containment: pivotal role for old-style public health measures in the novel coronavirus (2019-nCoV) outbreak. J Trav Med 2020;27.
5. Dickens BL, Koo JR, Wilder-Smith A, Cook AR. Institutional, not home-based, isolation could contain the COVID-19 outbreak. Lancet 2020;395:1541–2.
6. Meng Q, Yang H, Chen W. People’s Republic of China health system review. Health Syst Transit 2015;5.
7. Wang J, Wang Z. Strengths, weaknesses, opportunities and threats (SWOT) analysis of China’s prevention and control strategy for the COVID-19 epidemic. Int J Environ Res Publ Health 2020:17.
8. Liang XH, Tang X, Luo YT, Zhang M, Feng ZP. Effects of policies and containment measures on control of COVID-19 epidemic in Chongqing. World J Clin Cases 2020;8:2959–76.
9. Bartsch SM, Gorham K, Lee BY. The cost of an Ebola case. Pathog Glob Health 2015;109:4–9.
10. Lee BY, Alfaro-Murillo JA, Parpia AS, Asti L, Wedlock PT, Hotez PJ, et al. The potential economic burden of Zika in the continental United States. PLoS Negl Trop Dis 2017;11:e0005531.
11. Alfaro-Murillo JA, Parpia AS, Fitzpatrick MC, Tamagnan JA, Medlock J, Ndeffo-Mbah ML, et al. A cost-effectiveness tool for informing policies on Zika virus control. PLoS Negl Trop Dis 2016;10:e0004743.
12. Bartsch SM, Ferguson MC, McKinnell JA, O’Shea KJ, Wedlock PT, Siegmund SS, et al. The potential health care costs and resource use associated with COVID-19 in the United States. Health Aff 2020;39:927–35.
13. Ruhl AP, Huang M, Colantuoni E, Karmarkar T, Dinglas VD, Hopkins RO, et al. Healthcare utilization and costs in ARDS survivors: a 1-year longitudinal national US multicenter study. Intensive Care Med 2017;43:980–91.
14. Kraemer MUG, Yang CH, Gutierrez B, Wu CH, Klein B, Pigott DM, et al. The effect of human mobility and control measures on the COVID-19 epidemic in China. Science 2020;368:493–7.
15. Juni P, Rothengatter M, Bobos P, Thorpe KE, da Costa BR, Fisman DN, et al. Impact of climate and public health interventions on the COVID-19 pandemic: a prospective cohort study. CMAJ : Canadian Medical Association journal de l’Association medicale canadienne 2020;192:E566–73.
16. Yang Z, Zeng Z, Wang X, Wong SS, Liang W, Zanin M, et al. Modified SEIR and AI prediction of the epidemics trend of COVID-19 in China under public health interventions. J Thorac Dis 2020;12:165–74.
17. Atherly A, Whittington M, VanKaamdonk L, Lampe S. The economic cost of communicable disease surveillance in local public health agencies. Health Serv Res 2017;52(Suppl 2):2343–56.
18. Eshin MN, Whitney ON, Chong S, Maurer A, Darzaqz X, Tijan R. Overcoming the bottleneck to widespread testing: a rapid review of nucleic acid testing approaches for COVID-19 detection. Rtn 2020;26:771–83.
19. Beeching NJ, Fletcher TE, Beadsworth MBJ. Covid-19: testing times. *Bmj* 2020;369:m1403.

20. Hong KH, Lee SW, Kim TS, Huh HJ, Lee J, Kim SY, et al. Guidelines for laboratory diagnosis of coronavirus disease 2019 (COVID-19) in Korea. *Ann Lab Med* 2020;40:351–60.

21. Jin YH, Cai L, Cheng ZS, Cheng H, Deng T, Fan YP, et al. A rapid advice guideline for the diagnosis and treatment of 2019 novel coronavirus (2019-nCoV) infected pneumonia (standard version). *Mil Med Res* 2020;7:4.

22. Lipsitch M, Swerdlow DL, Finelli L. Defining the epidemiology of Covid-19 - studies needed. *N Engl J Med* 2020;382:1194–6.

23. Wang J, Shen J, Ye B, Yan X, Zhang Y, Yang W, et al. Disinfection technology of hospital wastes and wastewater: suggestions for disinfection strategy during coronavirus Disease 2019 (COVID-19) pandemic in China. *Environ Pollut* 2020;262:114665.

24. Fathizadeh H, Maroufi P, Momen-Heravi M, Dao S, Kose S, Ganbarov K, et al. Protection and disinfection policies against SARS-CoV-2 (COVID-19). *Infezioni Med Le* 2020;28:185–91.

25. Hirschmann MT, Hart A, Henckel J, Sadoghi P, Seil R, Mouton C. COVID-19 coronavirus: recommended personal protective equipment for the orthopaedic and trauma surgeon. *Knee Surg Sports Traumatol Arthrosc – Off J ESSKA* 2020;28:1690–8.

26. Bin-Reza F, Lopez Chavarrias V, Nicoll A, Chamberland ME. The use of masks and respirators to prevent transmission of influenza: a systematic review of the scientific evidence. *Influenza Other Respir Viruses* 2012;6:257–67.

27. Liu M, Cheng SZ, Xu KW, Yang Y, Zhu QT, Zhang H, et al. Use of personal protective equipment against coronavirus disease 2019 by healthcare professionals in Wuhan, China: cross sectional study. *Bmj* 2020;369:m2195.

28. Pan A, Liu L, Wang C, Guo H, Hao X, Wang Q, et al. Association of public health interventions with the epidemiology of the COVID-19 outbreak in Wuhan, China. *Jama* 2020;323:1915–23.

29. Zhu Y, Wang C, Dong L, Xiao M. Home quarantine or centralized quarantine, which is more conducive to fighting COVID-19 pandemic? Brain, behavior, and immunity. 2020.

30. Zhong BL, Luo W, Li HM, Zhang QQ, Liu XG, Li WT, et al. Knowledge, attitudes, and practices towards COVID-19 among Chinese residents during the rapid rise period of the COVID-19 outbreak: a quick online cross-sectional survey. *Int J Biol Sci* 2020;16:1745–52.

31. Konrad W. After battling COVID-19, survivors may have to fight big medical bills. CBS NEWS. 2020. Available from: https://www.cbsnews.com/news/covid-19-health-care-costs-medical-treatment.

32. Ma X, Xu X, Ji Y, Wang H, Liu J, Xu S, et al. China health statistics yearbook in 2019. Peking Union Medical College Press; 2019.

33. Iuliano AD, Roguski KM, Chang HH, Muscatello DJ, Palekar R, Tempia S, et al. Estimates of global seasonal influenza-associated respiratory mortality: a modelling study. *Lancet (London, England)* 2018;391:1285–300.

34. Zhou F, Yu T, Du R, Fan G, Liu Y, Liu Z, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *Lancet (London, England)* 2020;395:1054–62.

35. Roldrini P, Garcea M, Brichetto G, Reale N, Tonolo S, Falabella V, et al. Living with a disability during the pandemic. “Instant paper from the field” on rehabilitation answers to the COVID-19 emergency. *Eur J Phys Rehabil Med* 2020;56:331–4.