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Short Communication

Assessing the effects of metropolitan-wide quarantine on the spread of COVID-19 in public space and households



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ABSTRACT

Hubei province in China has completed cycle of quarantine-resumption in 23rd January and 8th April 2020, providing a unique opportunity as for now to assess its intervention impact and the pattern of SARS-COV-2 transmission during the quarantine period. In this study, we evaluate the impact of the metropolitan-wide quarantine on the trend and transmission route of the COVID-19 epidemic in Hubei, China. The intervention reduces more than 70% of new infections in both households and the public space, as well as the deaths caused by COVID-19 pneumonia. Household transmission is the dominant route of disease spread regardless of quarantine. This will provide important evidence and scientific insights to other worldwide countries that are currently under quarantine.

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Introduction

On 31st December 2019, a pneumonia case of unknown etiology from Wuhan, Hubei Province, China was reported to the World Health Organization (WHO), which was later confirmed as a new coronavirus disease (COVID-19) with infection of a novel coronavirus named as “severe acute respiratory syndrome coronavirus 2” (SARS-CoV-2) (World Health Organization, 2020a). As of 8th April 2020, more than 200 countries worldwide have reported over 1.35 million confirmed cases and 79,000 deaths (World Health Organization, 2020b). A total of 83,157 cases and 3,342 deaths were reported in China, and approximately 81% of (67,803) cases and 96% (3,215) of

deaths were from the Hubei Province (Health Commission of Hubei Province, 2020).

To contain the spread of COVID-19, the Chinese government initiated an unprecedented metropolitan-wide quarantine on 13 major cities in Hubei province since 23rd January 2020, which significantly reduced the movement of people by terminating most forms of transportation (Sina News, 2020; Chen et al., 2020a). The quarantine has substantially reduced social contacts in the public space but increased contacts in households. The quarantine lasted for eleven weeks, and Wuhan, the last city of Hubei province in quarantine, was eventually resumed its economic activities and public transportation on 8th April 2020. As for now, a major intervention in the first epicenter of the COVID-19 epidemic has formally concluded. During this quarantine, a WHO report (World Health Organization, 2020c) has shown that most (78–85%) of the transmissions in China had occurred in a household setting. The completed cycle of quarantine-resumption of Hubei province provides a unique opportunity to assess its intervention impact and the pattern of SARS-COV-2 transmission during the quarantine period. The preceding experiences in Hubei, China, will provide

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important evidence and scientific insights to other worldwide countries that are currently under quarantine.

Based on a dynamic compartmental model, this study aims to evaluate the impact of the metropolitan-wide quarantine on the trend and transmission route of the SARS-CoV-2 epidemic during the period of 23rd January–8th April 2020.

Methods

We collected data on the number of cumulative confirmed cases and deaths from 15th January 2020 to 8th April 2020 from the [Health Commission of Hubei Province \(2020\)](#) (Table S1). We developed a compartmental model (Figure S1) to describe the transmission of COVID-19 in Hubei Province. Different from most existing models ([Tian et al., 2020](#)), we modelled two modes of transmission, including social contacts in public space (e.g. public transportations, supermarkets, offices, etc.) and households. We assumed that the average number of daily contacts was reduced by 80% (71–94%) in the public space ([Kejixun, 2020](#)) but increased by two times in households ([Chen et al., 2020b](#)) during the quarantine. Detailed model structure, parameters, and calibration are shown in the Appendix.

Results

In the presence of the quarantine, we estimated that 100,610 (95%CI: 82,326–118,900) infections may have occurred and among which 68,975 (56,621–81,330) would be diagnosed, and 3,252 (2,667–3,837) would have died, which are closely consistent with the observations. This indicated that only 68.58% (65.58–71.58%) of infections could be diagnosed, whereas 31.42% (28.42–34.42%) of infections were spontaneously recovered and undocumented. Among these infections, we estimated that the number of

infections occurred in the public space and households were 30,351 (24,931–35,771) and 70,262 (57,391–83,133), accounting for 30.17% (29.96–30.38%) and 69.83% (69.62–70.04%) of all infections, respectively (Figures 1 and S4). If the quarantine had never been in place, the COVID-19 epidemic would result in 491,320 (331,470–651,180) infections and 15,907 (10,950–20,865) deaths. Among these infections, infections in the public space and households would reach 238,110 (162,390–313,830) and 253,210 (169,060–337,360), accounting for 48.49% (48.06–48.92%) and 51.51% (51.08–51.94%) of all new infections, respectively. This suggests that the quarantine would prevent 79.27% (75.10–83.45%) of deaths, 87.08% (84.68–89.49%) and 71.84% (66.39–77.29%) of infections in public space and households, respectively. Despite the reduction, household transmission accounts for a higher proportion (69.83%) of all transmission compared with 51.51% in the absence of quarantine.

Discussion

We estimated that the metropolitan-wide quarantine strategy implemented in Hubei province might have reduced more than 70% of epidemic compared with the absence of the quarantine. This is consistent with previous evaluations based on various modelling approaches ([Tian et al., 2020](#)).

Regardless of quarantine, household transmission appears to be the dominant route of transmission, although quarantine substantially increases the contribution of household transmission to the epidemic. Household contacts are often without preventive measures and prone to superspreading. It is estimated an average of 5.3 cases may subsequently be infected if there is a single seeding case in the household ([Liu et al., 2020](#)). Prevention of household transmission is difficult, especially when infected individuals are in the latent period or harbor an asymptomatic

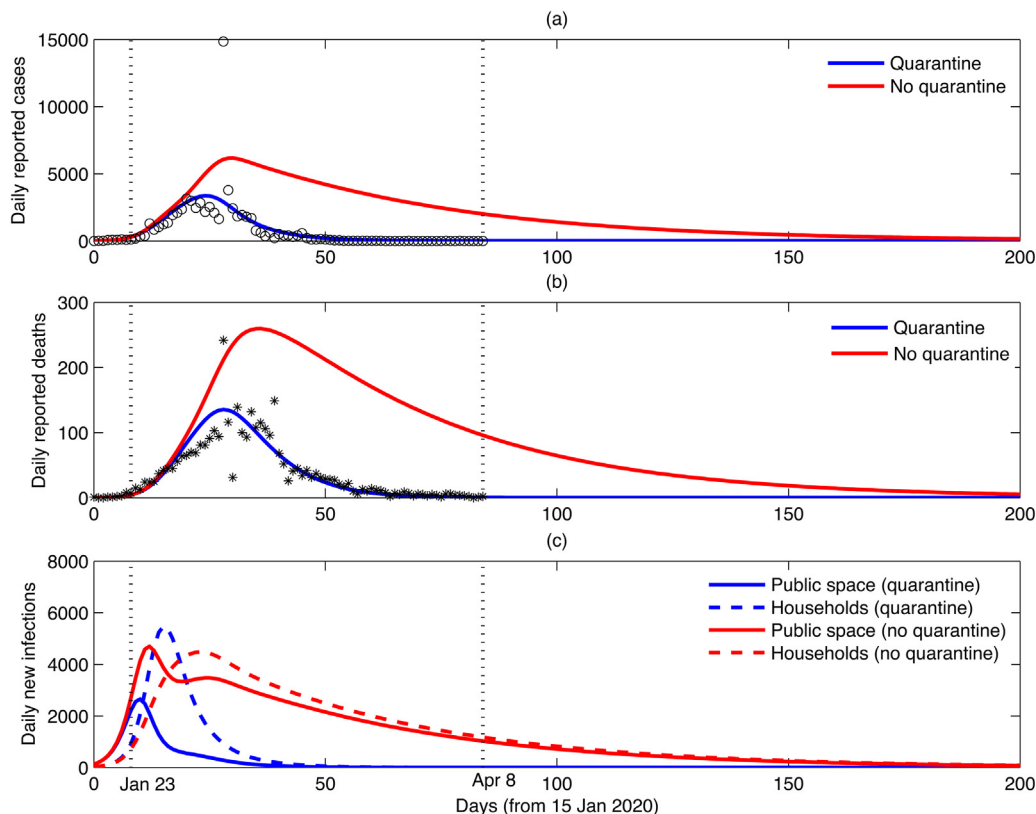


Figure 1. (a–b) Model calibration and prediction based on reported confirmed COVID-19 cases and deaths in Hubei province, China; (c) numbers of new infections in the public space and households with and without metropolitan-wide quarantine.

infection. Regular cleaning with disinfectants and active screening of household members may help to prevent the infection and facilitate early diagnosis. Providing effective protection to uninfected household members remains challenging until a vaccine becomes available.

This study has several limitations. First, we model the effects of metropolitan-wide quarantine with a reduction in the effective contact rate. We cannot distinguish whether the effects were due to media reports and voluntary isolation. Second, we assumed 100% adherence to the social distancing policy during the quarantine, which may not be the case in reality. The effect of policy on negative externalities such as fear and public disorder may undermine the value of the intervention. Third, we assumed the quarantine has the same impact on all 13 cities underwent quarantine. Fourth, we did not consider the effect of asymptomatic infection, which may underestimate the number of infected cases. Fifth, we did not consider nosocomial infections where more than 3000 medical staffs were infected during the early stage of the epidemic. This transmission route can be considered as a part of infections in public space and does not affect the main conclusions. Despite these limitations, this study fills an important research gap by assessing the impact of the metropolitan-wide quarantine on the trend and transmission route of the SARS-CoV-2 epidemic.

We concluded that the metropolitan-wide quarantine in Hubei has greatly reduced the number of new infections in the public space and, consequently, in households.

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Ethical approval

Waived, since all data utilized are publicly available.

Authors' contributions

M.S. and L.Z. conceived and designed the study. M.S. analyzed the data, carried out the analysis and performed numerical simulations. M.S. wrote the first draft of the manuscript. All the authors contributed to writing the paper and agreed with manuscript results and conclusions.

Conflict of interest

All authors declare that they have no competing interests.

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