Commentary

What Is Required to Prevent a Second Major Outbreak of SARS-CoV-2 upon Lifting Quarantine in Wuhan City, China

Lei Zhang,[1,2,3,4,*] Mingwang Shen,[1] Xiaomeng Ma,[5] Shu Su,[1] Wenfeng Gong,[8] Jing Wang,[1] Yusha Tao,[6] Zhuoru Zou,[1] Rui Zhao,[1] Joseph T.F. Lau,[7] Wei Li,[9] Feng Liu,[10] Kai Ye,[11,12,13,14] Youfa Wang,[15] Guihua Zhuang,[1,*] and Christopher K. Fairley[1,2,3]

BACKGROUND

The Chinese government implemented a metropolitan-wide quarantine of Wuhan city on 23rd January 2020 to curb the epidemic of the coronavirus COVID-19. Lifting of this quarantine is imminent. We modelled the effects of two key health interventions on the epidemic when the quarantine is lifted.

METHODS

We constructed a compartmental dynamic model to forecast the trend of the COVID-19 epidemic at different quarantine lifting dates and investigated the impact of different rates of public contact and facial mask usage on the epidemic.

RESULTS

We projected a declining trend of the COVID-19 epidemic if the current quarantine strategy continues, and Wuhan would record the last new confirmed cases in late April 2020. At the end of the epidemic, 65,733 (45,722-99,015) individuals would be infected by the virus, among which 16,166 (11,238-24,603, 24.6%) were through public contacts, 45,996 (31,892-69,565, 69.7%) through household contact, and 3,571 (2,521-5,879, 5.5%) through hospital contacts (including 778 (553-1,154) non-COVID-19 patients and 2,786 (1,969-4,791) medical staff). A total of 2,821 (1,634-6,361) would die of COVID-19 related pneumonia in Wuhan. Early quarantine

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*Corresponding author:
Email: lei.zhang1@xjtu.edu.cn (L.Z.), zhuanggh@mail.xjtu.edu.cn (G.Z.)
[1]China-Australia Joint Research Center for Infectious Diseases, School of Public Health, Xi'an Jiaotong University Health Science Center, Xi'an, Shaanxi 710061, PR China;
[2]Melbourne Sexual Health Centre, Alfred Health, Melbourne, Australia;
[3]Central Clinical School, Faculty of Medicine, Nursing and Health Sciences, Monash University, Melbourne, VIC, Australia;
[4]Department of Epidemiology and Biostatistics, College of Public Health, Zhengzhou University, Zhengzhou 450001 Henan, China;
[5]Institute of Health Policy Management and Evaluation, University of Toronto, Toronto, ON, Canada;
[6]School of Public Health and Preventive Medicine, Faculty of Medicine, Monash University, Melbourne, Australia;
[7]Centre for Research Behaviors, Centre for Health Behaviours Research, School of Public Health and Primary Care, The Chinese University of Hong Kong, Hong Kong, Hong Kong;
[8]Bill and Melinda Gates Foundation, Seattle, WA, USA;
[9]Department of Epidemiology and Health Statistics, School of Public Health, Southeast University, Nanjing, 210009 Jiangsu, China;

lifting on 21st March is viable only if Wuhan residents sustain a high facial mask usage of ≥85% and a pre-quarantine level public contact rate. Delaying city resumption to mid/late April would relax the requirement of facial mask usage to ≥75% at the same contact rate.

CONCLUSIONS

The prevention of a second epidemic is viable after the metropolitan-wide quarantine is lifted but requires a sustaining high facial mask usage and a low public contact rate.

The outbreak of the novel coronavirus SARS-CoV-2 was first identified in the Chinese city of Wuhan in early December 2019, when a group of 27 patients with close contact with a seafood market were diagnosed with a pneumonia of unknown cause.[1] The virus was found to be highly contagious and transmit in populations via droplet, person-to-person contact, and aerosol transmission.[2] The number of infected cases increased rapidly in Wuhan during the first few weeks of the outbreak, and then quickly spread to all 31 Chinese provinces and abroad.[3] By March 20, 2020, 180 countries worldwide had reported cases of COVID-19. So far, China has reported 80,695 confirmed cases and 3,097 deaths, accounting for about one-third of all cases and deaths worldwide.

To curb the epidemic, the Chinese government introduced a "metropolitan-wide quarantine" of the city of Wuhan from January 23, 2020, by terminating all public transportation in the city and intercity links.[4] During the metropolitan-wide quarantine, the National Health Commission and the Chinese Center for Disease Control urged the use of facial masks in all public spaces, put in place strict home containment policies, postponed schools and industry reopening to reduce communal activities and person-to-person transmission. A massive screening program was implemented for individuals in close contact with infected or high-risk individuals.[5] The strict control in Wuhan has been effective, with the daily reported confirmed cases significantly reduced from 1,500 to 2,000 at its peak to 10 cases or less a day.[6] However, the implementation of the quarantine has also severely damaged its economy, with predictions that the Chinese economy will grow by less than 4% in the first quarter of 2020.[7] The daily life of Wuhan residents has also been seriously disrupted, and the long duration of home containment may result in mental and psychological issues.[8]

Lifting the metropolitan-wide quarantine is imminent. Since late February, major cities across China have gradually eased their restriction levels and partially resumed public transportation.[9] As the epicenter of the outbreak, Wuhan faces the dilemma of balancing the substantial accumulating economic losses with the hard-earned control of the epidemic. Lifting the quarantine restrictions in the city and reopening transport links with the rest of China has become the top priority for the policy makers. We aim to determine what level of the two commonly used control measures, social distancing and facial mask usage, are necessary to prevent a resurgence of the epidemic due to either residual active cases in Wuhan or imported cases after lifting the quarantine.

[10]Shaanxi Provincial Center for Disease Control and Prevention, Xi'an, 710054 Shaanxi, China;
[11]MOE Key Lab for Intelligent Networks & Networks Security, Faculty of Electronics and Information Engineering, Xi'an Jiaotong University, Xi'an 710049 China;
[12]School of Automation Science and Engineering, Faculty of Electronics and Information Engineering, Xi'an Jiaotong University, Xi'an 710049 China;
[13]Genome Institute, the First Affiliated Hospital of Xi'an Jiaotong University, Xi'an 710061 China;
[14]The School of Life Science and Technology, Xi'an Jiaotong University, Xi'an 710049 China;
[15]Global Health Institute, Department of Epidemiology and Biostatistics, School of Public Health, Xi'an Jiaotong University Health Science Center, Xi'an, Shaanxi 710061, China

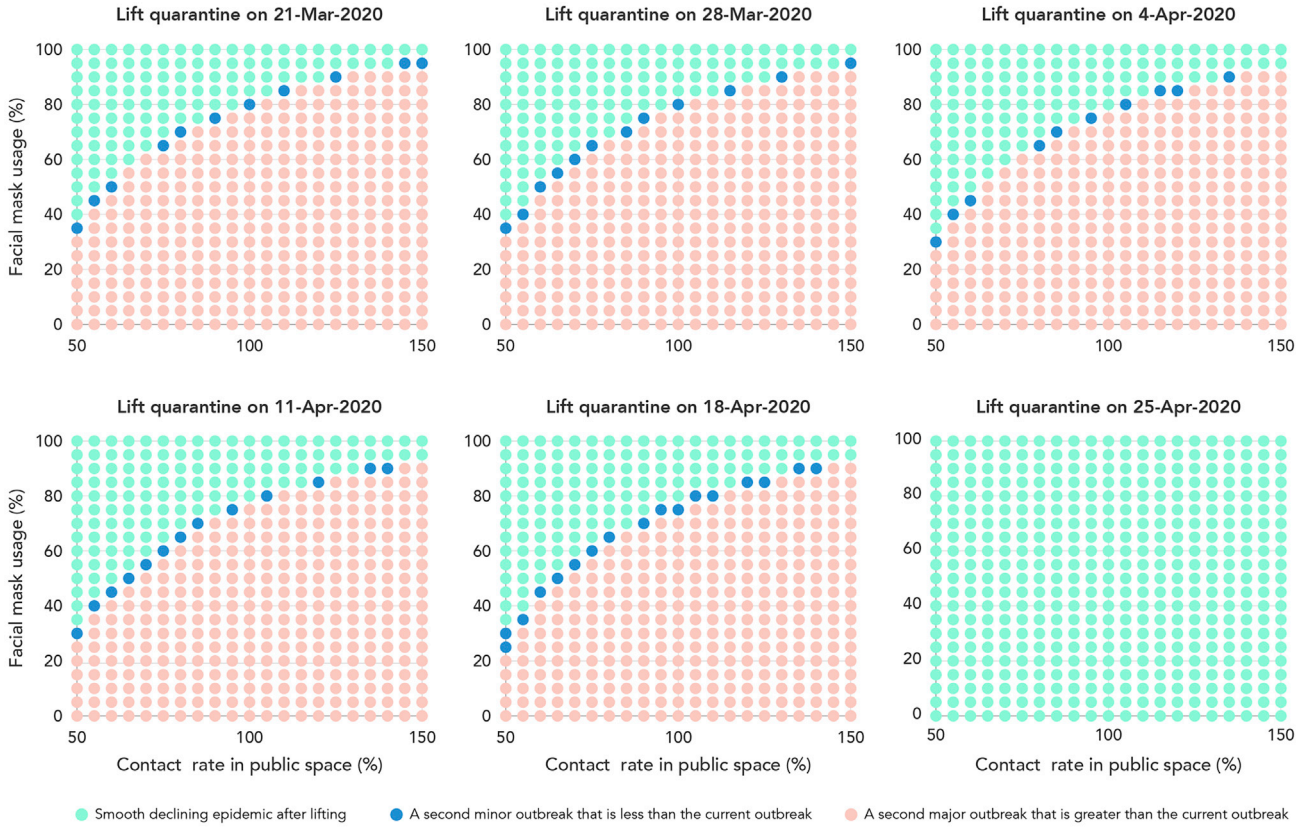

Figure 1 Impact of Various Combinations of Facial Mask Usage and Public Person-to-Person Contact Rates on COVID-19
Various quarantine lifting dates, including hypothetically waiting until all internal cases have resolved and continuing a travel ban, are presented. Green, smooth declining epidemic after lifting; blue, a second minor outbreak that is less than the current outbreak; red, a second major outbreak that is greater than the current outbreak.

We estimated that at the end of the epidemic, a total of 65,733 (45,722–99,015) individuals would be infected by the virus, among which 16,166 (11,238–24,603, 24.6%) would be infected through public contacts, 45,996 (31,892–69,565, 69.7%) through household contact, 3,571 (2,521–5,879, 5.5%) through hospital contacts (including 778 [553–1,154] non-COVID-19 patients and 2,786 [1,969–4,791] medical staff members). The estimated number of infected individuals was higher than the officially reported number of confirmed cases because the model estimate also accounted for those with undocumented infections who had recovered before being diagnosed. A total of 2,821 (1,634–6,361) would die of COVID-19 related pneumonia in Wuhan.

We examined six proposed dates for quarantine lifting in our model. When public contact recovered to 100% the pre-quarantine level and facial mask usage was high at 95%, the epidemic would follow a smooth decline to elimination regardless of which day quarantine was lifted (Figure S4A). In contrast, when facial mask usage was reduced to 50%, any quarantine lifting date before April 25 would result in a second major outbreak (Figure S4B). Similarly, when facial mask usage was sustained at 80%, and the public contact rate was recovered to 100% of the pre-quarantine level, an earlier lifting on March 21 may lead to a second minor outbreak (Figure S4C). But, if the public contact rate was 50% more than the pre-quarantine level, a second major outbreak would occur with all quarantine lifting dates except April 25 (Figure S4D).

Combinations of high facial mask usage and reduced public contacts may lead to a smooth decline of the epidemic on various quarantine lifting dates (Figure 1). For an early lifting date (March 21), facial masks

needed to be sustained at a relatively high rate (≥85%) if public contacts were to recover to 100% of the pre-quarantine level. In contrast, lifting the quarantine on April 18 allowed public person-to-person contact to be adjusted back to the pre-quarantine level with a substantially lower level of facial mask usage (75%). However, a low facial mask usage (<50%) combined with increased public contact (>100%) would always lead to a significant second outbreak in most quarantine lifting scenarios. Lifting the quarantine on April 25 would ensure a smooth decline of the epidemic regardless of the combination of public contact rates and facial mask usage.

The quarantine has substantially altered the transmission pattern of the virus in Wuhan. While our model predicts that public transmission accounts for the majority of transmission prior to the quarantine, household transmission is the dominant route of transmission during quarantine, consistent with a previous study.[12] This is intuitively reasonable because the quarantine has significantly reduced the public contacts of the residents and increased their contacts with family members in a closed household environment. In cases where the epidemic is able to be contained without a second outbreak, the dominant route of transmission would switch back to public transmission after lifting the quarantine (Figure S5A). In cases where the epidemic results in a second major outbreak (Figure S5B), the second outbreak would be predominantly driven by household transmission. Our estimate that ~70% of all infected cases were due to household transmission is also in broad agreement with a recent report from the World Health Organization (78%–85%[10]). Further, we estimated 5% hospital-acquired infections in patients (1.1%) and medical staff (3.8%), which is consistent with a recent clinical report.[11]

Our study suggests that maintaining a reduction in the contact rate below the pre-quarantine levels is an important ongoing intervention until a vaccine is available. If residents return to the same level of activities as pre-quarantine, a very high level of facial mask usage rate of 85% (or other powerful interventions) will be required. Any additional public interactions, such as the influx of the five million residents returning to Wuhan, may trigger a second outbreak. Governments will need to determine how to minimize public contacts from workplaces, venues for essential daily commodities, residents, leisure, entertainment venues, and public events although limiting or modifying the latter may be important. Intercity travel should be minimized, and the return of the residents may need to be staged. The full restoration of intercity public transportation may take months, and careful planning of the size of population inflow is necessary.

Maintaining ongoing high facial mask usage among the population may be challenging for a number of reasons. First, supplying this number of masks to a population the size of Wuhan let alone other cities in China and the world will be very challenging and may critically limit their availability for health care workers at high risk. Re-using disposable masks may limit their efficacy.

China is in a unique position to determine if the quarantine measures that successfully contained COVID-19 in Wuhan can be eased while allowing economic activity to resume. We recommend population facial mask usage only when provision of masks for high-risk health care workers is secured. We acknowledge the substantial pragmatic issues that exist in rolling out and maintaining such a program worldwide due to inadequate supply of facial masks. But notwithstanding this limitation, this information may be of use to other cities, in other parts of Asia, Europe, and the United States that are currently experiencing rising epidemics of COVID-19. Limiting transmission while maintaining economic activity until a vaccine is available would be the ultimate goal.

Declaration of Interests

The authors declare no competing interests.

Supplemental Information

Supplemental Information can be found online at https://doi.org/10.1016/j.xinn.2020.04.006.

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Author Contributions

L.Z. and M.S. conceived the study. L.Z. and C.K.F. contributed to the collection and interpretation of data. L.Z., M.S., and J.W. did the data cleaning and statistical analysis. L.Z. conducted model building with assistance from M.S. L.Z., M.S., X.M., and S.S. drafted the manuscript. All authors contributed to critical revision of the manuscript for important intellectual content. W.G., J.W., Y.T., Z.Z., R.Z., J.T.F.L., W.L., F.L., K.Y., Y.W., G.Z., and C.K.F. provided epidemiological, technical, or material support. L.Z. and M.S. had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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