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Epidemiology reveals mask wearing by the public is crucial for COVID-19 control

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ABSTRACT

Objective: The pandemic 2019 Coronavirus disease (COVID-19) is the greatest concern globally. Here we analyzed the epidemiological features of China, South Korea, Italy and Spain to find out the relationship of major public health events and epidemiological curves.

Study design: In this study we described and analyzed the epidemiological characteristics of COVID-19 in and outside China. We used GAM to generate the epidemiological curves and simulated infection curves with reported incubation period.

Results: The epidemiological curves derived from the GAM suggested that the infection curve can reflect the public health measurements sensitively. Under the massive actions token in China, the infection curve flattened at 23rd of January. While surprisingly, even before Wuhan lockdown and first level response of public emergency in Guangdong and Shanghai, those infection curve came to the reflection point both at 21st of January, which indicated the mask wearing by the public before 21st Jan were the key measure to cut off the transmission. In the countries outside China, infection curves also changed in response to measures, but its rate of decline was much smaller than the curve of China's.

Conclusion: The present analysis comparing the epidemiological curves in China, South Korea, Italy and Spain supports the importance of mask wearing by the public. Analysis of the infection curve helped to clarify the impact of important public health events, evaluate the efficiencies of prevention measures, and showed wearing masks in public resulted in significantly reduced daily infected cases.

1. Introduction

The Coronavirus disease 2019 (COVID-19) pandemic is of significant global concern. To date, COVID-19 has spread to 211 countries worldwide, there are 1279722 confirmed cases and 72616 confirmed deaths as of April 8, 2020 [1]. The infection is difficult to control with extremely high transmission rates [2,3]. The transmission routes for COVID-19 are suggested to be mainly by droplet and contact transmissions [3]. Although only a limited number of patients were assessed, the saliva samples from patients with COVID-19 have been demonstrated to carry high-titers of the virus. Yuen and colleagues revealed a median viral load of 5.2 $\log_{10}$ copies per ml in posterior oropharyngeal saliva samples from COVID-19 patients [4,5]. The significantly higher viral titer in saliva during COVID-19 increases the risk for viral transmission during routine talking and dining. Limiting dispersion of saliva and ensuring healthy individuals avoid respiratory contact with saliva droplets of infected patients maybe especially important for COVID-19 prevention and control. It is reported that wearing masks [6] and practicing hand hygiene methods disrupts transmission routes. At the beginning of the outbreak, masks are only recommended for healthy individuals who care for suspected COVID-19 patients [7]. However, the emergence of asymptomatic carriers and individuals who do not recognize abnormal body temperatures or mild respiratory symptoms can promote transmission of COVID-19 in the absence of mask wearing. Due to all kinds of reasons including medical resource shortage and differences in social cultures and behaviors, people were still arguing about whether masks should be worn by the public.

In this paper, we analyzed the epidemiology patterns in and outside China, found out that different strategies of prevention and control and human behaviors in different countries can largely affect the outcome of COVID-19's epidemic, we proposed that everyone wearing masks when encountering with others in public is crucial in COVID-19 epidemic control.

2. Methods

Study design: we described and analyzed the epidemiological characteristics of COVID-19 cases in China from the first case shown to 25th

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of February, in South Korea, Italy and Spain from the first case shown to 5th of April. In this epidemiological data analysis, the following assumptions were made in the model: the interval from symptom onset to report was about 8 days, and the median of the incubation period was 5.2 days (95% confidence interval, CI: 4.1 to 7.0) as reported [3]. We simulated the curve of daily infected cases by predicting from the curve the date of onset as 5.2 days (95% CI as shown shaded: 4.1–7.0 days). We simulated the curve of daily infected cases by predicting the curve for date of report as 13.2 days (95% CI as shown shaded: 12.1–15.0 days). When modelling the curve, daily reported cases data of China from 12th to 13th February were excluded due to clinical diagnosis resulting data surge.

Patient and Public Involvement statement: This manuscript does not contain personal and/or medical information about an identifiable living individual.

Data source: Daily available epidemiological data were collected from publicly sources (news articles, press releases and published reports from public health agencies).

Data analysis and visualization: We organized the publicly available daily data from various countries into a data.frame, used R (version 3.6.3) and R package ggplot2 [8] to visualized the daily cases to a bar plot, and used the generalized additive model (GAM) [9] to model the daily infection curves and daily reported curves.

3. Results

The present analysis comparing the epidemiological curves of China, South Korea, Italy and Spain supports the importance of mask wearing by the public. According to China's epidemiological characteristics as shown in Fig. 1A, in the evening of January 20, 2020, when it was announced that COVID-19 could be transmitted from person-to-person, majority of the population started to wear masks whilst in public on 21st January. On 23rd January, the epidemic prevention and control headquarters of Wuhan city announced suspension of the city's public transport, and temporarily closed the airport and railway station. These measures officially put Wuhan, the epicenter of the outbreak, into lockdown. On 24th January, the first day of the Chinese New Year holiday, the traffic outside Wuhan area peaked because of the annual reunion of families. From 23rd to 25th of January, thirty provinces, autonomous regions and municipalities across the country declared the first-level response to major public health emergencies [2,10]. Under the first-level response situation, all possible measures are undertaken to contain the epidemic, and these include setting up designated medical institutions and fever clinics, quarantining infected and suspected cases and compulsorily mask wearing by the public. Additionally, maximum restriction on movement and public gatherings is imposed even during the Spring Festival. Although significant measures were taken, the epidemiological curves of daily reported cases for China [2] still increased exponentially and peaked on 8th of February. At that time, the public were greatly concerned by the increasing number of daily confirmed cases being reported.

The curve for date of symptom onset peaked on 28th January (Fig. 1B), which suggests that the peak date of daily infection was around 23rd January (from 22nd to 25th January) with subsequent reduction of infected cases. This means that even though the number of reported cases continued to rise, the key event implemented before 22nd January impacted on the epidemic and caused a reduction in the number of infections. Therefore, as illustrated, mandatory mask wearing by the public likely played an important role in stopping the spread of the disease. In addition to citywide lockdown and wearing of mask by the public, medical resources were reinforced to Wuhan. The combination of these measures collectively contained the epidemic and dramatically reduced the number of infected cases.

Further, we analyzed the epidemiological curves of Guangdong (Fig. 1C) and Shanghai (Fig. 1D), two important and highly populated areas of China outside the epicenter. We found interesting results showing overlap between the date of mask wearing by the public with the peak date of daily infected cases, even before 23rd and 24th January when the first-level response to the public health emergency took place in Guangdong and Shanghai respectively. It should also be noted that even during the first-level response of public health emergency was enforced

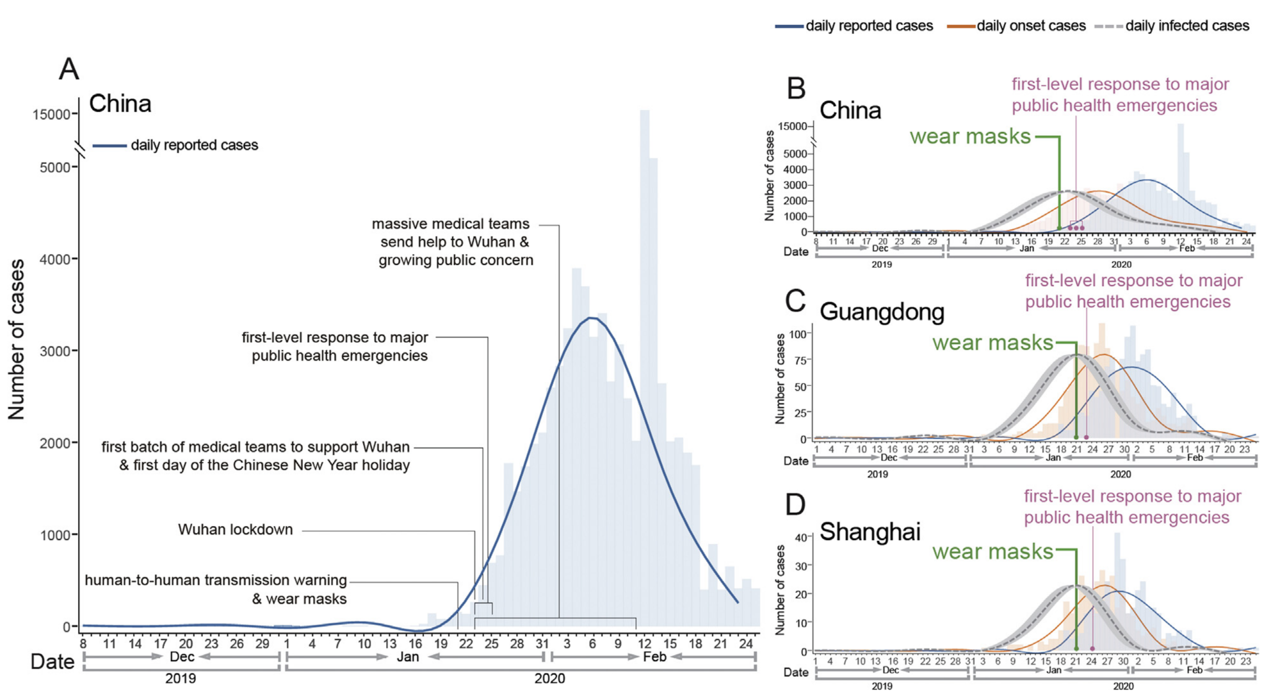

Fig. 1. Epidemiological curves for China (A, B), Guangdong (C) and Shanghai (D). A: daily reported cases of COVID-19 in China from Dec 8, 2019 to Feb 24, 2020, bar plot shows the exact case numbers and the curve is fitted from data. Key events labelled. B: daily reported case (blue), daily onset of cases (orange), and simulated daily infected cases (dotted line), shadow area indicated the confidence interval; C: epidemiological curve for Guangdong; D: epidemiological curve for Shanghai.

in Guangdong and Shanghai, the local public transport including tubes and buses were still functioning normally and public utilities such as shopping center and restaurant were still open for a couple of days, but with a significant drop in human traffic. Most importantly, the infection cases analyzed above suggests that majority of the population in China had already started to wear masks in public on or even before 21st January, and this may have significantly reduced the number of infected people.

In South Korea, the situation was more complicated. The epidemiological curve (Fig. 2A) peaked at 3rd of March and the daily number of reported cases started to fall thereafter. In late January, when the first COVID-19 case was diagnosed in South Korea, the government raised the alert level from yellow to orange [11], and because the public were more alert to the COVID-19 epidemic due to the situation faced in China, the sales of masks increased by 373 times compared to the same time last year. The simulated daily infected cases increased exponentially from the 6th to 18th of February, which overlaps with the dates of a confirmed patient's activities who is from a religious group. This overlap also verified the reliability of our simulating model accordingly. The epidemic in South Korea was predominantly confined to spread within religious groups [11] and not to the wider community, and this maybe because of the general practice of mask wearing by the general public in South Korea. The strong control of religious groups by the government of South Korea resulted in a significant decrease in the number of daily infected cases. Concurrently, on 22nd February, the government also instructed individuals in the epidemic area to wear masks whilst in public in order to reduce transmission of the virus, and 10 days later, the number of daily reported cases declined.

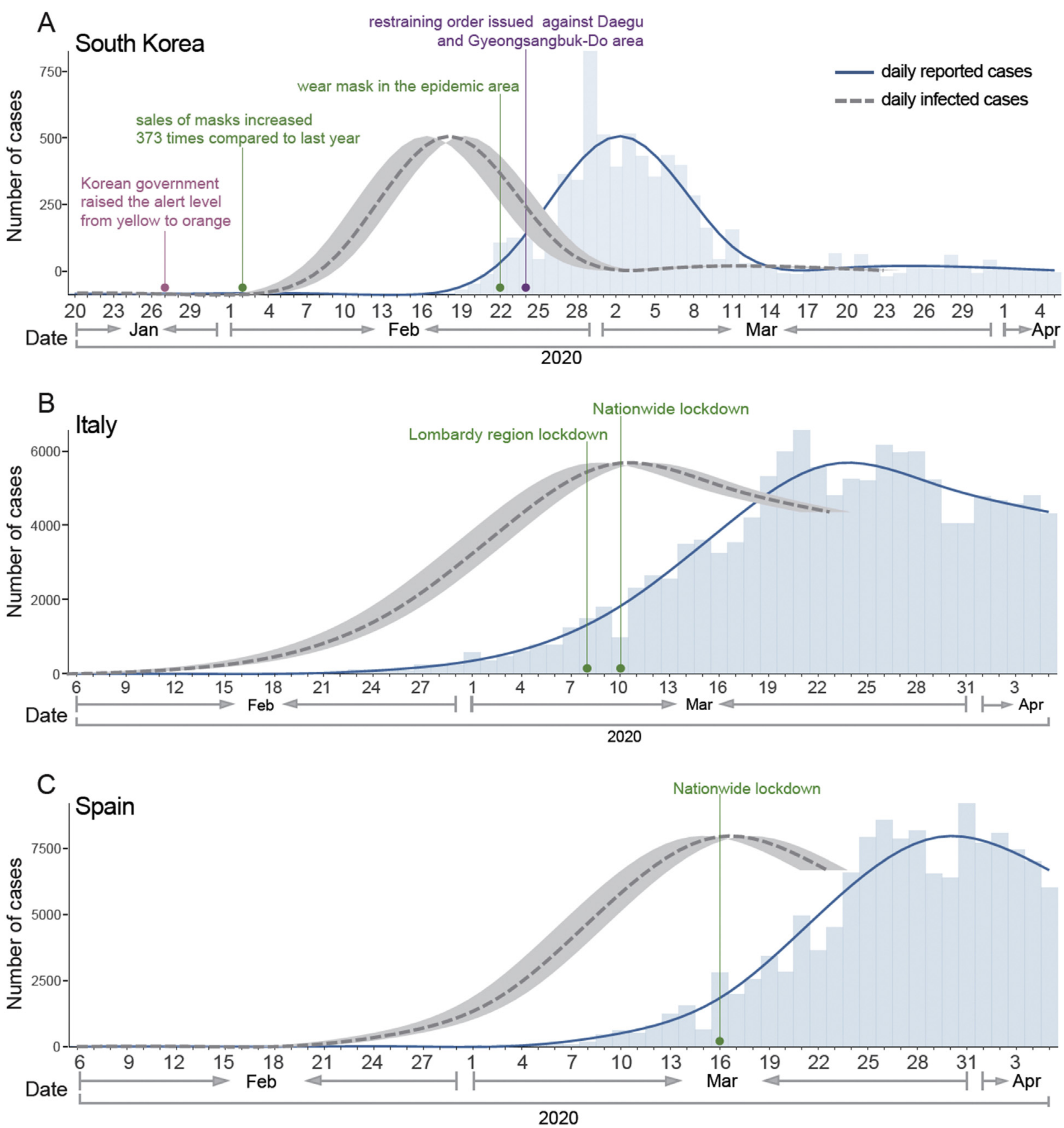

Fig. 2. Epidemiological curves for South Korea (A), Italy (B) and Spain (C). Daily reported case (blue), and simulated daily infected cases (dotted line), shadow area indicated the confidence interval, key events labelled.

Meanwhile, in Italy, the lockdown in Lombardy region was announced on 8th March, with a subsequent nationwide lockdown declared on 10th March. Although the numbers of daily reported cases were still rising exponentially, as shown in Fig. 2B, the daily infected cases in Italy has reached an inflection point, which also reflects the reliability of the stimulation model. The results suggest the transmission was partially disrupted due to the lockdown. Although the daily number of infected cases is decreasing, the thick tail of the curve implies that there remain massive new infected cases within the epidemic area. A similar situation has happened in Spain (Fig. 2C), the latest data shown that the daily reported case curved at 31st of March, which was exactly the date we predicted according to our model. While due to the shortage of medical resources, non-mandatory advice on wearing of masks and the people are not adapted to wearing masks, the epidemic cannot be satisfactorily contained in these two countries.

4. Discussion

In this study, we demonstrated that, by modelling the epidemiological curves using GAM, it is more important in analyzing the infection curve pattern then daily reported cases. We found that the infection curve showed different trends under different public health policies which also reflected the reliability of the model.

The number of daily reported cases is of public concern, while the infection curve is crucial from a public health perspective. The infection curve reflects whether current public health efforts are effective in cutting off transmission of the virus and reducing the number of newly infected cases. Analysis of the infection curve helped us to identify the impact of important public health events and showed wearing of mask by the public resulted in reduced number of daily infected cases, and the curve of daily infected cases came to the inflection point rapidly. Meanwhile, the infection curve helped to evaluate the effectiveness of preventive measures. If the curve of reported cases comes to the reflection point in 8–14 days since the undertaking of measures, this means the epidemic is contained effectively. Also, mask wearing by the public will be an important policy during the lifting of lockdown, as continued wearing masks can help prevent the epidemic from spreading again. Due to the detection capabilities varies at different stages of the epidemic, the model can be optimized with the help of epidemiological investigations to be more accurate.

As illustrated above, wearing masks in public is crucial for COVID-19 control, but the shortage of medical or surgical grade masks is a key problem in setting up mask wearing guidelines [12]. Chinese experience shows that during an epidemic, the N95/FFP2 masks should be saved for healthcare workers whilst disposable medical masks should be worn by the general public when going to crowded public places, seeking medical treatment or taking public transport, and there are proper ways for masks to be reused if necessary. However, masks with breathing valves are not recommended in the epidemic since the one-way vented breathing valve spreads saliva to the air and cannot prevent the dispersion of virus containing saliva. In addition, several studies [13,14] have described significant efficacy of home-made face masks in protection from infection. Using many daily available materials like 100% cotton T-shirts, scarfs, tea towels and pillowcases, home-made face masks achieve a mean viral particle filtration efficiency of >50% [14]. Until now, more and more health care authorities recommended wearing cloth face coverings in public settings where other social distancing measures are difficult to maintain and detailed instructions have been introduced for home-made masks [15].

In this article, by reanalyzing the epidemiological curves and simulated daily infected cases, we provide evidence that wearing masks in the public is the most crucial measure for public health control of COVID-19, where it may significantly change the infection curve to reach the plateau and cut off routes of transmission to save tens of thousands of lives.

Data availability

The data used in this article were epidemiological data from publicly available data sources (news articles, press releases and published reports from public health agencies). All the epidemiological information that we used is documented in the main text, the extended data and supplementary tables.

Contributorship

Prof. Hongwei Zhou and Dr. Dingqiang Chen conceived the research, Prof. Hongwei Zhou designed the study, reviewed drafts of the paper, and approved the final draft. Nianyi Zeng prepared figures and authored drafts of the paper. Zewen Li analyzed the data, prepared figure. Dr. Sherrianne Ng reviewed drafts of the paper.

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Declaration of competing interests

We have no interests to declare.

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