Sufficient COVID-19 quarantine and testing on international travelers from China

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Abstract

Removal of zero-COVID restrictions in China led to a surge in COVID-19 cases. In response, countries imposed restrictions on Chinese travelers. However, border policies may not provide substantial benefits, and their assessment depends on accurate prevalence data. Therefore, we analyzed quarantine and testing policies that would be sufficient to prevent additional in-country transmission for February 13–19, 2023, based on World Health Organization (WHO) and individual self-reported infection rates to estimate prevalence. We show that analyses based on individual self-reported prevalence data entailed more stringent border restrictions, compared to analyses based on WHO-published prevalence statistics. For in-country infection to not be greater than in complete border closure, no travel restrictions were required for Singapore. A 1-day quarantine, 2-day quarantine, and a 3-day quarantine were indicated for England, Germany, and Scotland respectively. To prevent an increase in the number of within-country infections due to travel, a 10-day quarantine, 11-day quarantine, and 13-day quarantine were required for Italy, Japan, and France, respectively, while South Korea required a complete border shutdown. Our results demonstrated the necessity for accurate and timely reporting of pandemic statistics to invoke policies regarding border protection based on a principle of preventing additional in-country infection. Through the minimum-quarantine analysis, countries can use science to determine policy, minimize international friction, and improve the cost-efficiency of interventions.

Introduction

Early in the pandemic, the government of China imposed strict “zero-COVID” lockdown measures that successfully prevented the spread of the SARS-CoV-2 virus throughout its population [1]. However, this policy required substantial socioeconomic tradeoffs. In response to widespread protest in December 2022, the Chinese government suddenly lifted its restrictions [2,3]. Fearing that travelers from China would spur yet another wave of COVID, other countries imposed restrictions on Chinese travelers, even though community transmission was ubiquitous.

At the start of the pandemic, border controls instituted around the world effectively delayed viral spread [4,5]. However, with near-worldwide ongoing community transmission by 2022, it was no longer clear that international border controls substantially decreased infection within countries [6,7]. Here we compile statistics regarding population demographics, COVID rates, and international travel rates (**Appendix**). We extract demographic data, travel data, COVID vaccination uptake, and infection prevalences from national and World Health Organization (WHO) databases and from self-reported infection rates of Chinese citizens [8]. Based on these data, we estimate quarantine durations for each destination country that were sufficient to prevent an increase in infections when compared to a complete border closure [6].

Methods

Population sizes were based on country-specific census data. Travel data between China and other countries were based on travel during pre-pandemic times scaled to predictions of total travel to and from China in 2023, or from late 2022 travel (**Appendix**). COVID prevalence data for February 13–19, 2023, were derived from weekly infection rates provided by the WHO

COVID Dashboard. For China, the prevalence of COVID was also alternatively estimated based on the self-reported infection rate of Chinese citizens from February 2–4, 2023 [8].

For the vaccination status to be considered efficacious, we collected the cumulative number of individuals vaccinated between mid-2021 and February 2023 [9]. Infection-derived immunity was similarly assigned to be equal to cumulative infections reported by the WHO COVID Dashboard between mid-2021 and February 2023 [10]. These data were supplied to a model that computed the destination country quarantine and testing approach sufficient to match or better the in-country transmission expected from complete border closure. To determine the suggested quarantine, the number of imminent infections that would occur in the destination country at each duration of quarantine under each type of testing was calculated, then compared to the number of infections in the destination country with a complete travel ban. The quarantine duration that equalized these rates of infection was set as the minimum sufficient quarantine.

Results

The minimum sufficient quarantine was relatively constant across the different testing methods in each nation (**Appendix, Tables 1–2**). Therefore, we here focus on trends in the sufficient quarantines with RT-PCR testing, which minimized quarantine duration. Using WHO data, to prevent an increase in infection in South Korea, a quarantine longer than 14 days against Chinese travelers was required. For Italy, Japan, and France to prevent an increase in in-country infection due to travel, a minimum sufficient quarantine duration of 9 days, 11 days, and 12 days was required, respectively. No quarantine was necessary to prevent an increase in infections when compared to complete border closure for Scotland, England, Germany, and Singapore. Alternatively, when using self-reported infection rates from Chinese citizens, a quarantine

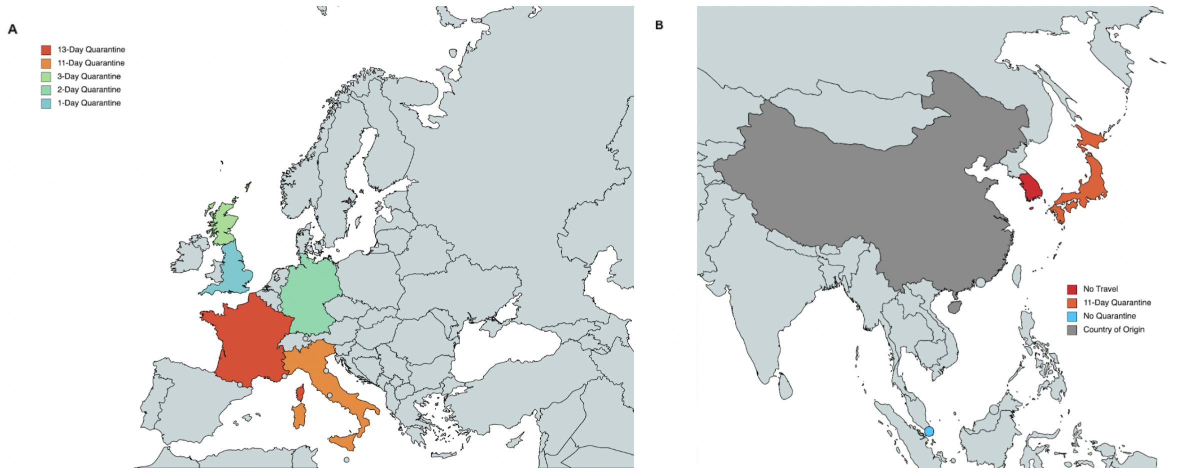

Figure 1: Sufficient minimum durations of quarantines with RT-PCR testing to ensure that in-country transmission will not increase due to travel compared to a complete travel ban, based on Chinese self-reported infection rates [8], are mapped to (**A**) Scotland (Green, 3-Day Quarantine), England (Blue, 1-Day Quarantine), France (Reddish Orange, 13-Day Quarantine), Germany (Aquamarine, 2-Day Quarantine), and Italy (Orange, 10-Day Quarantine), and to (**B**) Singapore (Blue, No Quarantine), Japan (Reddish Orange, 11-Day Quarantine), and South Korea (Red, No Travel).

longer than 14 days against Chinese travelers was still required to prevent an increase in infection in South Korea, while a minimum sufficient quarantine duration of 10 days, 11 days, and 13 days was required for Italy, Japan, and France, respectively. A minimum sufficient quarantine of 1 day, 2 days, and 3 days was required for England, Germany, and Scotland, respectively, while no quarantine was required for Singapore (**Figure 1**).

Sufficient quarantines for Chinese travelers in each destination country varied significantly depending on the source of the prevalence data. Quarantines for countries with fewer daily inbound travelers from China tended to have shorter minimum quarantine durations to match complete border closure. For example, Scotland, with 226 travelers daily, had a suggested quarantine of 3 days using RT-PCR testing and self-reported survey data for prevalence in China. Using the WHO data, alternatively, suggested no quarantine (**Appendix, Figure 3A–B**). With fewer inbound travelers, a less stringent quarantine was required to prevent an increase in imminent infections. Countries with higher immunity, whether infection-derived or vaccine-derived, tended to have more strict sufficient quarantines. France and South Korea, for instance, required quarantines of 13 days and >14 days, respectively, using survey data, and quarantines of 12 days and >14 days, respectively, using WHO data (**Appendix, Figure 2E–F**, **Figure 3E–F**). In countries with high immunity to COVID-19, inbound tourists from China with infection add a high number of imminent infections, more than the number of in-country infections under complete border closure. For the rest of the countries in the analysis, these trends remained consistent (**Appendix, Figs. 2–3**). Other factors, such as disease prevalence and population size, also affected the sufficient quarantine, though the effects of these factors were not as pronounced as the trends seen with changing immunity and prevalence.

Discussion and Conclusions

Our result demonstrates the importance of documenting and publishing accurate and timely information regarding COVID-19 rates in different countries. The official WHO case numbers we used in the analysis [11], supplied by Chinese officials, may be under-representative of the actual infection rate in China [12]. Officially published statistics from China through the World Health Organization [11] reported a lower prevalence than was estimated based on self-reported data [8]. Accurate prevalence estimates are essential to policy decision-making, as the survey-based estimate led to a substantially greater number of additional infections due to travel, and required a longer quarantine to prevent the rate of in-country infections from increasing.

Our results illustrate how many factors can affect the transmission prevalence for traveling. As a pandemic progresses, sufficient quarantines vary as the prevalence of disease, vaccine efficacy, and travel rates change. Countries can make beneficial decisions only when they consider up-to-date data regarding a wide range of factors before imposing restrictions. Instead of responding to domestic or international political pressures or emulating other nations that have distinct and incomparable circumstances, governmental, non-governmental, and commercial entities can utilize these analysis tools and country-specific and time-sensitive data to assist their decision-making process.

Policies may not be determined to ensure that travel does not increase in-country infection. A comparison of the imminent infection with different border control strategies for each nation indicates that with ongoing community transmission, there is little difference in national infection rates across quarantine and testing strategies—often within margins of difference of less than one infection per day. The small scale of these differences emphasizes the importance of weighing the practicality of the quarantine strategy. If there is no tangible difference between enforcing a travel restriction or not, it may be in a country's best interest to refrain from border controls and spend public health resources in more effective ways. Rather than enforcing a quarantine, there may be better, more productive manners to allocate these resources, such as for case-finding and isolation of positive cases.

Numbers of inbound and outbound travelers, as well as the length of stay in each destination country, are only estimates instead of real-time data. Since the travel numbers were computed by scaling data from the same country in years before the pandemic, the lengths of stays and numbers of travelers may not be representative of traveling habits after recovery, which could affect sufficient quarantine estimates. Access to more accurate data for recent travel and vaccination would yield more realistic results and more accurately predict the rate of viral transfer through international travel. This minimum sufficient quarantine approach should be applied in the evaluation of future policy decision-making as nations weigh the public health effects of quarantine with the economic and social effects.

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Appendix

A) Raw Data and Analysis Documents

All raw data, documentation, sourcing, and analysis files can be accessed via Zenodo: https://zenodo.org/record/8194600

B) Model Description

The optimal quarantine model [6] determines quarantine duration for which the number of imminent infections in the destination country due to travel is fewer the number of imminent infections in the destination country under a policy of border closure. To do this, the model incorporates the demographics of each nation, travel statistics between the origin and destination country, the immunity rate due to vaccination and infection recovery for each nation, and the prevalence of COVID in each country to model the number of potential new infections in the destination country.

The number of imminent infections due to travel is categorized into six parts: (1) from non-traveling susceptible residents of the destination country, (2) from susceptible residents of the origin country residing in the destination country, (3) from infectious residents of the destination country traveling to the origin (and need to be removed from the total imminent infections of the destination), (4) from residents of the destination country who became infected in the origin country, underwent quarantine, and re-entered the destination country, (5) from residents of the origin country who became infected in the origin country, underwent quarantine, and entered the destination country, and (6) from infectious residents of the origin country who became infected in the destination country and are returning to the origin country (and need to be removed from the total imminent infections of the destination). These factors are considered when calculating the imminent infection due to travel for a quarantine lasting from 0 days to 14 days. The first duration for which the imminent infections due to travel is lower than the number of imminent infections with no travel is determined to be the minimum sufficient quarantine, as travel with such quarantine restrictions would be, from a quantitative epidemiological perspective, equivalent to a policy of complete border closure, while still allowing for travel.

C) Complete Results

For each destination country paired with China as the origin, suggested quarantines to prevent an increase in infections were determined. For each country, quarantines were determined for policies of no testing, RT-PCR vs isolation test, rapid antigen quarantine exit vs isolation test, and rapid antigen quarantine entry and exit vs isolation tests. Minimum sufficient days of quarantine using Chinese prevalence estimates from official WHO Data and a self-reported survey of Chinese citizens were compared (**Table 1–2**).

Table 1: Minimum sufficient days of quarantine based on WHO Data

Country	No Test	RT-PCR	Rapid antigen exit	Rapid antigen entry and exit
Scotland	1	0	0	0
England	0	0	0	0
France	12	12	12	12
Germany	0	0	0	0
Italy	9	9	9	9
Singapore	0	0	0	0
Japan	11	11	11	11
South Korea	>14	>14	>14	>14

Table 2: Minimum sufficient days of quarantine based on self-reported survey

Country	No Test	RT-PCR	Rapid antigen exit	Rapid antigen entry and exit
Scotland	7	3	5	3
England	3	1	1	1
France	13	13	13	13
Germany	3	2	2	1
Italy	11	10	11	10
Singapore	2	0	0	0
Japan	11	11	11	11
South Korea	>14	>14	>14	>14

D) Modeling Imminent Infections Through Travel

For each destination country paired with China as the origin, the suggested quarantines were determined by comparing the number of imminent infections in the country with a specific duration of quarantine, and comparing it to the number of imminent infections with a complete travel ban. For each country, imminent infections were determined for policies of no testing, RT-PCR vs isolation test, rapid antigen quarantine exit vs isolation test, and rapid antigen quarantine entry and exit vs isolation tests. The duration for which the number of imminent infections because of travel is equal to the number of imminent infections with no travel is considered the sufficient quarantine. Minimum sufficient days of quarantine using Chinese prevalence estimates from official WHO Data and a self-reported survey of Chinese citizens were compared (**Figures 2–3**).

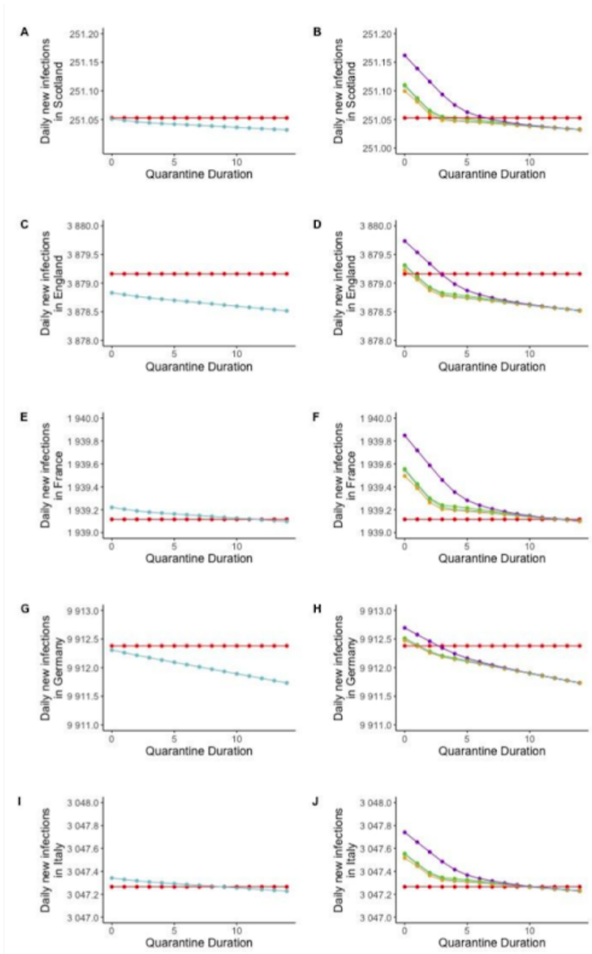

Figure 2: Recommended travel quarantines for Scotland based on Chinese prevalence data from (**A**) World Health Organization data from China and (**B**) self-reported infection rates from Chinese citizens; for England based on (**C**) WHO data and (**D**) self-reported rates, for France based on (**E**) WHO data and (**F**) self-reported rates, for Germany based on (**G**) WHO data and (**H**) self-reported rates, and for Italy based on (**I**) WHO data and (**J**) self-reported rates. Differences in daily new infections among travel restrictions are negligible based on (**A**, **C**, **E**, **G**, and **I**) World Health Organization data from China, but are more substantial based on the self-reported infection rates (**B**, **D**, **F**, **H**, and **J**), where policies of no testing (purple), RT-PCR vs isolation test (blue) a rapid antigen quarantine exit vs isolation test (green), a rapid antigen quarantine entry and exit vs isolation test (yellow), and a complete travel ban (red).

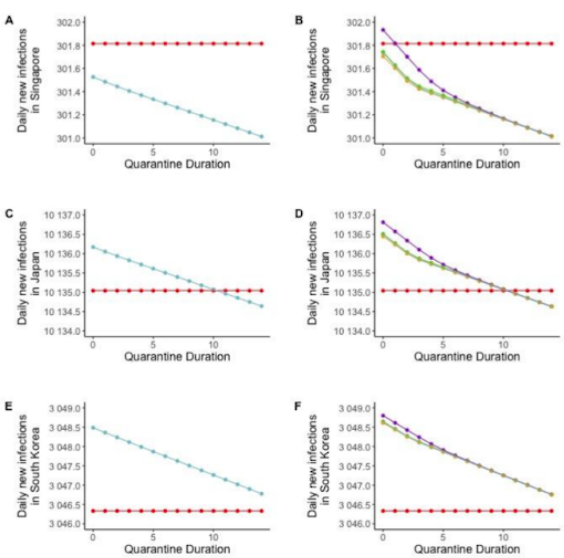

Figure 3: Recommended travel quarantines for Singapore based on Chinese prevalence data from (**A**) World Health Organization data from China and (**B**) self-reported infection rates from Chinese citizens; for Japan based on (**C**) WHO data and (**D**) self-reported rates, and for South Korea based on (**E**) WHO data and (**F**) self-reported rates. Differences in daily new infections among travel restrictions are negligible based on (**A**, **C**, **E**) World Health Organization data from China, but are more substantial based on the self-reported infection rates (**B**, **D**, **F**), where policies of no testing (purple), RT-PCR vs isolation test (blue) a rapid antigen quarantine exit vs isolation test (green), a rapid antigen quarantine entry and exit vs isolation test (yellow), and a complete travel ban (red).