Sufficient COVID-19 quarantine and testing on international travelers to forestall cross-border transmission after China's removal of the Zero-COVID policy in early 2023

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Abstract

Background

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 imposed may not have been informed by accurate data and may not have provided substantial benefits.

Methods

We analyzed quarantines sufficient to prevent additional in-country transmission for February 13–19, 2023 based on World Health Organization (WHO) and self-reported infection rates to estimate prevalence.

Results

We have shown that self-reported prevalence data indicated more stringent border restrictions compared to WHO-published prevalence statistics. No travel restrictions were required for Singapore, South Korea, and Japan so that infections would not be greater than with complete border closure. However, a 1-day, 2-day, and 3-day quarantine were indicated for England, Germany, and Scotland respectively. A 10-day, 13-day, and 14-day quarantine were required for Italy, France, and the Philippines, respectively, to prevent an increase in within-country infections due to travel. Vietnam and Thailand required a complete border shutdown.

Conclusions

Our results demonstrated the necessity for accurate and timely reporting of pandemic statistics to prevent an increase in viral spread. Through the minimum-quarantine analysis, countries can use science to determine policy, minimize international friction, and improve the cost-efficiency of interventions.

Keywords: Pandemics, Prevalence, Epidemiology, COVID-19, World Health Organization, Policy

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 populations. However, this policy required of the populace a substantial socioeconomic tradeoff. In response to widespread protests in December 2022, the Chinese government suddenly lifted its restrictions [1]. The largely unvaccinated Chinese population was subjected to a rapid increase in cases, with infection and death rates skyrocketing between December 2022 and January 2023 [2].

Fearing that travelers from China would spur yet another wave of COVID, other countries imposed restrictions on Chinese travelers to prevent an influx of the virus, even though ongoing community transmission was ubiquitous elsewhere. Border controls can help stop disease transfer by localizing the virus and preventing geographic spread [3]. However, with near-worldwide ongoing community transmission by 2022, it was no longer clear that international border controls substantially decreased infection within countries [4,5].

Here we compiled statistics regarding national demographics, COVID rates, and international travel rates (**Supplementary Materials**). We extracted population data, travel data, COVID vaccination uptake, and infection prevalences from national and World Health Organization (WHO) databases and compared them to COVID prevalence estimates based on self-reported infections of Chinese citizens [6]. We then estimated quarantine durations for each destination country that were sufficient to prevent an increase in infections compared to a complete border closure [4].

Methods and data collection

Population sizes were based on country-specific census data. Travel between China and other destinations was based on pre-pandemic data scaled to predictions of total travel to and from China in late 2022 or 2023 (**Supplementary Materials**). COVID prevalence for February 13–19, 2023 was extracted from WHO COVID Dashboard weekly infection rates [7]. The prevalence of COVID-19 in China was alternatively estimated from self-reported infections in Chinese citizens from February 2–4, 2023 [6].

We collected vaccination in each country only for individuals receiving it during the relevant preceding timespan between mid-2021 and February 2023 via government and census data (**Supplementary Materials**). We used 20.5 months for the durability of immunity conferred by Chinese-made inactivated viral vaccines, based on the Ad26.COV2.S inactivated adenovirus vaccination [8] and specified 21.5 months for natural infection [8]. Our established model [4] computed the destination country quarantine and testing approach sufficient to match or better the in-country transmission expected from complete border closure.

The number of imminent infections in the destination country at each duration of quarantine was calculated under each type of testing and was compared to the number of imminent infections with no travel. The quarantine duration where the imminent infections are equal was considered the minimum sufficient quarantine.

Results

The minimum sufficient quarantine remained relatively constant across the different testing methods (**Table 1**). As self-reported survey data based on rigorous RT-PCR testing is generally considered a more reliable metric for the prevalence of infection in China, we use it for the following analyses. Sufficient quarantines for Chinese travelers in each destination country varied significantly depending on the source of the prevalence data (**Figure 1**). Quarantines for countries with fewer daily inbound travelers from China tended to have shorter minimum durations to be sufficient to match complete border closure. For example, the suggested quarantine for Scotland—with 226 travelers daily—was only 3 days in duration using RT-PCR testing; no quarantine using the WHO data for prevalence in China (**Figure 1A–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 require stricter quarantines to be sufficient to match border closure. The sufficient quarantine for France was 13 days using self-reported estimates of prevalence in China, and 12 days using WHO data (**Figure 1E–F**). In countries with high immunity to COVID-19, inbound tourists from China with infection would add a high number of imminent infections—more infections than the number of in-country infections under complete border closure. Finally, in countries with higher prevalences, a less stringent quarantine was sufficient, as any incoming infections would have a marginal effect on the total number of infections. Due to the high prevalences of in-country infection at the time, no quarantine was necessary in Singapore, South Korea, and Japan to prevent an increase in imminent infections. However, to prevent an increase in in-country transmission, Vietnam and Thailand required a complete border shutdown (**Figure 1K–T**), due largely to their low prevalence of infection. For the rest of the countries in the analysis, these trends remained consistent.

Discussion

Here we have shown that the length of quarantine sufficient to enable travel without increasing within-country transmission differs significantly by country. The travel duration and the number of travelers influenced these changes: increased travel required more stringent restrictions to prevent excessive disease transfer. Increased vaccine coverages also enable nations to have more relaxed border controls, as individuals are well-protected from foreign infection. Other factors, such as disease prevalence and population size, also affected the sufficient quarantine.

Our result demonstrates the increasing importance of reporting accurate and timely information regarding COVID-19 rates in different countries. Official WHO case numbers, supplied by Chinese officials, may have been under-representative of the actual infection rate in China, and are far lower than alternative estimates of prevalence such as that derived from self-reported rates of infection [6]. When comparing results using WHO data and self-reported infection rates, an accurate and precise estimate of the prevalence of COVID-19 in China is essential to policy decision-making, as the survey-based estimate from Fu et al. [6] requires a substantially longer quarantine to prevent the rate of in-country infections from increasing. Based on surveyed Chinese travelers to Italy [9], the prevalence was 22.7%, which would lead to longer recommended quarantines.

At the time of this analysis, there were multiple variants circulating. If novel variants pose a greater threat of disease prevalence or severity, then the presence of multiple variants drives a more conservative border policy that can be computed [4]. Indeed, at the time of this event, there was a turnover of novel variants detected by surveillance. However, there were not specific variants that were considered to be of special concern, a perception that has not changed in response to further post-hoc analyses [10]. Therefore, sufficient quarantines would be unaffected by circulating variants at the time.

As a pandemic progresses, sufficient quarantines vary with disease prevalence, vaccine efficacy, and travel rates. Increasingly accurate, fine-scaled data for recent travel and vaccination would yield increasingly accurate and precise results that are representative of real-time travel patterns. Governmental, non-governmental, and commercial entities can utilize these tools as well as country-specific and time-sensitive data to assist their decision-making process. Well-advised decision-making would provide better public health benefits than responding to domestic or international political pressures or emulating other nations that have distinct circumstances concerning disease prevalence, natural or vaccine-mediated immunity, population size, demographics, and rates of travel.

Comparing the imminent infection under different border control strategies for each nation, there is little difference between the infection rates–often within margins of difference of less than one infection per day. The small scale of these differences emphasizes the substantial importance of weighing the practicality of the quarantine strategy. When there are marginal differences between enforcing a travel restriction or not, refrainment from border controls and devotion of resources to more productive ways of prevention—such as case-finding and isolation of positive cases—is advisable.

Conclusions

Our model indicated that after the removal of China's Zero-COVID policy, quantitatively, some quarantines were too strict, while others were as strict as necessary—emphasizing the generalizability of this methodology in unique pandemic situations, regardless of geographic location or pandemic stage. Compared to using the WHO data, using prevalence based on self-reported infection rates for prevalence in China yielded a stricter minimum sufficient quarantine duration. This modeling of disease transfer and border policies crucially informs policy decisions on healthcare-oriented quarantines. It demonstrates the importance for nations to publish accurate infection statistics to make informed policy decisions and argues for justification of quarantine and testing decision-making. A full assessment of the effects on in-country transmission should be performed in the evaluation of policies to be enacted as nations weigh the public health effects of quarantines with their economic and social effects.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Ethical Approval

This work does not reference data derived from any human or animal experimentation, and ethical approval was not required.

Author Contributions

Bojja Dinesh: Conceptualization, Formal analysis, Data curation, Writing – Original Draft, Visualization **Zuo Scott**: Conceptualization, Validation, Data curation, Writing – Original Draft **Townsend Jeffrey**: Conceptualization, Methodology, Writing – Review & Editing, Supervision

Supplementary

All raw data, documentation, sourcing, and analysis files can be accessed via Zenodo: https://zenodo.org/records/11077585. The analysis spreadsheet tools in the Zenodo files can be downloaded, as well as adjusted to analyze sufficient quarantines under different conditions.

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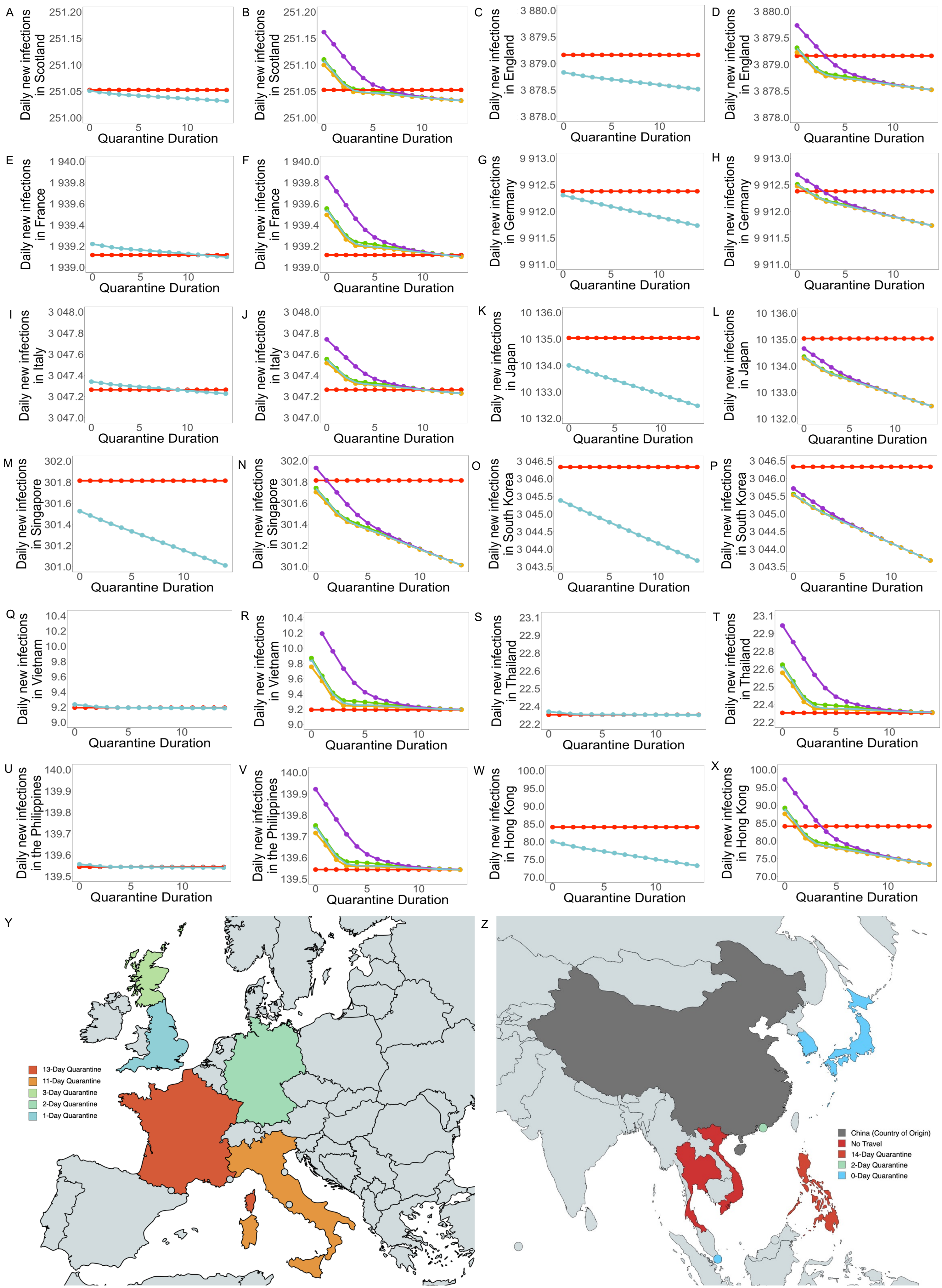
Table 1: Minimum sufficient days of quarantine based on WHO Data

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
Japan	0	0	0	0
Singapore	0	0	0	0
South Korea	0	0	0	0
Vietnam	9	5	7	3
Thailand	11	10	11	9
Philippines	8	4	6	3
Hong Kong	0	0	0	0

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
Japan	0	0	0	0
Singapore	2	0	0	0
South Korea	0	0	0	0
Vietnam	>14	>14	>14	14
Thailand	>14	>14	>14	>14
Philippines	>14	14	14	13
Hong Kong	4	2	2	2



A
Daily new infections in Scotland
Quarantine Duration
B
Daily new infections in Scotland
Quarantine Duration
C
Daily new infections in England
Quarantine Duration
D
Daily new infections in England
Quarantine Duration
E
Daily new infections in France
Quarantine Duration
F
Daily new infections in France
Quarantine Duration
G
Daily new infections in Germany
Quarantine Duration
H
Daily new infections in Germany
Quarantine Duration
I
Daily new infections in Italy
Quarantine Duration
J
Daily new infections in Italy
Quarantine Duration
K
Daily new infections in Japan
Quarantine Duration
L
Daily new infections in Japan
Quarantine Duration
M
Daily new infections in Singapore
Quarantine Duration
N
Daily new infections in Singapore
Quarantine Duration
O
Daily new infection in South Korea
Quarantine Duration
P
Daily new infection in South Korea
Quarantine Duration
Q
Daily new infections in Vietnam
Quarantine Duration
R
Daily new infections in Vietnam
Quarantine Duration
S
Daily new infection in Thailand
Quarantine Duration
T
Daily new infection in Thailand
Quarantine Duration
U
Daily new infections in the Philippines
Quarantine Duration
V
Daily new infections in the Philippines
Quarantine Duration
W
Daily new infections in Hong Kong
Quarantine Duration
X
Daily new infections in Hong Kong
Quarantine Duration
Y
13-Day Quarantine
11-Day Quarantine
3-Day Quarantine
2-Day Quarantine
1-Day Quarantine
Z
China (Country of Origin)
No Travel
14-Day Quarantine
2-Day Quarantine
0-Day Quarantine

Figure 1: Recommended travel quarantines for selected European/Asian countries.

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, for Italy based on (**I**) WHO data and (**J**) self-reported rates, for Japan based on (**K**) WHO data and (**L**) self-reported rates, for Singapore based on (**M**) WHO data and (**N**) self-reported rates, for South Korea based on (**O**) WHO data and (**P**) self-reported rates, for Vietnam based on (**Q**) WHO data and (**R**) self-reported rates, for Thailand based on (**S**) WHO data and (**T**) self-reported rates, for the Philippines based on (**U**) WHO data and (**V**) self-reported rates, and for Hong Kong based on (**W**) WHO data and (**X**) self-reported rates. Differences in daily new infections among travel restrictions are negligible based on (**A**, **C**, **E**, **G**, **I**, **K**, **M**, **O**, **Q**, **S**, **U**, and **W**) World Health Organization data from China, but are more substantial based on the self-reported infection rates (**B**, **D**, **F**, **H**, **J**, **L**, **N**, **P**, **R**, **T**, **V**, and **X**), 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). 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, are mapped to (**Y**) 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 (**Z**) Singapore (Blue, No Quarantine), Japan (Blue, No Quarantine), South Korea (Blue, No Quarantine), Vietnam (Red, No Travel), Thailand (Red, No Travel), the Philippines (Red, 14-Day Quarantine), and Hong Kong (Aquamarine, 2-Day Quarantine).

Figure 1 should be printed in color.

Supplemental

All raw data, documentation, sourcing, and analysis files can be accessed via Zenodo: https://zenodo.org/records/11077585. The analysis spreadsheet tools in the Zenodo files can be downloaded, as well as adjusted to analyze sufficient quarantines under different conditions.