Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Journal of Hospital Infection 106 (2020) 214–216

Available online at www.sciencedirect.com

Journal of Hospital Infection

journal homepage: www.elsevier.com/locate/jhin

Letter to the Editor

Comparing the impact of various interventions to control the spread of COVID-19 in twelve countries

Sir,

Since the start of the coronavirus disease 2019 (COVID-19) pandemic (caused by severe acute respiratory syndrome coronavirus 2, SARS-CoV-2), multiple countries have implemented various interventions to reduce the disease transmission into their populations [1]. These have included border closure, travel restrictions, and compulsory quarantine for foreigners entering these countries [2,3].

Additional interventions to reduce the local spread of the virus have included the wearing of surgical masks, mass-testing for SARS-CoV-2, travel restrictions, the banning of mass gatherings (of various sizes), the closure of mosques, bars and restaurants, schools and universities, curfews and stay-at-home orders, and the stoppage of all 'non-essential' work [2,3].

Here we examine the impact of these interventions across 12 countries with the most complete data available from either media or government websites: the USA, Canada, the UK, France, Germany, Italy, Denmark, India, Thailand, Malaysia, Singapore, and Australia.

For each country, the daily number of COVID-19 cases was extracted and plotted over time, along with the number of diagnostic tests or people tested for SARS-CoV-2 performed, the proportion of the population wearing masks (percentage masking), and the degree of travel restriction by examining the change in volume of people walking in their communities to provide a country-based mobility trend ('mobility index') [4–7]. Next, we indicated the dates where individual or combined intervention was implemented, and plotted the estimated daily effective reproductive number, R_t (an average number of secondary cases generated by a typical case at time t under the control measures in place), with 90% confidence intervals plotted on the same timeline (Figure 1) [8,9]. R_t is a useful measure to evaluate the effectiveness of public health interventions at a regular interval. In Italy and the UK (Figure 1), the R_t values have decreased to $\leq$1, from a previously higher value of $\sim$2, which may be attributed to the interventions that were implemented. While these two study populations became more mobilized after lockdown easing, R_t remained slightly smaller than 1 with improving testing capacity.

From each of the countries' plots, we can observe several trends: (i) the testing pattern follows the daily number of new COVID-19 cases, which is not unexpected — you will only identify more cases by testing; (ii) similarly, the percentage masking also follows the number of cases (or R_t) (Supplementary Figure S1), which may be a likely population response to the increasing numbers of cases, where sufficient masks are available; (iii) the mobility index and R_t are strongly correlated — this is reasonable as R_t will depend on the number of contacts with susceptibles, and this will be reduced if mobility is reduced when the social interventions are in place (Supplementary Figure S2), though the relationship of both these parameters with the number of cases is unclear; (iv) any decrease in the number of cases due to any intervention (Supplementary Table S1) tends to be seen two to four weeks later, but this is not consistent and seems not to depend on the country's population size. For example, Australia, Italy, and Germany appear to show a decrease in the number of daily COVID-19 cases approximately two weeks after their first intervention (Supplementary Figure S3), i.e. a 14-day quarantine imposed in Australia, a 'lockdown' in Italy, where citizens had to stay at home except for essential needs, and the closure of mosques in Germany. The R_t values for these three countries are currently $<$1 (at the time of analysis), though that for Australia appears to be drifting upwards.

The USA, India, and Singapore show similar patterns of daily new cases in the early phase despite their massively different population sizes (Supplementary Figure S3), with the USA first banning public events and state-wide stay-at-home orders being issued in the majority of states, India first closing restaurants, and Singapore first imposing a 14-day quarantine for all foreign visitors. India has not yet reached its peak of cases, though its R_t values are decreasing towards 1 (at the time of analysis). The number of cases in Singapore and the USA are now both decreasing with R_t at $\sim$1. No single intervention was observed to produce a definitive and immediate reduction in the number of daily COVID-19 cases.

For the other countries, R_t values of Canada, France, Denmark, Malaysia, and Thailand have reached or have fallen to $<$1, though worryingly (at the time of analysis), some are showing signs of rising beyond this threshold again (France, Denmark, Malaysia, Thailand) — which may be due to a fluctuating degree of compliance with the interventions in a proportion of these populations or the easing of lockdown (Supplementary Figure S3).

Despite the data uncertainty, the different intervention combinations implemented within each country, and a variable

https://doi.org/10.1016/j.jhin.2020.06.029

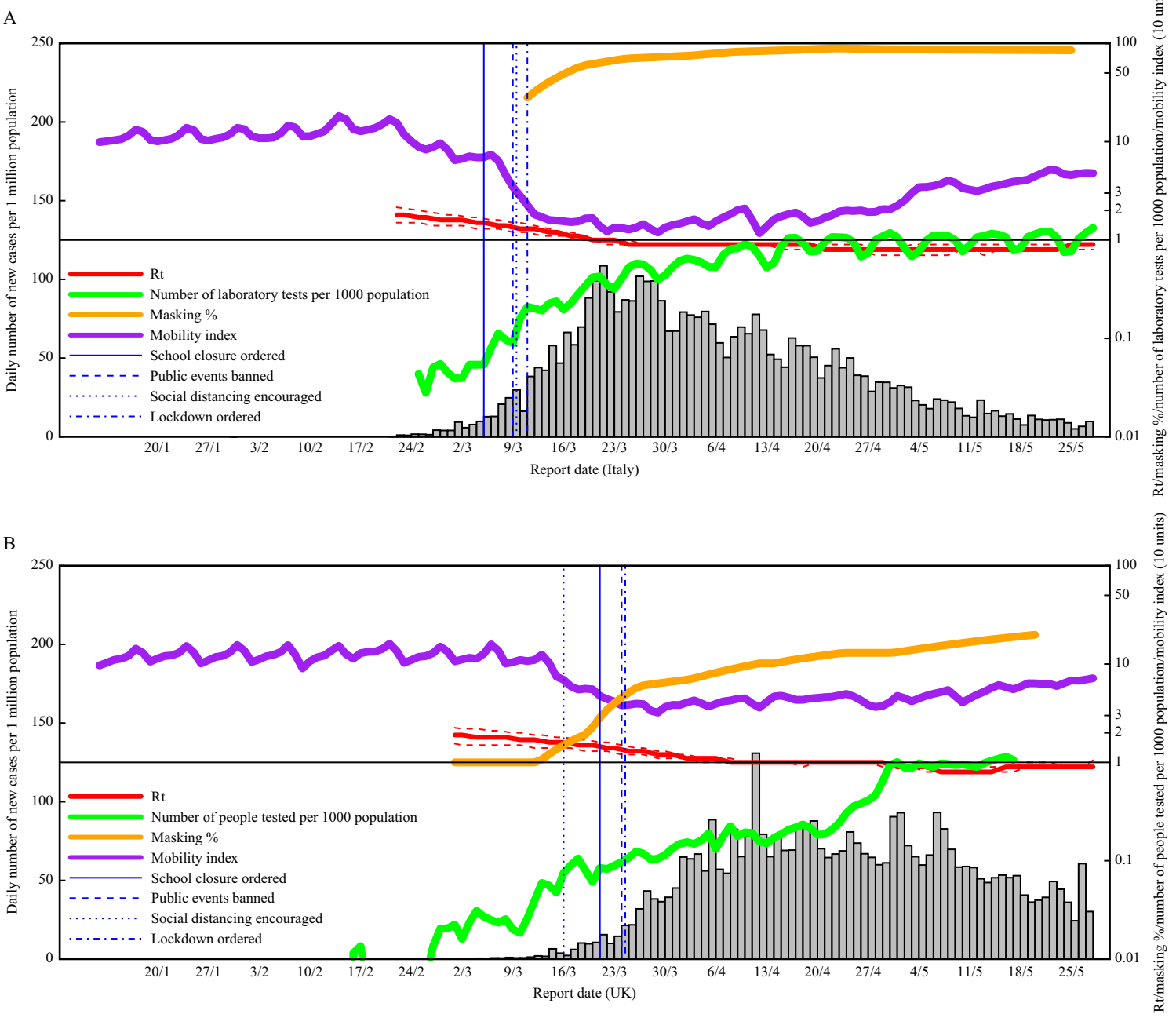

Figure 1. Impact of masking, testing, mobility restrictions and other interventions on daily numbers of COVID-19 cases and value of R_t (dotted lines showing the corresponding 90% confidence interval), for example in (A) Italy, (B) UK.

level compliance with them within each population, we have observed some useful and encouraging trends in the multi-country COVID-19 data presented here. Nation- or territory-specific modelling should be conducted individually to quantify the impact of single or bundled measures on COVID-19 activity and to determine the level of lockdown easing that would trigger another phase of the epidemic.

Acknowledgements

This work has been partially supported by Research Fund for the Control of Infectious Diseases, Hong Kong (No. INF-CUHK-1); General Research Fund (No. 14112818); Health and Medical Research Fund (Ref. 18170312); Wellcome Trust (UK, 200861/Z/16/Z). The authors also thank Li Ka Shing Institute of Health Sciences for technical support.

Conflict of interest statement
None declared.

Funding sources
None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jhin.2020.06.029.

References

[1] World Health Organization. COVID-19 situation in the WHO European Region. 2020. Available at: http://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19/news/news/2020/3/who-announces-covid-19-outbreak-a-pandemic [last accessed June 2020].
[2] Centres for Disease Control and Prevention (CDC). Social distancing, quarantine, and isolation. Available at: https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/social-distancing.html [last accessed June 2020].
[3] Public Health England (PHE). Guidance on social distancing for everyone in the UK. Available at: https://www.gov.uk/government/publications/covid-19-guidance-on-social-distancing-and-for-vulnerable-people/guidance-on-social-distancing-for-everyone-in-the-uk-and-protecting-older-people-and-vulnerable-adults [last accessed June 2020].
[4] European Centre for Disease Prevention and Control. COVID-19. Available at: https://www.ecdc.europa.eu/en/covid-19-pandemic [last accessed June 2020].
[5] Roser M, Ritchie H, Ortiz-Ospina E, Hasell J. Coronavirus pandemic (COVID-19). Our world in data 2020. Available at: https://ourworldindata.org/coronavirus [last accessed June 2020].
[6] Smith M. International COVID-19 tracker update: 18 May | YouGov. YouGov 2020. https://yougov.co.uk/topics/international/articles-reports/2020/05/18/international-covid-19-tracker-update-18-may [last accessed June 2020].
[7] Apple. Mobility trends reports. Available at: https://www.apple.com/covid19/mobility [last accessed June 2020].
[8] Imperial College, London, UK. Report 13: Estimating the number of infections and the impact of non-pharmaceutical interventions on COVID-19 in 11 European countries. Available at: https://www.imperial.ac.uk/media/imperial-college/medicine/mrc-gida/2020-03-30-COVID19-Report-13.pdf [last accessed June 2020].
[9] London School of Hygiene and Tropical Medicine, Centre for the Mathematical Modelling of Infectious Diseases. Temporal variation in transmission during the COVID-19 outbreak. Available at: https://github.com/epiforecasts/covid-global [last accessed June 2020].

K.O. Kwok[a,d,e,*]
F.Y.L. Lai[b]
V.W.I. Wei[a]
M.T.F. Tsoi[a]
S.Y.S. Wong[a]
J.W.T. Tang[c]

[a]*JC School of Public Health and Primary Care, The Chinese University of Hong Kong, Hong Kong Special Administrative Region, China*

[b]*Department of Cardiovascular Sciences, University of Leicester, Leicester, UK*

[c]*Respiratory Sciences, University of Leicester, Leicester, UK*

[d]*Stanley Ho Centre for Emerging Infectious Diseases, The Chinese University of Hong Kong, Hong Kong Special Administrative Region, China*

[e]*Shenzhen Research Institute of The Chinese University of Hong Kong, Shenzhen, China*

* Corresponding author. Address: Room 419, 4/F, JC School of Public Health and Primary Care Building, Prince of Wales Hospital, Shatin, N.T., Hong Kong. Tel.: +852 22528473.
E-mail address: kkokwok@cuhk.edu.hk (K.O. Kwok)

Available online 30 June 2020