The 40 health systems, COVID-19 (40HS, C-19) study

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BACKGROUND

The health, social and economic consequences of the COVID-19 pandemic have loomed large as every national government made decisions about how to respond. The 40 Health Systems, Covid-19 (40HS.C-

19) Study aimed to investigate relationships between governments' capacity to respond (CTR), their response stringency, scope of COVID-19 testing, and COVID-19 outcomes.

METHODS

Data to April 2020 were extracted for 40 national health systems on pre-pandemic government capacity to respond (CTR) (Global Competitiveness Index), stringency measures (Oxford COVID-19 Government Response Tracker Stringency Index), approach to COVID-19 testing and COVID-19 cases and deaths (Our-World-in-Data). Multidimensional scaling (MDS) and cluster analysis were applied to examine latent dimensions and visualise country similarities and dissimilarities. Outcomes were tested using multivariate and one-way analyses of variances and Kruskal-Wallis H tests.

RESULTS

The MDS model found three dimensions explaining 91% of the variance and cluster analysis identified five national groupings. There was no association between national governments' pre-pandemic CTR and the adoption of early stringent public health measures or approach to COVID-19 testing. Two national clusters applied early stringency measures and reported significantly lower cumulative deaths. The best performing national cluster (comprising Australia, South Korea, Iceland and Taiwan) adopted relatively early stringency measures but broader testing earlier than others which was associated with a change in disease trajectory and the lowest COVID-19 death rates. Two clusters (one with high CTR and one low) both adopted late stringency measures and narrow testing and performed least well in COVID-19 outcomes.

CONCLUSION

Early stringency measures and intrinsic national capacities to deal with a pandemic are insufficient. Extended stringency measures, important in the short-term, are not economically sustainable. Broad-based testing is key to managing COVID-19.

Keywords: COVID-19; global health; health systems; capacity to respond; stringency of response; public health consequences

Introduction

As severe acute respiratory syndrome coronavirus (SARS-CoV-2, henceforth COVID-19) cases have spread around the world, the pace and nature of each nations' public health response has differed, with the consequences measured in terms of disease contagion and lives lost. The pandemic triggered a chain reaction, yet within the limited range of response options available we have seen significant national differences in management and outcomes.[1] On March 16, 2020, the World Health Organisation's (WHO's) Director General reported to the global media that, while social distancing measures were escalating, there was not enough emphasis on testing and he urged member states and territories to: "Test, test, test. Test every suspected case".[2]

Citizens and the media within individual nations and states continue to question their governments' reactions. Yet less attention has been placed on identifying common national factors associated with effective pandemic responses, which is central to informing future pandemic planning. In all member states and territories, the enormous economic risks of stringent isolation-related prevention strategies have been central to decisions about how, and how quickly, to respond nationally. Nations with stable governments and stronger economies might be anticipated to be more willing and better positioned to respond rapidly and more comprehensively.[3] The 40 Health Systems Covid-19 (40HS, C-19) Study aimed to investigate the relationships between national governments' initial capacity to respond (CTR), their level of early response stringency, scope of COVID-19 testing, and the associated public health consequences (see Box 1 for definitions and measures).

Methods

Sample: We included 40 national health systems; 36 in the Organisation for Economic Co-operation and Development (OECD) and four additions (Singapore, Malaysia, Taiwan and Iran) for which there were reliable data on COVID-related deaths and testing outcomes for the period February to April 2020. For the purposes of this paper, The Republic of China (Taiwan) has been included as a national health system. At the time of writing and the period we examined for analysis, Colombia had not yet joined as an OECD country and was therefore not included as part of the OECD countries that were analysed. For analysis, we examined the 61 days between March 1 and April 30, 2020. We excluded the People's Republic of China as its response to the pandemic occurred on a different timeline to the rest of the world.

Box 1: Definitions and measures

Construct	**Definition**	**Measure and Data Sources**
Governments' capacity to respond	National competitiveness, government policy stability, responsiveness to change, and government long term vision for the future	Global Competitiveness Index 4.0: https://www.weforum.org/reports/how-to-end-a-decade-of-lost-productivity-growth[4]
Stringency	Strategies governments take to manage COVID-19 including containment, delay and mitigation	Oxford COVID-19 Government Response Tracker Stringency Index (OxCGRT-SI): https://www.bsg.ox.ac.uk/research/research-projects/coronavirus-government-response-tracker[1,5]
Approach to testing	Scope of COVID-19 testing protocols	Coronavirus (COVID-19) Testing https://ourworldindata.org/coronavirus-testing# [6]
Public health consequences	COVID-19 deaths; new COVID-19 cases between March 1 and April 20, 2020.	COVID-19 deaths per million population; COVID-19 new daily deaths per million population; total COVID-19 cases per million population; and COVID-19 new daily cases per million population. March 1 and April 30, 2020 (61 days)

		https://ourworldindata.org/coronavirus-data [7]

Measures: National governments' inherent, pre-pandemic CTR was measured using the Global Competitiveness Index (GCI) 4.0 [4] which assesses factors that drive a state's or territory's productivity, growth, and human development including its resilience, agility, innovation and human-centric approach. The data in this index show that enhanced competitiveness is related to high living standards, income and life satisfaction. We included each jurisdiction's GCI index, as well as their scores for 'policy stability', 'responsiveness to change', and 'government long-term vision'.

National pandemic response was measured in terms of early stringency and approach to testing. Stringency was measured using the Oxford COVID-19 Government Response Tracker Stringency Index. [1, 5] Until April 29, 2020 the Stringency Index was developed from seven policy decisions relating to 'containment and closure', such as the closing of schools and workplaces, cancellation of public events, and restrictions on internal and international movement. Latvia and Lithuania were not included in OxCGRT-SI so we applied the same methods to estimate their stringency scores. We used the OxCGRT-SI at three time points (at the time of the 1st, 5th and 10th recorded COVID-19 attributed to deaths in each country).

Approach to COVID-19 testing was assessed in terms of the adoption of broad or narrow testing criteria, as measured by the index number of tests per case identified from April 13, 2020. Broader testing was indicated by a larger index number, meaning many tests were performed before identifying a COVID-19 case. The April 13 date was when testing data were available from all the states in the sample.

The consequences of each national response were measured by COVID-19 deaths per million population; COVID-19 new daily deaths per million population; COVID-19 total cases per million population; and COVID-19 new daily cases per million population.

Analysis: Statistical analyses were conducted using SPSS version 25, [8] multidimensional scaling (MDS) analysis, and k-means clustering were conducted using functions from R version 3.5.2.[9, 10] To characterise and group the 40 states based on their national CTR and their actual response to the pandemic, eight variables (four GCI measures, three OxCGRT-SI scores and the tests per COVID-19 case identified) were included in an MDS model. MDS was used to examine the underlying latent dimensions from multivariate data and to visualise the level of similarity or dissimilarity of the nations to each other based on these dimensions. Since the eight variables are not exact metrics, all variables were first standardised by transforming them to z-scores. As MDS examines similarity indices, the variables were converted into a Euclidean distance matrix and the MDS model was visualised on a 3-dimensional plot. Cluster analysis was then conducted on the MDS result using k-means, to determine the clustering structure. Nations within the same cluster are more similar to each other than those in other clusters.

Statistical comparisons between cluster groups in terms of government CTR and response variables were conducted using one-way multivariate analysis of variances (MANOVA). Univariate tests were conducted with one-way ANOVAs. For outcome measures consisting of COVID-19 total deaths, new daily deaths, total cases and new daily cases, data were non-parametric. Thus, to test for differences between the clusters and outcome measures, Kruskal-Wallis H tests were conducted for the average of the last five days in March (day 27-day 31) and the last five days in April (day 57- day 61). For all tests, a significance level of .05 was used.

Results

Table 1 reports the descriptive statistics for each of the five national clusters for the measures investigated.

Table 1: Descriptive statistics for the five national clusters

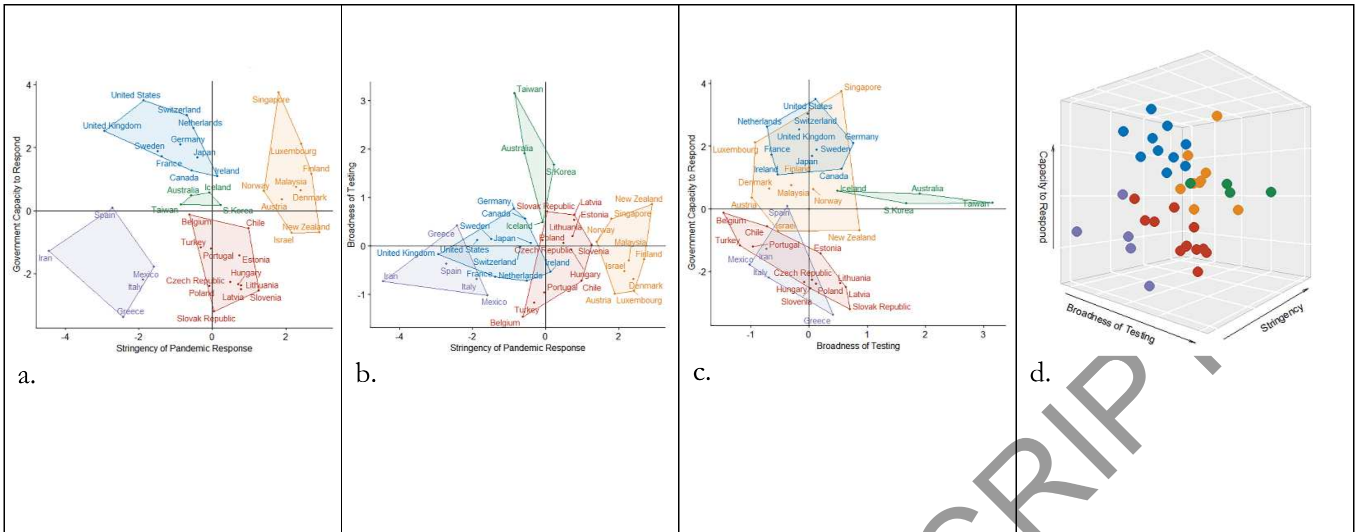
Variable	Cluster 1 (Purple) M(SD)	Cluster 2 (Red) M(SD)	Cluster 3 (Green) M(SD)	Cluster 4 (Orange) M(SD)	Cluster 5 (Blue) M(SD)	P*
GCI score	67.5 (5.7)	69.0 (3.6)	78.4 (3.1)	78.3 (2.5)	80.8 (2.5)	<0.001
Policy stability	3.0 (0.9)	3.8 (0.6)	5.5 (0.6)	4.4 (0.5)	5.2 (0.5)	<0.001
Responsiveness to change	2.9 (0.3)	3.6 (0.4)	5.0 (0.6)	4.2 (0.3)	4.6 (0.3)	<0.001
Government long-term vision	2.6 (0.4)	3.4 (0.4)	5.1 (0.8)	4.0 (0.4)	4.6 (0.3)	<0.001
OxCGRT-SI at 1st Death	24.8 (19.2)	75.4 (17.0)	79.4 (19.5)	40.5 (9.9)	21.9 (13.4)	<0.001
OxCGRT-SI at 5th Death	42.9 (26.7)	82.1 (8.2)	85.2 (17.9)	48.8 (15.2)	36.9 (16.2)	<0.001
OxCGRT-SI at 10th Death	61.0 (17.3)	83.7 (6.6)	90.5 (7.5)	57.1 (12.9)	48.8 (18.4)	<0.001
COVID-19 tests per case identified	8.9 (6.7)	23.1 (13.5)	20.2 (15.6)	63.2 (44.0)	8.5 (4.6)	<0.001

*p-values are from one-way ANOVAs to examine differences between the 5 cluster groups.

Using goodness-of-fit statistics, the number of dimensions with best fit for the MDS model was found at three dimensions, with 91% variance explained. From the MDS plots, we identified each of the dimensions as: (1) government CTR; (2) the level of early stringency response; and (3) approach to testing. Cluster analysis identified five national clusters from the MDS plots as shown in Figure 1. Figures 1a to 1c each illustrate cluster performance on the three dimensions. Figure 1d is the three-dimensional representation of the national health systems in the MDS model.

Figure 1a shows three clusters (above the horizonal zero axis) with a higher government CTR compared to two clusters performing with lower government CTR (below the horizontal zero axis). The two clusters (orange and red) on the right of the vertical zero axis applied early stringency measures relative to those on the left. Figure 1b shows the middle green cluster from Figure 1a adopted a much broader testing strategy than all the remaining clusters. There was little relationship between government CTR, adoption of early stringency measures or testing approach (Figures 1a and 1c). Figure 1a shows that clusters with high CTR and clusters with low CTR both demonstrated early high and low stringency adoption. Figure 1b shows similar testing approaches for 4 of the 5 clusters despite differences in stringency response and Figure 1c shows similar testing approach despite differences in government CTR. There were no clear linear relationships between these factors. Figure 1d is a three-dimensional depiction of Figures 1a-c.

Figure 1: National health systems' cluster performance on capacity to respond, stringency of response, and approach to testing



A one-way MANOVA found an overall significant difference in the five cluster groups with CTR and response measures, ($F(32, 104.9) = 9.4$, $p<0.001$; Wilk's $\lambda = 0.007$, partial $\eta^2 = 0.71$). The univariate ANOVAs showed that the differences were in all the eight variables ($p<0.001$) between the five clusters.

Figure 2 provides a diagrammatic representation of the characteristics of each cluster. Cluster 1 (purple) and Cluster 5 (blue) were both characterised as low early stringency adopters with narrow scope of testing. However, Cluster 1 had low whereas Cluster 5 had high government CTR scores.

Cluster 2 (red), like Cluster 1, was below the horizontal zero axis (in Figure 1a) with low government CTR scores, but it adopted early stringency measures and had medium testing levels. Cluster 3 (green) and Cluster 4 (orange) were similar in their government CTR scores, but Cluster 3 had broader testing, and Cluster 4 had adopted early high stringency measures.

Figure 2: Graphical summary of national health system's capacity to respond, adoption of early stringency measures, and approach to COVID-19 testing

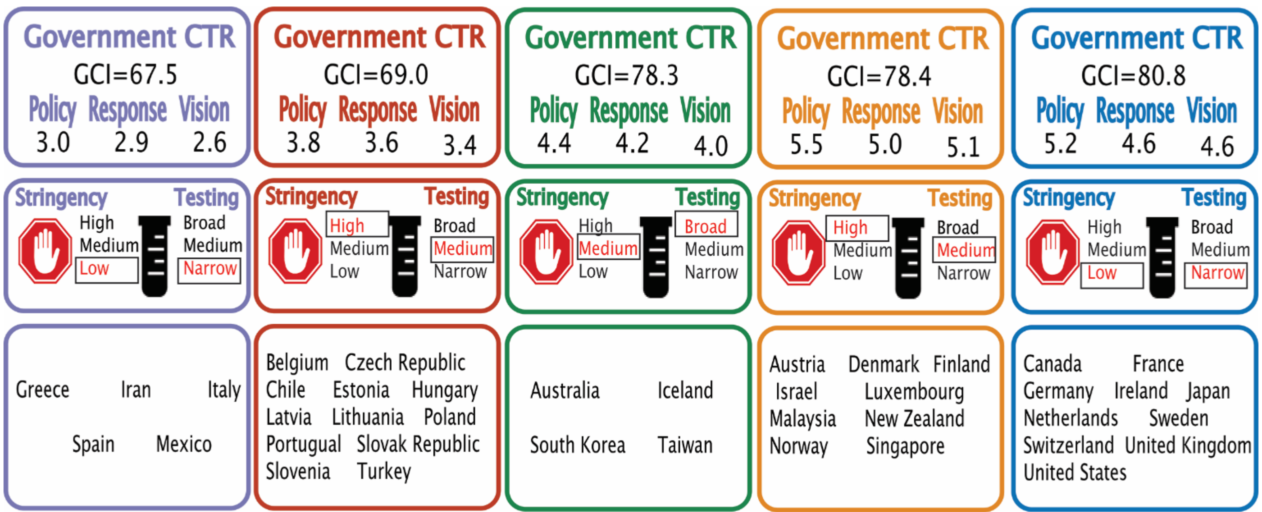
Cluster 1

Cluster 2

Cluster 3

Cluster 4

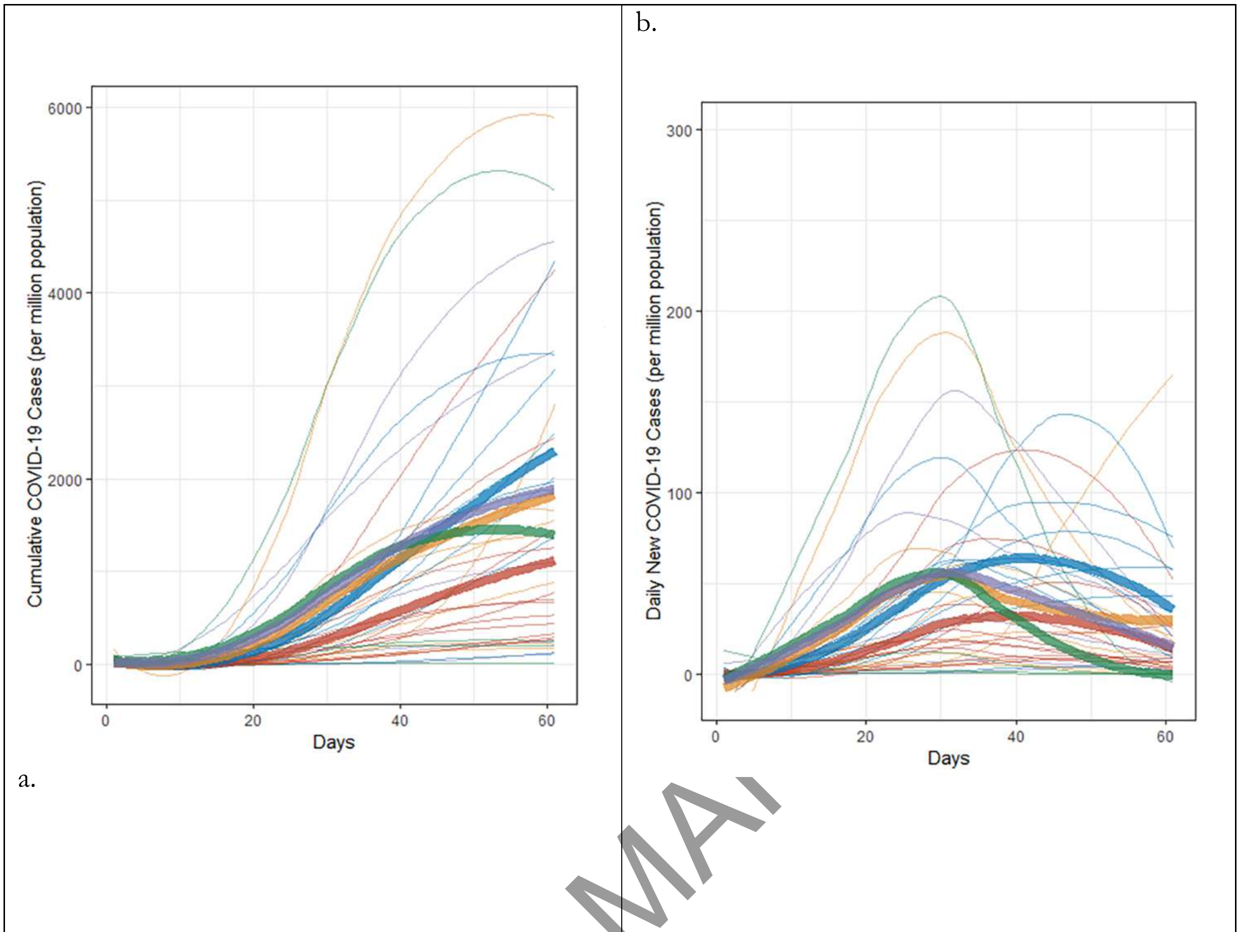
Cluster 5



Performance of the clusters for COVID-19 outcomes were examined. The Kruskal-Wallis H tests showed no differences between the five clusters for both COVID-19 cumulative cases reported (χ^2= 4.2, p=0.4) and new daily cases (χ^2= 7.9, p=0.1) for March. However, by the end of April there was a significant difference for the five clusters in terms of new daily COVID-19 cases (χ^2= 12.8, p=0.01) and a just significant difference for cumulative COVID-19 cases (χ^2=9.5, p=0.05).

Figures 3a and 3b show the cumulative and new daily cases for the five clusters over the 61 days examined. Cluster 3 (green) shows a significant fall in new cases after day 30, while clusters 2 (red) and 5 (blue) with low and high CTR scores had a plateau of daily new COVID-19 cases at days 30-40.

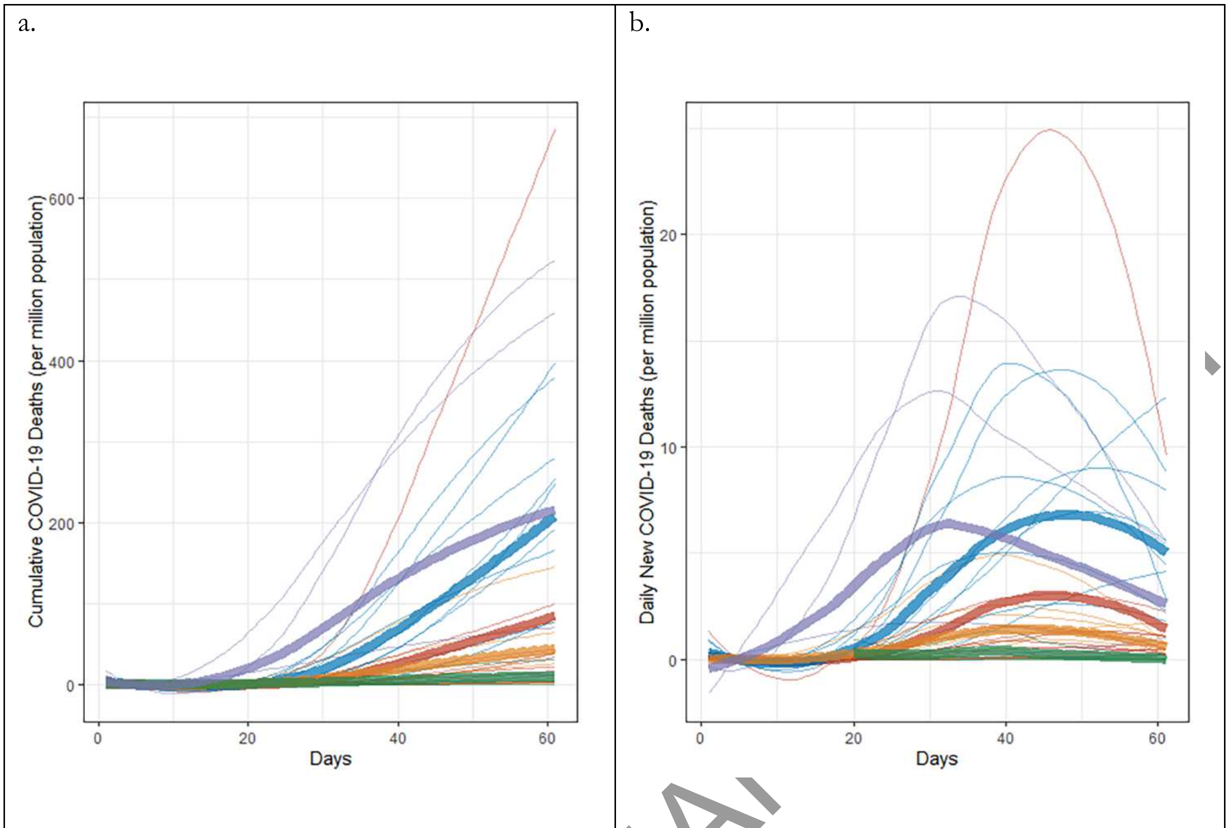
Figure 3: Spaghetti plots of cumulative COVID-19 cases (Figure a) and daily new COVID-19 cases (Figure b) in 40 national health systems over the 61 days examined (March 1 to April 30, 2020)



Legend: Individual national responses are represented by the thin lines. Thick lines are the mean changes for each cluster over time. Lines are smoothed using LOESS regression.

For cumulative COVID-19 deaths and daily new COVID-19 deaths, applying Kruskal-Wallis H tests, we found significant differences in daily new deaths between the five clusters (χ^2=12.0, p=0.02) but not for cumulative deaths (χ^2= 8.8, p= 0.06) for the last five days in March. By the end of April, there were significant differences between the five clusters for both cumulative COVID-19 deaths (χ^2=12.0, p=0.02) and daily new COVID-19 deaths (χ^2=12.0, p=0.02). Figure 4b shows cluster 3 (green) and cluster 4 (orange) substantially lower on new COVID-19 death rates compared to the other clusters.

Figure 4: Spaghetti plots of cumulative deaths (Figure a) and new daily deaths (Figure b) for the five clusters over the 61 days examined (March 1 to April 30, 2020)



Legend: Individual national responses are represented by the thin lines. Thick lines are the mean changes for each cluster over time. Lines are smoothed using LOESS regression.

Discussion

Statement of principal findings

We found no association between national governments' CTR, and adoption of early, stringent public health measures and broad COVID-19 testing. Regardless of inherent government potential based on their national capabilities and economic strength, those states represented in clusters 2 (red) and 4 (orange) adopted early high stringency measures and reported significantly lower cumulative death rates. Cluster 3 (green) comprising Australia, South Korea, Iceland and Taiwan, implemented relatively early stringency measures and a broad approach to testing (with the highest index of tests to positive COVID-19 case). These actions were associated with a change in the disease outcome trajectory. By the end of April 2020, the curve for new cases had flattened in this cluster, and these national health systems reported the lowest rate of COVID-19 deaths.

Clusters 5 (blue) and 1 (purple) were at opposite ends of the government CTR scale, yet reacted to the pandemic in similar ways, with low early stringency adoption, a 'wait and see' approach, and narrow testing. These two clusters experienced the highest number of COVID-19 deaths over the time period of this study of all the clusters.

It maybe thought counter-intuitive that there was no association between pre-pandemic governments' inherent CTR and actual response. This suggests that other factors which we were unable to measure in our study are important drivers of the public health policy response. Such factors are likely to include the political landscape in each state or territory, [11] effectiveness of pandemic leadership, [12] willingness to listen to medical science, [13] and capacity to learn fast, and early. [14]

Strengths and limitations

A notable strength of the 40HS, C-19 study is our approach to providing a meaningful way to group national health systems according to multiple elements of their responses (stringency and testing) and to assess the consequences of those responses on both COVID-19 cases and deaths. A limitation is that it provides only snapshot at a point in time. A repeat analysis following second-wave COVID-19 outbreaks, experienced by many countries, would be valuable to understand the longer-term influence of stringency and testing policies. We were only able to investigate 40 health jurisdictions due to limited data availability, especially data in relation to COVID-19 testing. Nonetheless, our three dimensions accounted for over 90% of the variance between clusters. Our findings build on those which have shown separate relationships between stringency measures and COVID-19 cases within geographic areas in one jurisdiction, [15] and between individual jurisdictions. [1, 5] However we have demonstrated the value of the combination of both stringency measures and a broad testing approach on new COVID-19 cases and deaths.

Interpretation within the context of the wider literature

As the pandemic has progressed governments have moved towards more stringent measures. Overall, by March 31 most states and territories had moved to adopt many of the internationally supported strategies of stringency and extensive testing. [16] Our results confirm that early stringency measures were necessary but not sufficient. Broad testing in tandem with stringency measures were central to improving outcomes. States and territories around the world are now confronting the fact that high stringency measures are being seen as economically unsustainable for long periods. [17] Thus broad testing, which allows identification of asymptomatic cases, and good contact follow-up with fast isolation, are crucial in managing the spread of the disease.

Implications for policy, practice and research

The effectiveness of public health responses has many drivers. Previous epidemics have demonstrated the key role that trust in governments, political institutions and the information they generate has on public confidence and compliance with critical public health measures. [18, 19] Indeed, during the current COVID-19 outbreak in the United States, citizen responsiveness to the various strategies implemented has been shown to be strongly associated with individuals' political persuasion and views of government. [20] In the rapidly changing environment of a pandemic, with an increasingly wide range of formal and informal communication channels, trust in information generated from government sources is likely to play a progressively critical role in determining uptake and support for public health measures now and in the future. [21, 22]

Conclusion

Governments around the world are seeking evidence to inform their decisions about the most effective pandemic responses. The 40HS, C-19 study provides a cross-sectional snapshot of 40 health systems and their responses to COVID-19, and underscores the importance of stringency and broad-based testing.

DECLARATIONS

Disclosure of conflicts of interests

Nothing to disclose.

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Author contributions

JB, YT, LAE and JW conceptualised and designed the manuscript. YT analysed the data and created the figures. All authors were part of the data interpretation, drafting and finalisation of the manuscript.

Data Availability Statement

The data underlying this article were accessed from 1. Global Competitiveness Index 4.0 (https://www.weforum.org/reports/how-to-end-a-decade-of-lost-productivity-growth) 2. Oxford COVID-19 Government Response Tracker Stringency Index (OxCGRT-SI) (https://www.bsg.ox.ac.uk/research/research-projects/coronavirus-government-response-tracker) 3. Coronavirus (COVID-19) Testing (https://ourworldindata.org/coronavirus-testing#) and 4. COVID-19 deaths per million population; COVID-19 new daily deaths per million population; total COVID-19 cases per million population; and COVID-19 new daily cases per million population. (https://ourworldindata.org/coronavirus-data). The derived data generated in this research will be shared on reasonable request to the corresponding author.

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