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An Epidemiological Comparison of COVID-19 Waves in Malaysia

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Abstract

COVID-19 has affected nearly every country and territory in the world, hitting some harder than others. It is imperative that the reasons behind these differences in severity are understood so that the lessons learned can be applied to controlling future pandemics. Malaysia was chosen as the study target for this cross-wave comparison study as the COVID-19 pandemic there proceeded in distinct large-scale waves, making direct particularly effective and insightful. It was found that strict movement control orders (MCOs) were highly important in controlling outbreaks, especially when implemented quickly after super-spreader events like the Sri Petaling gathering that caused a spike of over 200 new cases a day. Higher case numbers and deaths in Wave 3 were caused by government negligence in the form of loosened travel restrictions being enacted too late to have an effect, which manifested in citizen mobility data as well. Interestingly, the virus seemed to get less severe over time; this may be attributed to infection of less susceptible members of the population.

Introduction

The origins of the COVID-19 pandemic can be traced to an initial outbreak of cases in December 2019 that occurred in Wuhan, China. Extensive human transmission ensued, and the SARS-CoV2 virus rapidly spread around the world within a few months (Liu et al. 2020). The rapid spread of the virus created many unprecedented social, political, and economic challenges, forcing nations around the world to respond quickly, strategically, and sometimes unconventionally with political and health measures in order to coordinate an effective response (Harris et al. 2020). Many factors are known to impact the success and ability of different countries in governing through the pandemic, including healthcare infrastructure and quality,

scientific literacy, timeliness of control policies, and public perception of risks (Madhav et al. 2017). However, because government resources are limited, it is not feasible to implement most measures in most situations. Understanding the relative importance of these factors is crucial for responding effectively to future pandemics, saving lives and resources.

Malaysia, an upper-middle-income country in Southeast Asia, presented itself as a particularly interesting case study for the COVID-19 pandemic. COVID-19 cases in Malaysia can be broken up into three main waves (Rampal & Seng, 2021), each of which proceeded differently. The first wave began on January 25th, 2020 when Malaysia reported its first case of COVID-19 along with other imported cases from hotspots like Wuhan, China. The initial cases were effectively contained, and the wave was over by the middle of February 2020. Wave 2 began at the end of February 2020 and is believed to have been caused by Sri Petaling, a religious gathering of over 16,000 people in the capital city of Kuala Lumpur that attracted individuals from various countries across South East Asia. Subsequently, daily case numbers increased into the hundreds in March and April before subsiding to single digits by late June and remaining there for the next two months. Wave 3 began in September 2020, and is believed to have been caused by public gatherings due to elections in Sabah, which was further exacerbated by the government's refusal to implement further lockdown orders (Rampal & Seng, 2021). Malaysia reached a peak of over 5000 new cases a day in late January 2021, and though that number fell into the 1000's within 2 months, case numbers remained far above those of waves 1 and 2. The disparity between sizable waves in the same country makes it possible to evaluate how important different factors are by making a direct comparison between the waves.

Methods

Data Collection. Daily case count, cumulative case count, ICU capacity, respiratory assistance, and deceased patient data were scraped from kpkesehatan.com, a website maintained by the Malaysian Director-General of Health. Citizen movement data was compiled from Google's COVID-19 Community Mobility Report dataset for Malaysia. Personal choice and behavior data was taken from yougov.co.uk, a website containing COVID-19 behavioral data on multiple countries. The positivity rate of COVID-19 testing data in Malaysia was extracted from ourworldindata.org, a website overseen by the University of Oxford. Qualitative data including news reports on major political and social events were gathered from local Malaysian newspapers including The Star and the New Strait Times.

Statistical Analysis. To test the possible correlation between different sets of time-series data, cross-correlation tests were performed in Google Sheets and MATLAB. Relationships between time-independent data were assessed using paired t-tests and Pearson's correlation coefficient.

Results

Government response. A chronological list of government-enacted policies for each wave can be found in Figure 1. Details of the various movement control orders, henceforth referred to as MCOs, can be found in Figure 2.

Figure 1: Comparison of government response throughout waves

<p>Wave 1 (Jan 25, 2020 to Feb 16, 2020)</p>	<p>Wave 2 Feb 27, 2020 to July 2020</p>	<p>Wave 3 Sep 6, 2020 to Present</p>
<p>Jan 25th</p> <ul style="list-style-type: none"> • First reported case of COVID-19 confirmed by the Ministry of Health <p>Jan 27th</p> <ul style="list-style-type: none"> • Travel from China restricted <p>Feb 1st</p> <ul style="list-style-type: none"> • All non-Malaysian citizens prohibited from entering the state of Sarawak unless employment or student pass was presented where a 14-day quarantine was imposed • Malaysian embassy in Beijing organizes a plan to bring back citizens from Wuhan <p>Feb 4th</p> <ul style="list-style-type: none"> • 107 Malaysians return from Wuhan • Ministry of Tourism, Arts, and Culture (MOTAC) alters the Visit Malaysia campaign <p>Feb 24th</p> <ul style="list-style-type: none"> • Prime Minister Mahathir Mohamed unexpectedly resigns from the position <p>Feb 27th to March 1st - Sri Petaling</p> <ul style="list-style-type: none"> • Religious movement and gathering at the Sri Petaling mosque in the capital city of Kuala Lumpur attracting individuals from all over Asia and a total of about 16,000 people attending • Attracted People from Singapore, Brunei, 	<p>Testing and contact tracing</p> <ul style="list-style-type: none"> • Testing generally available • comprehensive contact tracing <p>Feb 27th</p> <ul style="list-style-type: none"> • Interim Prime Minister Dr. Mahathir Mohamad announces an Economic Stimulus Package to boost the economy in response to the outbreak <p>March 1st</p> <ul style="list-style-type: none"> • Muhyiddin Yassin was sworn in as Malaysia's new prime minister <p>March 16th</p> <ul style="list-style-type: none"> • 14-day Movement Control Order announced by Prime Minister effective from March 18th to March 31st <p>March 18th to May 12th, 2020</p> <ul style="list-style-type: none"> • Movement Control Order <p>March 17th</p> <ul style="list-style-type: none"> • first COVID-19 related death was reported <p>March 25th</p> <ul style="list-style-type: none"> • Movement Control Order was extended from April 1st to April 14th <p>March 31st</p> <ul style="list-style-type: none"> • Regulations were made to Movement Control Order to restrict necessary travel to one person per household and within a radius of a 	<p>September 10th, 2020 - Recovery Movement Control Order</p> <ul style="list-style-type: none"> • Temporary Entry Ban of citizens from 23 countries • On 18th September 2020, the National Disaster Management Agency (NADMA) has decided that all foreign nationals, including Malaysian permanent residents, are subjected to bear the full quarantine cost without any Malaysian government subsidies amounting to RM4,700, effective from 24th September 2020 <p>October 9th to November 2020 -Recovery Movement Control Order</p> <p>December 2020 -Enhanced Movement Control Order</p> <p>January 12th, 2021-Recovery Movement Control Order</p> <ul style="list-style-type: none"> • State of emergency is placed until August <ul style="list-style-type: none"> ○ Parliament is closed therefore no elections will be held • On 12th January 2020, the Malaysian Ministry of Health (MOH) announced that Level 1 and Level 2 COVID-19 patients would undergo treatment, home

<p>Cambodia, the Philippines, Thailand, and Vietnam</p> <ul style="list-style-type: none"> • Largest COVID-19 cluster reported in Malaysia, involving a total of 3,375 cases <p>Movement control orders</p> <ul style="list-style-type: none"> • No nationwide movement control order <p>Testing and contact tracing</p> <ul style="list-style-type: none"> • Testing available for symptomatic and eligible individuals • Comprehensive contact tracing throughout the wave 	<p>maximum of ten kilometers from a residence</p> <p>April 14th</p> <ul style="list-style-type: none"> • Movement Control Order was extended from April 15th to April 28th <p>April 28th</p> <ul style="list-style-type: none"> • Movement Control Order was extended from April 29th to May 12th with slightly less restrictive regulations, removing the one person traveler policy <p>May 13th to June 19th, 2020</p> <ul style="list-style-type: none"> • Conditional Movement Control Order <p>June 10th, 2020 to February 1st, 2021</p> <ul style="list-style-type: none"> • Recovery Movement Control Order <p>May 25th</p> <ul style="list-style-type: none"> • Gatherings at places of worship are no longer prohibited by a movement control order • Regulations on public transportation removed and allowed to operate at full capacity again <p>July 14th</p> <ul style="list-style-type: none"> • Sports events allowed to occur without spectators <p>July 28th</p> <ul style="list-style-type: none"> • All incoming international individuals are required to quarantine and wear a government-provided wristband 	<p>quarantine for 10 days, and a screening test on day 10 while being monitored strictly by health workers.</p> <p>February 2021 - Conditional Movement Control Order</p>
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Figure 2: The regulations set for the different types of Motion Control Orders

- No MCO were set in place during Wave 1

Movement Control Order	Policies,
<p>EMCO (Enhanced Movement Control Order) <i>Wave 3</i> <i>Dec 2020</i></p>	<ul style="list-style-type: none"> • All social activities are prohibited. Screening, testing, and quarantine (up to 28 days) are mandatory for all areas' residents • Movement in and out of premises or areas is prohibited, similar to the stay-at-home-order. • Only those providing essentials are allowed in, while only the head of a family can venture outside to buy food or household goods
<p>MCO (Movement Control Order) <i>Wave 2</i> <i>March-May 2020</i></p>	<ul style="list-style-type: none"> • Restricts movement unnecessary to essential services and necessities • Ban on international travel except those returning to Malaysia • Restricts all gatherings including religious, sports, recreational, social, or cultural • Required all educational institutions of all levels to close
<p>CMCO (Conditional Movement Control Order) <i>Wave 2</i> <i>May-June 2020</i> <i>Wave 3</i> <i>February 2021-Present</i></p>	<ul style="list-style-type: none"> • Individuals are allowed to travel for work in addition to traveling for essential services • Restricts all gatherings including religious, sports, recreational, social, or cultural that could cause a crowd with no explicit definition of the size of a "crowd" • 20 people maximum in attendance of a funeral • Only 30% of workers within a companies' management group are allowed to be in the office. Non-essential services staff to work from home.
<p>RMCO (Recovery Movement Control Order) <i>Wave 3</i> <i>Sep-Nov 2020</i> <i>Jan 2021</i></p>	<ul style="list-style-type: none"> • Allowed any movement within the country for work-related purposes • Limited travel within the state of Sarawak where COVID-19 cases were surging • Allowed home gatherings for specific cultural and religious holidays including 1) Pesta Kaamatan, 2) Gawai Dayak Day, and 3) Hari Raya Puasa • Allowed flight travels between states within Malaysia with a maximum passenger limit • Allowed the resumption of parliamentary and state assembly sittings and meetings • Only two members of a household may leave the house to buy necessities • All schools, higher education institutions, training institutes, kindergartens, childcare centers, public parks, and recreational centers will be closed

On March 18th, 2020, a 14-day Movement Control Order (MCO) that was later extended to nearly two months was introduced by the office of the prime minister. This order prevented non-essential travel, banned international travel with the exception of those returning to Malaysia, closed educational institutions of all levels, and restricted religious, social, or recreational gatherings among other things. First the initial MCO was announced, there were several modifications made to relax regulations. On March 31st, 2020, the MCO was altered to allow one person per household to travel within a 10 kilometer radius of place of residence. Later on April 28th, the MCO was again amended to remove the one traveler per household restriction. With promising achievements in control of virus transmission in the late spring and early summer, the MCO was reduced to a Conditional Movement Control Order (CMCO) on the 13th of May 2020 and then further reduced to a Recovery Movement Control Order (RMCO) on the 10th of June 2020. The CMCO contained several of the policies included in the MCO with a few regulations that relaxed limitations. The CMCO lifted the ban on social gatherings, only banning those that could result in a “crowd” with no explicit definition of a crowd. The RMCO also further relaxed policies regarding social gatherings, allowing them to occur on a limited basis; places of worship could operate on a limited basis with capacities varying from region to region and depending on place of worship. The RMCO also permitted interstate travel with the exception of regions under the Enhanced Movement Control Order (EMCO) in an effort to contain spread in regions with large clusters. In addition, on July 1st 2020, the RMCO allowed the opening of businesses that fell under the sector of Tourism, Arts, and Culture including conventions, exhibitions, and trade fairs with a maximum capacity of 250 attendees allowed. The RMCO continued until November where EMCOs were initiated in the regions of Kedah, Penang,

Perak, Negeri Sembilan, Malacca, Johor and Terengganu instead (Team, 2020). The EMCOs clarified that all social activities were prohibited, movement in and out of premises were restricted, and only one person from each household was allowed out for groceries and necessities. RMC0 orders were then reinstated on January 12th, 2021 along with the state of emergency that shut down the government.

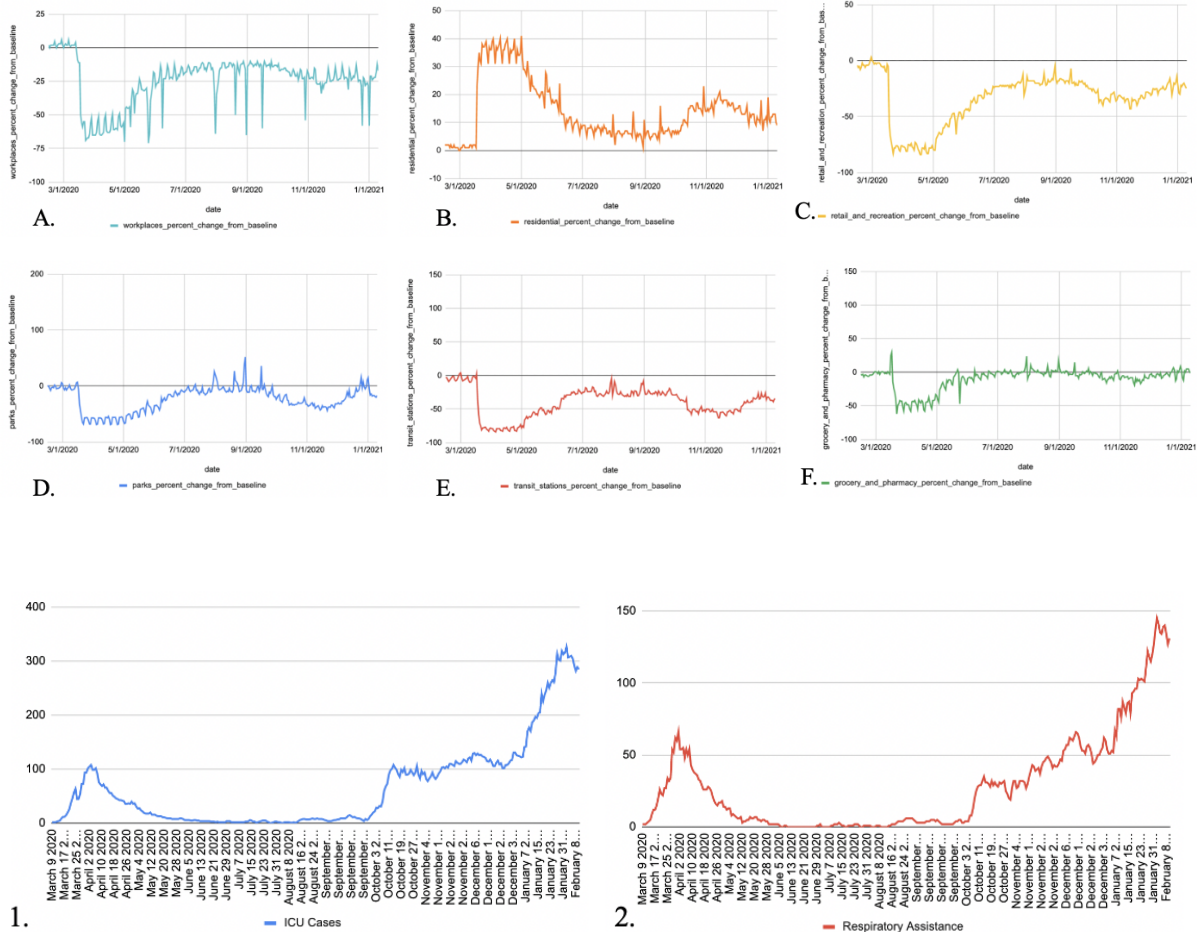
Political Instability. Prime minister Mahathir Mohamed unexpectedly announced his resignation on February 14th, 2020 after coming to office in 2018 and previously serving as prime minister for over 20 years from 1981 to 2003. The monarch of Malaysia then appointed Muhiddin Yassin to the position on March 1st 2020. After already facing much backlash, especially for his inaction during wave 3 of the pandemic, the king announced on January 12th, 2021 that Malaysia would be placed into a state of emergency, which suspended the action of parliament until August. Many in Malaysia say that this was an attempt by Yassin to cling to power. In addition, 2020 was an election year in Malaysia's second most populated state, Sabah. While there were some modifications made to satisfy COVID-19 regulations, the elections that occurred in September 2020 and the campaigning by officials in the months led to a regional and national rise in cases.

Comparison of ICU/respiratory assistance cases and mobility data. To analyze and determine if there was any correlation between Google's mobility dataset and the ICU and respiratory assistance cases, a cross correlation test was performed between the two data sets. ICU and respiratory cases were taken from blog posts by Malaysia's Director General of Health: Dr. Noor Hisham Abdullah. The mobility data was reported in percentages from baselines determined by

pre-COVID-19 data collected by Google through its user's mobile locations. The cross correlation test allows for an understanding of how public movement patterns were affected by the government's actions and how much this had an impact on the severity of COVID-19 in Malaysia. Both data sets were split up into three time periods based on the spikes in hospitalizations from the ICU and Respiratory assistance data that roughly corresponded with the waves. Since both data sets were on the same time scale, a lag of zero was used initially to calculate the cross correlations. To do the cross correlation tests, the ICU and respiratory assistance data were analyzed separately, as was the mobility data, which consisted of six movement behavior categories: retail, grocery, parks and recreation, transit stations, workplaces and residential. For all of the mobility categories, both ICU and respiratory had a negative correlation, except for the residential mobility data. In these tests, cross correlation results of -0.7 and 0.7 or greater was considered to be a significant correlation. There appeared to be a more significant correlation between the number of COVID-19 ICU cases and grocery mobility data for the first time period, as well as for transit and workplace mobility, both of which had a negative correlation of about -0.7 . With the respiratory assistance data, there was not much correlation except a negative cross correlation between the grocery and workplace mobility data. For the second rise in ICU cases, there were similar correlations to the first rise in ICU cases, except between the ICU and transit data there was a higher negative correlation of about -0.8 . For the third rise in cases however there was a much higher negative correlation with retail, recreation, and transit mobility data all having a result of -0.8 when crossed with the ICU data. This was also reflected in the respiratory assistance data, which was slightly less correlated with a value of -0.7 , but it was still higher than the other time periods. For all three time periods, there was essentially no correlation between the residential mobility data and the ICU and respiratory

assistance cases, which allows for further discussion into the MCO orders and if they were successful in keeping people home at this point.

Figure 3: Mobility and ICU/Respiratory Assistance Data

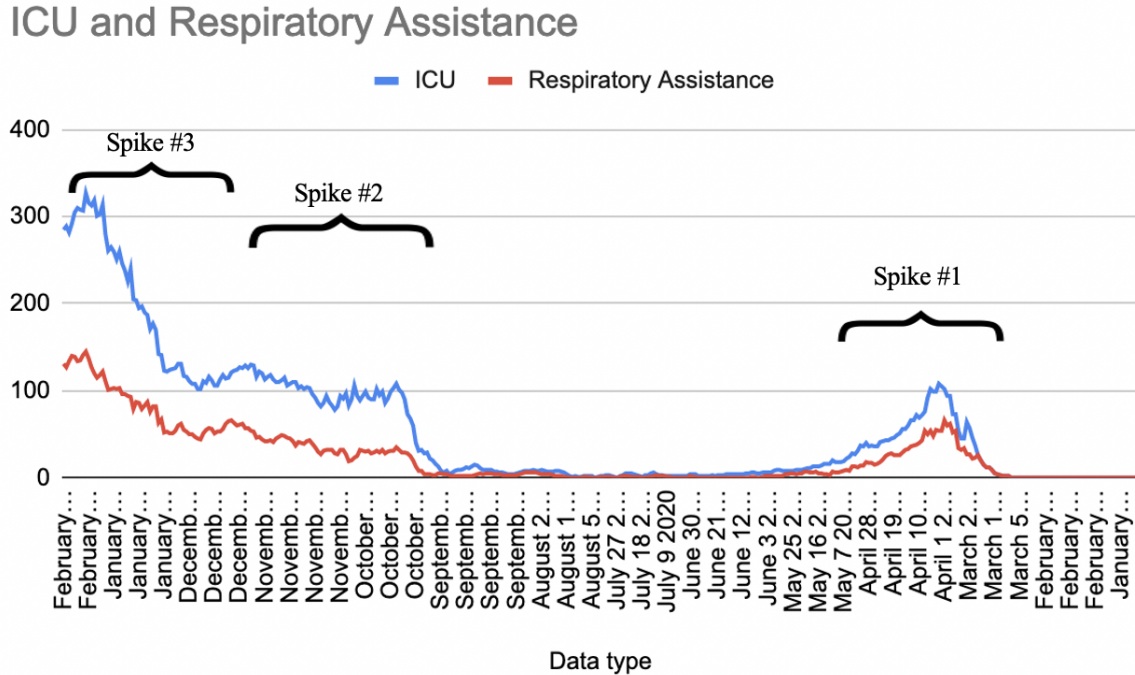


These graphs represent the data that was crosscorrelated with each other. The top six graphs show the Google mobility data with each graph representing the deviation from the baseline for each movement behavior category in percent changes from the months of March 2020 to January 2021. The graphs for each movement behavior category are labeled as follows: A. Workplaces, B. Residential, C. Retail and Recreation, D. Parks, E. Transit Stations, F. Grocery and Pharmacy. These data were each cross correlated with the ICU and respiratory assistance cases shown in the graphs labeled 1 and 2 with graph 1 showing the ICU cases and graph 2 the respiratory assistance numbers. Graphs 1 and 2 represent the timespan of these cases between the months of March 2020 to February 2021.

Severity of COVID-19 cases across waves. Another point of analysis is the percentage of total COVID-19 cases to the ICU and respiratory assistance numbers. The percentages were determined for an average of all total cases and ICU hospitalizations, with an average of around 23.7% for all cases since March 14th, 2020. This average, however, is not entirely accurate as each of Malaysia's waves of COVID-19 had differing percentages, and this heavily affects the average percentage of ICU cases in relation to total cases. The percentage of ICU cases from the total number of cases was then calculated in relation to the three spikes of hospitalizations. For the first spike of hospitalizations, the percentage of cases that were hospitalized was 50.89% and for the second spike: 10.87% and the third spike was 7.31%. During the first spike and the first wave in Malaysia, the highest daily count never reached above 235 cases. In contrast to this, the third wave that Malaysia experienced had a percentage of ICU cases to its daily cases of 7.31% a 14% decrease in the percentages but this third wave also had daily case counts as high as almost 6000 cases, although the ICU hospitalizations never reaching about 350 cases a day.

Interestingly, the average age of individuals who passed away due to COVID-19 remained constant at 64 for waves 2 and 3, and the majority of those individuals had a history of chronic disease. Patient data for wave 1 was not released by the Malaysian government, so no information could be gathered.

Figure 4: Comparison of ICU and Respiratory Assistance Data

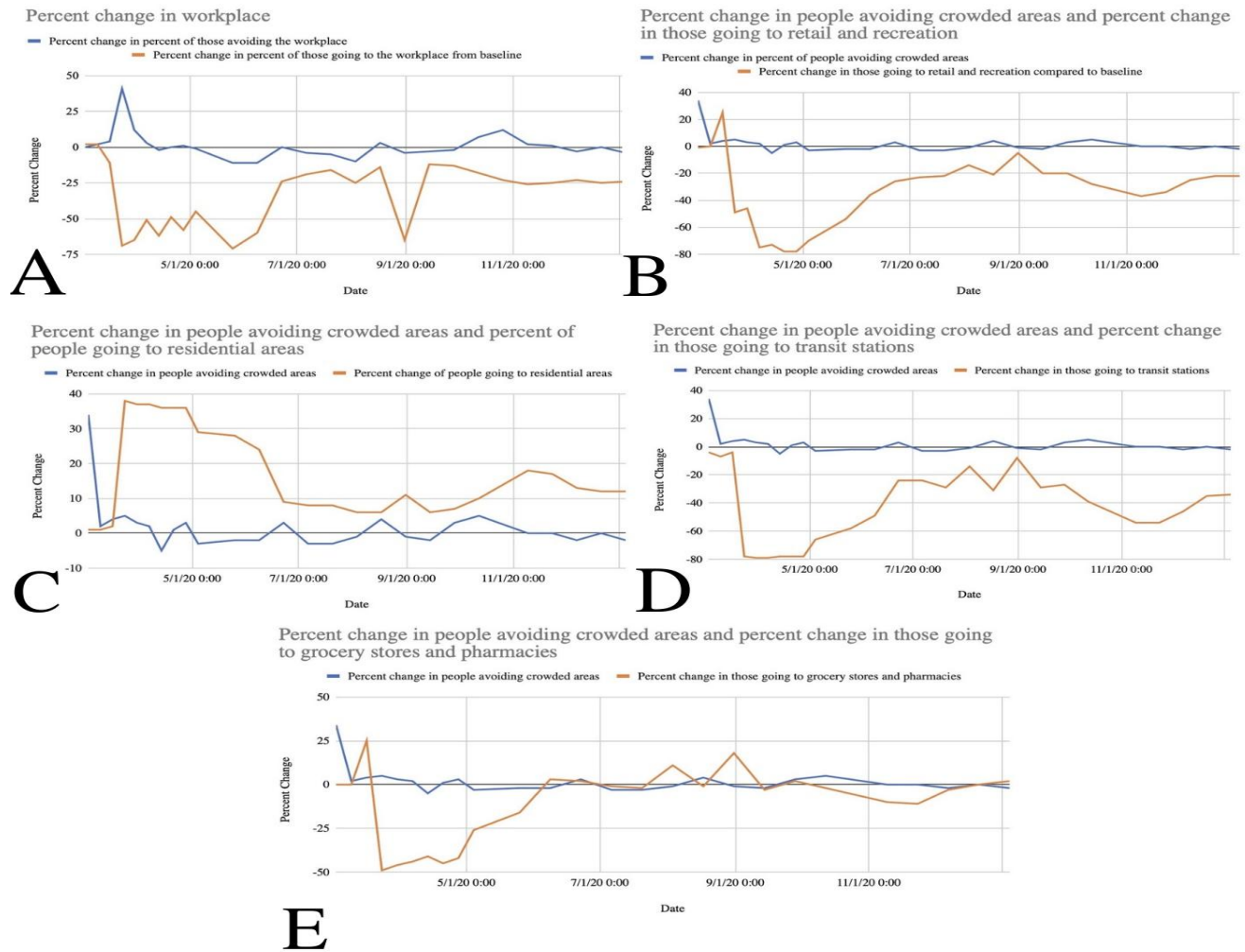


This figure shows the ICU and respiratory assistance cases graphed together using data starting from March 2020 and spanning until February 2021 and the three 64 day spikes that were used for statistical analysis as described above. The graph is in reverse chronological order.

Comparing percent change between mobility data and behavioral data. In comparing the change in the percent reported to be avoiding the workplace and percent change in mobility data of those going to work, it was found that there was a difference in magnitude. This difference mainly occurred around the 4th of May 2020 and continues until the 22nd of June of 2020 which is essentially time in between the waves. There are also several other dips and trends that do not correlate between the data sets, a problem that was magnified by the fact that the term “crowded area” is somewhat ambiguous, and it is hard to decipher what is defined as a crowded space. This prompted comparison of mobility data against the different changes in mobility data to different areas. The magnitude in differences between the change in percent of people avoiding crowded areas and the percent change of those going to retail and recreation as compared to baseline

suggest that people avoided retail and recreation much more than other crowded areas. The two data sets also do not correlate to spikes and shifts found within either graph. The next data set that was analyzed, was the percent change in those going to grocery stores and pharmacies. In comparing this data to the percent change in those avoiding crowded areas, there was little correlation found between the two data sets. However, there was one spot that correlated well. From 8/3/20 to 8/31/20, the trends align and demonstrate an increase in those avoiding crowded areas, with a decline in those going to grocery stores and pharmacies. Despite the general lack of correlation between the data sets, there are still some areas that show correlation. Although the overall picture portrays that while people avoided going to crowded areas, this did not necessarily strongly translate into grocery stores and pharmacies. There was also never a huge surge in those going to grocery stores as the level of those going stayed relatively consistent throughout the pandemic. Next, the percent change of those going to transit stations was analyzed against the percent change of those avoiding crowded areas. The graphs depicted few relationships between the two data sets, however, there is an area from 9/28/20 to 10/12/20 that demonstrates an increase in people avoiding crowded areas with a decline in people going to transit stations. There is little correlation between the two data sets and does not present a strong argument for correlation, however, it presents some form of causality. The last data set analyzed was the percent change in those going to residential areas. There is an initial correlation between the percent change in those going to residential areas and those avoiding crowded areas, however, this quickly changes as the percent change of those going to residential areas remains rather high while the percent change of those avoiding crowded places quickly declines. Finally, the data set of parks was not analyzed due to current research that supports that outside activity reduces COVID-19 transmission.

Figure 5: Comparison of Mobility Data and Behavior Data



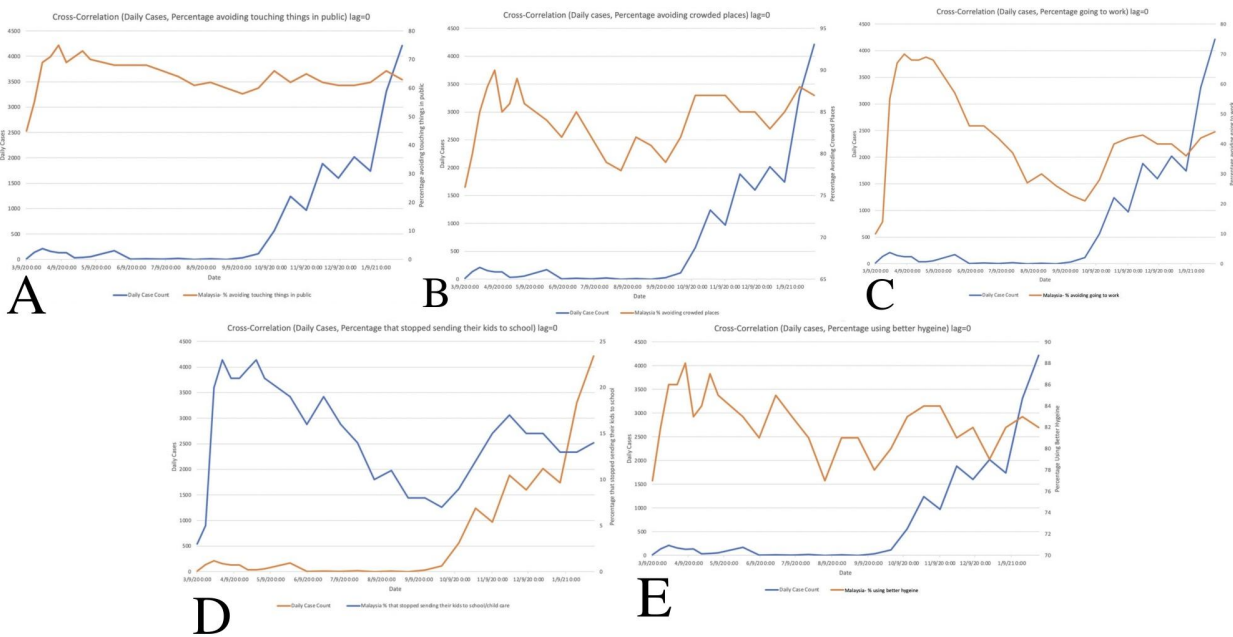
These graphs represent the deviations from baseline values in mobility data compared to the percent change in behavioral data from the months of March 2020 to January 2021. Graph A represents a comparison between the percent change of those going to work from the baseline and those avoiding the workplace. Graph B represents a comparison between the percent change in people avoiding crowded areas and the percent change of those going to retail and recreation from the baseline. Graph C represents a comparison between the percent change in people avoiding crowded areas and the percent change of people going to residential areas. Graph D symbolizes a comparison between the percent change in people avoiding crowded areas and people going to transit stations. Graph E represents the percent change in people avoiding crowded areas and the percent change in people going to grocery stores and pharmacies.

Cross-correlation between daily case count and behavioral data. In comparing behavioral data against the case count, a cross correlation test was utilized. It was first conducted without accounting for lag and it was found that there was a similar trend for a decrease in people

avoiding going to work with a significant increase in cases. However, it is known that for COVID-19, it usually takes 14 days for patients to see symptoms and get tested. Therefore, lag had to be considered to account for contraction time. From a correlation test for lag, it was determined that the maximum amount of correlation was found when lag was 2, or equal to two weeks because opinion polling data points are spread over a weekly basis. On the graph, it is shown that a steady decrease in percent avoiding going to work is met with a sharp increase in daily cases. While the maximum correlation value is somewhat low at 0.095567, it is still the highest at lag 2, indicating support for current findings of contraction time of about 2 weeks. Following this, daily case data was compared to the percentage of people avoiding touching things in public. When initially viewing the graph, the behavioral data is seemingly stable throughout the pandemic and does not have much correlation with the trends shown in daily case data. However, this contradicts the correlation value found at lag 4, 0.2853919, which is higher than the correlation found between daily cases and the percentage of those avoiding work. Next, a cross correlation test was performed between daily cases and the percentage of people avoiding crowded places. The highest correlation value was found at lag 0, 0.36273432, and demonstrates correlation between trends of both data sets. This is most explicitly seen around 9/28/2020 as a sharp decrease in those avoiding crowded places is seen with a sharp increase in daily cases. A cross-correlation test was then performed between daily cases and percentage of people using better hygiene. In initially viewing the graphs, there is a correlation between the increase of daily cases and decrease of percentage of people using better hygiene (and vice versa) starting at 9/28/20. During the test, it was found that the greatest correlation occurs at lag 3, 0.2558795, and demonstrates a relationship between hygiene and daily case counts. Finally, a cross-correlation test was performed between daily case numbers and the percentage of people who stopped

sending their children to school or daycare. During the test, it was found that lag 2, 0.0724662, was the highest value of correlation. While this value is not significant and points towards there being no correlation, it again conforms to the idea that COVID-19 takes about two weeks to incubate. However, it is seen in the data that there is no correlation between daily case counts and the percentage of those who stopped sending their kids to school or daycare.

Figure 6: Cross-correlation of Behavioral Data and Case Counts



These graphs represent the results of cross-correlation tests performed between daily case count and behavioral data at lag 0 from the months of May 2020 to February 2021. The graphs represent the daily case count and the following categories as follows: A. percentage of people avoiding touching things in public, B. percentage of people avoiding crowded places, C. percentage of people avoiding going to work, D. percentage that stopped sending their children to school, E. percentage that are using better hygiene. These datasets were cross-correlated with daily case counts to find optimal lag values and correlation.

Discussion

High effectiveness of MCOs. Malaysia has dealt with epidemics in the past including severe acute respiratory syndrome (SARS) in 2002-2003 and the Middle East Respiratory Syndrome Coronavirus (MERS-CoV) so it was well prepared for another outbreak. The country also has Universal Health Coverage (UHC) for the entire population of 32 million. The first cases of

COVID-19 in Malaysia were traced to Chinese officials that entered Malaysia after contact with an infected person in Singapore. Cases grew at a minimal rate with the government taking strict actions against international travel and doing extensive contact tracing. These measures were enough to completely contain the first wave within a month. With Sri Petaling occurring from February 27th, 2020 to March 1 however, cases in the capital city of Kuala Lumpur and all over Malaysia began exponentially increasing not long after wave 1 ended and marking the start of a second wave. Over 16,000 people attended Sri Petaling, about 1500 from neighbouring countries including Singapore, Cambodia, Indonesia, Thailand, and others. After Sri Petaling, Malaysia reported the most COVID-19 cases in Southeast Asia, with over 500 participants testing positive in the weeks after. The event not only was a superspreader for cases in Malaysia, but also caused increases in cases throughout the entire region. In addition, prime minister Yassin's rise to power under an ongoing national health crisis, economic recession, and continued opposition from other political leaders and parties, created political instability that further worsened the pandemic. The strictness of the initial MCO was powerful and effective in limiting the spread after the super-spreader Sri Petaling event. Preventing and limiting movement allowed the government to decrease chances of spread and allowed for better contact tracing in impacted individuals and communities. While the passing of further orders such as the CMCO and RMCO seemed to be effective methods of reducing virus spread while also returning the country back to some normalcy, these more lenient orders were eventually unable to control the spread of COVID-19 and increase in cases toward the end of the second wave as another major super-spreader event occurred.

In the beginning of the COVID-19 pandemic in Malaysia the strict MCO made a clear difference

in the rate of infection as compared to in the third wave. The strict orders resulted in as little as seven new cases a day throughout the summer leading into the end of September. However, the election campaign that took place on September 26th in Sabah led to a much worse outcome for the third outbreak due to the lack of strict orders that were put in place. With suggestions of expanding postal voting declined by election officials, the Sabah election period resulted in movement of voters living in Sabah and Sabah residents living in Peninsular Malaysia. Under these orders, citizens were still allowed to go out to restaurants, gather with others outside their house and hold religious gatherings until 2021. This, in combination with the people traveling to different states for the holidays, caused the virus to spread a lot faster than before. A state of emergency was placed into effect on January 12th until the end of August, but many thought this was just a way to cling onto power for Muhyiddin Yassin seeing as how elections wouldn't be able to take place until August. As of now the MCO have been enhanced towards interstate traveling, no social gatherings, and very minimal religious gatherings allowed which has helped in lowering the amount of COVID-19 cases following its peak in early January. However, by the time orders were put into place, daily cases had reached 5000 a day, an order of magnitude over the previous peak during wave 2. Overall we can conclude that the stricter the motion control orders were instrumental to lessening the amount of COVID-19 cases there were in each outbreak, particularly when implemented effectively and early into a wave. Additionally, it was important that political figures were seen following the motion control orders because it let the country know that they needed to take precautions as well.

Changes in COVID-19 severity over time. The high percentage of hospitalizations of the total cases in wave 1 could potentially be explained in multiple ways, with either the severity of the

cases being higher, the treatment methods being less developed, or the caution applied being higher due to the novelty of the disease at the time. Treatment of COVID-19 was not yet widely explored at the time and preventative measures for COVID-19 patients were not implemented yet, so that could have caused more susceptible patients to fall victim and require ICU and respiratory assistance treatment. There were relatively few COVID-19 cases in wave 1, which could have made the hospitalization numbers appear to be much higher as doctors were more concerned and could afford to house less serious patients in the ICU. However, since the percentage is so much higher than wave 2 and wave 3, it could be that the disease became less severe over time. The decrease in severity over time can potentially be due to mutations of Covid-19 or different age groups of people getting infected. [More discussion needed].

Implications of movement data. Contradictions in the comparison of polling and movement data, particularly at the end of wave 2, could be indicative of a lack of compliance with distancing guidelines by civilians in Malaysia, even if the perception was still the same. This decrease in compliance with social distancing could mean that companies demanded workers return in person, and that may have contributed to the rise of the third wave [citations needed]. Another possibility is that the data from YouGov could have been skewed towards more cautious individuals completing the survey. It is interesting to note that there was never a huge surge of those going to grocery stores, which may suggest that only a select population of individuals would repeatedly go to grocery stores. This could be a point of further research in this specific population and how their movement reflects greater daily case trends. As for residential data, there is not much correlation between that dataset and the amount of people going to crowded places, which demonstrates that the public does not deem traveling to residential areas as going

to a large gathering. This point could be analyzed in further research regarding the makeup of residential gatherings and how certain amounts of people or households can relate to an increase in daily cases.

Implications of polling data. While going to work may not be the only factor, the trends in the graph indicate some relationship with a general increase in cases when the percentage of people avoiding going to work decreases, although the correlation value is admittedly low. In fact, there was a higher correlation value for people avoiding touching surfaces; however, this could be the result of faulty data as it is much harder to track someone avoiding touching things in public as opposed to those avoiding going to work, explaining why the graph may not reflect the high correlation value. The highest correlation value occurs at lag 4 which also goes against the common idea that COVID-19 symptoms occur two weeks (lag 2) after exposure. This could call for further research to determine incubation times related to exposure through common surfaces. A longer lag, lag 3, was also found for better hygiene. While lag 3 contradicts the general idea that COVID-19 symptoms appear after 2 weeks, a third week could account for testing and for any misinterpreted data that is associated with the idea of having “better” hygiene. Lastly, the lack of correlation between cases and the percentage of people who stopped sending kids to school and daycare somewhat supports the idea that kids do not contract COVID-19 as readily as adults and addresses the possibility that school is not as much of a COVID-19 risk. However, further research must be done to determine if in-person schooling is safe enough to continue throughout a pandemic.

Conclusion

Malaysia's different movement control orders, more specifically the stricter measures of the MCO and the CMCO, were extremely important in controlling the spread of COVID-19 in the country, especially when enacted early after an outbreak. The passing of more lenient measures by the Malaysian government followed by super spreader events like the religious event Sri Petaling and the regional election in the state of Sabah led to new and more dangerous waves of the virus. The carelessness of politicians and election officials in the Sabah elections specifically and the resulting large and deadly third wave highlights the consequences of government negligence on public health and safety. Government negligence was found to translate to citizen negligence, as indicated by mobility data, which showed some correlation between the hospitalizations and movement to retail areas and transit. This is a strong suggestion for the increased movement of individuals creating a higher number of cases. The ICU and Respiratory assistance also show a significant difference between the different spikes since the start of the pandemic in Malaysia, implying that they could have been caused by differences in government management and restriction orders or other factors that leave room for further investigation. Interestingly, the percentage of ICU and respiratory assistance relative to total Covid-19 cases decreased in the months of December and January through the beginning of February. This apparent decrease in severity of disease may be due to less susceptible populations being exposed to the virus but not displaying severe symptoms. Between daily case counts and behavioral data, the strongest correlation was found with the percentage of people who avoided crowded spaces. This implies that the strongest factor towards creating trends within the daily count data is related to changes in the percentage of people avoiding crowded spaces. Finally, the

percent changes in mobility data and those who avoided crowded spaces was found to be most related to the percent of people going to residential areas.

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