Analytical Study of the Non-pharmaceutical Public Health Interventions to Control the Novel Coronavirus Disease 2019 (COVID-19)

Aseel Addawood[1][0000−0002−2247−1298], Sultanah M. Alshammari[2][0000−0003−0042−7429], Amal A. Alqahtani[3,4][0000−0002−1739−9025], and Amal A. Almansour[2][0000−0001−6689−4666]

[1] Information System Department, Imam Mohammad bin Saud University, Riyadh, Saudi Arabia
aaddawood@imamu.edu.sa
[2] Department of Computer Science, King Abdulaziz University, Jeddah, Arabia
{sshammari,aalmansour}@kau.edu.sa
[3] Department of Computer Science, George Washington University, DC, USA
[4] Department of Computer Science, King Saud University, Riyadh, Saudi Arabia
amalqahtani@gwu.edu

Abstract. The novel coronavirus disease (COVID-19) has spread rapidly all over the world, imposing severe preventive measures in many countries. These non-pharmaceutical interventions, such as travel restrictions, public closures, full curfew, and lockdown of cities, ensure social distancing manage to slow down the spread of the disease. The global impacts of these strict measures on humans and economies require an analytical assessment of their effectiveness. In this study, we provide a time-series analysis of the COVID-19 response for selected countries, including China, Italy, Iran, UK, USA, Taiwan, Singapore, and Saudi Arabia. In addition, correlating public response towards government's announcements about COVID-19 daily reports and the applied measures can be an indicator of the effectiveness of these measures. We gathered and analyzed social media official announcements for each country. We believe our results will provide insights into the epidemic control procedures and can assist the decision-makers in identifying the right time frame and scope to set or lift the different precautionary measures. The obtained analysis can contribute to improving country-based response to potential waves of COVID-19 and future disease outbreaks.

Keywords: Infectious diseases · Novel coronavirus · COVID-19 · Public health · Prevention measures · Social distancing interventions.

1 Introduction

On December 31, 2019, SARS-CoV-2, a novel coronavirus, has been identified to cause an acute respiratory disease (COVID-19) outbreak in Wuhan, China. Within a few weeks, the World Health Organization characterized COVID-19 as

a pandemic, with various rates of transmission in more than 110 countries [15]. Under uncertainty and limited time to contain this rapidly spread disease, governments in many affected countries had to enforce several non-pharmaceutical interventions [1, 2]. The implemented control measures include quarantine, travel restrictions, school closure, public lockdown, suspension or cancellation of major events, and curfew. The extent and the timing of these measures vary from one country to another. These measures help to prevent direct interactions among individuals to minimize the number of new COVID-19 cases and potential failure of the health care systems in some of the affected countries. However, due to their large economic and social implications, it is important to assess their expected impact of controlling the epidemic.

The analysis presented in this study compares different strategies that selected countries have taken in response to COVID-19. These countries were selected based on the number of COVID-19 cases in the early stages of the pandemic [3, 10] and how the applied measures managed to slow down the disease [17, 19]. Besides China, where the novel coronavirus discovered and the first COVID-19 outbreak started, we include the USA, Italy, UK, Iran, Singapore, Taiwan, and South Korea. We also compared our results with the COVID-19 response in Saudi Arabia. For each country, we study the correlation between the size of the epidemic, applied measures, and people's reactions towards COVID-19 official announcements and daily reports on social media.

Our study encompasses social distancing measures, travel restrictions, lockdown, isolation of confirmed COVID-19 cases and quarantine of suspected cases [21]. In addition to these non-pharmaceutical interventions we included widespread testing [23]. To analyze public reactions to country-based COVID-19 response in each country, we gathered data in one of the most well-known information sources during crises and public health emergencies, Twitter [20].

The obtained results in our study can provide insights into the epidemic control procedures and can assist the public health authorities, governments, and international organizations in identifying the right time frame and scope to set or lift the different precautionary measures. The findings can contribute to improving country-based response to potential waves of COVID-19 and future disease outbreaks.

2 Data and Methods

2.1 Country-based Response Data

Data was collected from publicly available international data sources on COVID-19 situation to create a profile for each selected country. Every profile includes daily numbers of COVID-19 confirmed cases, deaths, active, and recovery. For the COVID-19 daily updates, we collocated data in the early stage of the COVID-19 outbreak from January 23, 2020, until the end of April 2020. The timing of the main decisions of enforcing prevention measures in the COVID-19 response timeline was obtained from official published reports, official webpages, and social media accounts of the different government entities for each country.

To be able to understand the effects of prevention measures applied in the selected countries on the growth of the pandemic, we first identified four major non-pharmaceutical interventions used by most of these countries. These measures were implemented to restrict the interactions and movements between individuals and limit the spread of the disease. Literature and media may refer to several different applied strategies as one of these four measures. Therefore, we have identified these measures as follows [11, 12, 21]:

1. Travel restriction: Travel restriction to and from infected countries starting with China was the first countermeasure applied in many countries to prevent importing COVID-19 cases among arriving travelers. Travel restrictions is implemented to limit the movements of individuals between communities, states, or countries. Travel-related precautionary measures also include screening at entry points and border closures.
2. Case-based measures: One of most effective measures against COVID-19 spreading includes isolation and quarantine of individuals to restrict their interactions with others. While isolation is used to separate confirmed COVID-19 cases, a voluntary or mandatory quarantine is applied to presumed exposed individuals (e.g. contacts of COVID-19 confirmed case) or suspected cases (e.g. individuals arriving from infected countries).
3. Lockdown: Lockdown is an emergency practice of preventing people from entering or leaving a specific geographical area. Under this definition we consider schools closure, suspension of mass gatherings, workplace closures, public closures including closing malls, sport facilities, parks, and faith-based communities.
4. Social distancing: Social distancing is a precautionary recommendation of maintaining a physical distance of six feet or more from others to avoid direct contact with people during an outbreak of close-contact infectious diseases.

In addition to these measures, widespread COVID-19 testing is included for each country. Widespread of COVID-19 testing is implemented via drive-through testing stations to identify confirmed COVID-19 cases and trace their contacts. Widespread testing strategy combined with contact tracing proven to be successful in flatting the COVID-19 curve in countries such as South Korea and Taiwan [6]. Over the last few months, the countries have performed different forms of mitigation to limit the spread of the virus. Figure 1 summarizes the dates of imposing the main measures in each country, compared to the dates of reporting the first COVID-19 confirmed case and the first COVID-19-related death.

2.2 Twitter Data

We used Crimson Hexagon [9], a social media analytics tool, to collect public Twitter posts submitted by the official health ministry account for each country. Twitter data was collected from September 1, 2019, before the discovery of the

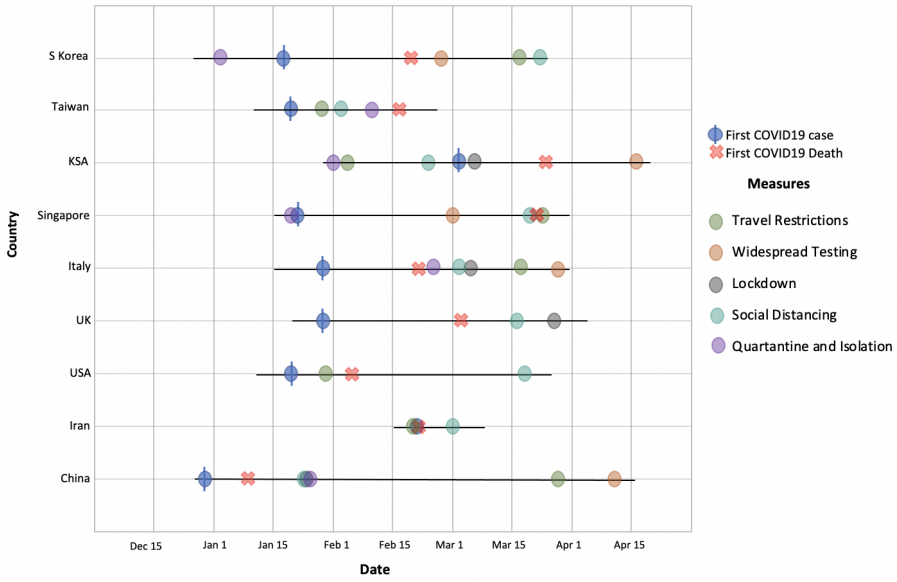

Fig. 1: Timeline of the major imposed measures per country showing the first COVID-19 confirmed cases and first COVID-19 fatalities in each country.

SARS-CoV-2 virus until 30, April 2020 after applying the prevention measures. We also collected the reaction to the posted tweets by each official account as a number of mentions and number of retweets. Table 1 lists the Twitter official accounts for each governmental entity in the selected countries. The variation in the number of posted tweets by each official Twitter account can be due to cultural differences and the preferable communication channels to share information with the public during such emergencies and health concerns [8].

2.3 Methodology

For social media analysis, each official twitter account was used to collect the number of retweets, tweets, and mentions between the time frame September 1st 2019 until 30 April 2020. To measure the social interaction happened for each twitter account we used a mathematical equation to measure the amount of interaction from the public towards these governmental accounts. Based on previous research [4], the number of mentions and the number of retweets can capture user engagements. In this paper, we measure online user engagements with governmental accounts for each country by using the below equation, where the social interaction is measured as the number of retweets (denoted by T) summed with the number of mentions (M) and divided by 2, [Equation 1]:

Table 1: Twitter accounts for governmental entities in the selected countries.

Twitter account	Twitter account description	Number of Tweets
@SaudiMOH	Ministry of Health in Saudi Arabia	1,396
@chinascio	State Council Information Office of China	937
@mohwpr	Ministry of Health and Welfare in South Korea	2,650
@MinisteroSalute	Ministry of Health in Italy	1,053
@HHSGov	U.S. Department of Health & Human Services	1,678
@Iran_GOV	Government of Islamic Republic of Iran	3,456
@sporeMOH	Ministry of Health in Singapore	448
@MOHW_Taiwan	Ministry of Health and Welfare in Taiwan	947
@DHSCgovuk	Department of Health and Social Care in UK	3,177

$$P(SocialInteraction) = (T + M)/2$$

While social media analysis conducted to provide insights into public reactions towards the implemented measures, we preformed a time-series analysis using epidemic forecasting tool [16] to assess the impact of these interventions on the effective reproduction number (R) in the selected countries. The epidemic forecasting tool calculates values of R based on epidemic growth data since the start of the epidemic. R represents the average number of new infections generated by each infected person. We compared the baseline values of R ($R_{baseline}$) which is the effective reproduction number after the first case occurrence and before applying any strict mitigation between [Feb 10th - Mar 25] to the current values of effective reproduction number ($R_{current}$) which represent the R values after the beginning of the epidemic by eight months until 23 August, 2020. $R_{current}$ reflect all mitigation measures taken and some of these measures have been reduced over time. We also compared the values of $R_{baseline}$ to the values of R after two months of introducing each measure. The value of R in most countries falls between 2 and 5. The results can be classified into 3 cases: if R is below 1, this means the number of new cases will decrease over time and the outbreak will end on it is own. If the value of R is around and slightly above 1, it means the cases are stable and the epidemic could be either shrinking or growing, but slowly. If the value of R is larger than 2, it means the outbreak is self-sustaining unless effective control measures are implemented [16].

3 Results

3.1 Social Media Reactions

Based on our proposed method to evaluate the public reactions to governmental announcements of prevention measures and health awareness of COVID-19 pandemic, we compared the collected Twitter data of the official accounts for

countries under study. The percentage of users who use social media in Singapore had the lowest number of tweets compared to other countries. Based on our analysis, the official account for Singapore did not start posting tweets until January 2020 which can be explained by the date of the first reported COVID-19 case in the country, the 24th of January. Since then the government started using Twitter more often to ensure effective communication with its population. China comes second in the number of tweets due to the fact that Weibo is more popular in China and used as the main outlet for transferring information instead of Twitter [22]. UK and Iran are among the highest in the number of cases compared to other countries in this study. Thus the two countries had the highest number of posted tweets from the government official accounts. Regardless of the number of posts in each country, we are more interested in the social interaction towards these posts, therefore we calculated the social interaction using equation 1, for each country. Figure 2 shows the monthly distribution of the social interaction measure.

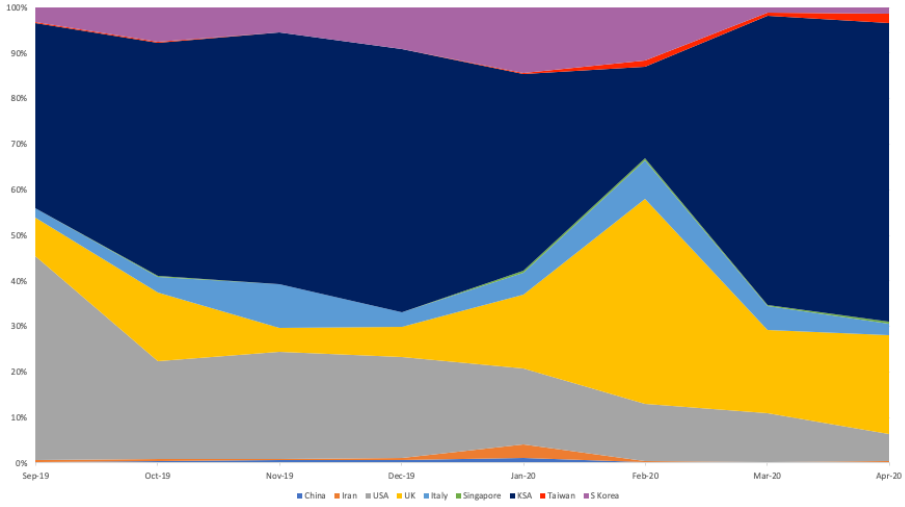

Fig. 2: Monthly distribution of the social interaction measure for each country.

According to the social interaction measure, Saudi Arabia (KSA) scores the highest interaction compared to other countries (Figure 2). This might be because Saudi Arabia is among the countries with the highest number of Twitter users among its online population [5, 18]. Moreover, Saudi Arabia is producing 40% of all tweets in the Arab world [14]. The amount of interaction with the account almost doubled in March 2020, that might have happened since the first case in Saudi Arabia was in March 2nd 2020. Singapore comes in last in the amount of interaction with its governmental account, where the interaction did

not start until the account was active in sharing tweets on January 2020 after the first case happened in that month. people started interacting with the accounts tweets by retweeting and mentioning the account. The interaction escalated since that month.

As the number of cases is grown in each country and the first death emerged, the measure of interaction increases, we can see that in the UK, South Korea and Italy. There were two countries were this did not apply, China and Iran. In these two countries, the changes in cases did not effect the social media interaction as it did with other countries, where the amount of interaction doubled and even tripled. This might have happened because citizens of these countries do not mobilize Twitter as their main source of information as other countries.

3.2 Time Series Analysis of COVID-19

Table 2 show the time-series analysis of COVID-19 among the seven different countries based on the values of the effective reproduction number, R, over time. Moreover, the R after each prevention measure is shown in the table 2. One of the limitations associated with epidemic forecasting tool [16] is that the values of effective reproduction number R for China and Taiwan are not available.

According to listed values in table 2, it can be clearly observed that $R_{baseline}$ value is the highest for USA, which means that the growth data is rapid since the start of the epidemic; whereas the value of $R_{baseline}$ for Singapore is the lowest, and this means that the epidemic is growing, but slowly. The $R_{baseline}$ values for both UK and Italy are more than 2, which is considered to be high. However, we notice a decreasing in the values of $R_{current}$, which represent the effective reproduction number after applying the mitigation, for all the countries comparing to theirs $R_{baseline}$. The values of $R_{current}$ for all countries are between 0.52 and 1.71. We can infer here that the correlation is positive between applying prevention measurements in these countries and the decreased values in the effective reproduction number. We also can conclude that people have practiced and followed these measures effectively.

Table 2 summarized the obtained results of $R_{baseline}$ and the values of R_{TR} (Travel restriction measure), R_{SD} (Social distancing), R_{LD} (Lockdown), and R_{WT} (widespread testing). We can see that the values of R_{LD} for both UK and Italy, 0.85 and 0.73, have been decreased which indicates that lockdown has an effect on $R_{baseline}$ for both countries. We can observe that both travel restriction and social distancing measures have a great impact on $R_{baseline}$ for both Italy and Singapore. There was a dramatic decrease in value of $R_{baseline}$ for South Korea from 1.89 to 0.54 after two months of applying the widespread testing measure. Generally speaking, we can say that introducing the social distancing measure plays a crucial role in reducing the value of $R_{baseline}$ for many countries such as USA, UK, Italy, Iran, and Singapore, and this is inline with previous studies results [7],[13].

Table 2: The time-series analysis of COVID-19 by using the effective reproduction number, R.

Country	$R_{baseline}$	R_{TR}	R_{WT}	R_{LD}	R_{SD}	$R_{current}$
China	NA	NA	NA	NA	NA	NA
USA	**3.70**	1.98	-	-	**0.93**	**0.91**
UK	2.52	-	-	**0.85**	**0.82**	1.08
Italy	2.56	**0.70**	**0.71**	**0.73**	**0.78**	1.41
Iran	2.01	-	-	-	**0.82**	0.97
South Korea	1.89	1.27	**0.54**	-	1.13	1.71
Saudi Arabia	2.22	1.36	1.30	1.18	1.47	**0.93**
Singapore	1.74	**0.89**	1.10	-	**0.91**	**0.52**
Taiwan	NA	NA	NA	NA	NA	NA

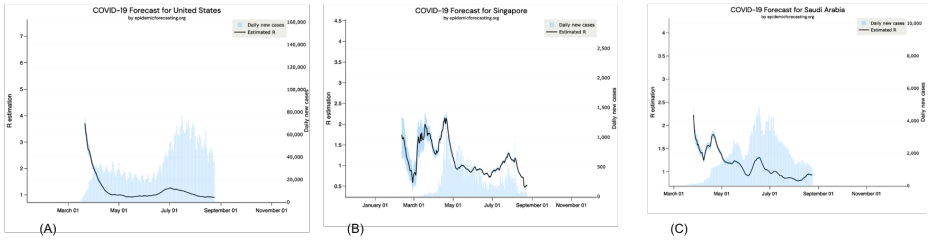

Fig. 3: The time-series analysis of COVID-19 in some of the selected countries (A) US, (B) Singapore, and (C) Saudi Arabia.

4 Conclusion

In response to the COVID-19 pandemic outbreak, many countries around the world have imposed strict measures and regulations in an attempt to mitigate and slow the spread of the new coronavirus. In this research, we examined the impact of COVID-19 prevention measures for selected countries, including China, Italy, Iran, UK, USA, Taiwan, Singapore, and Saudi Arabia in two different directions. (1) Quantifying the public reactions on Twitter regarding the governmental announcements of prevention measures.(2) Studying the relation between applying prevention measurements and the values of the reproduction number (R). Based on the presented results, we noticed that official twitter accounts for countries with higher number of cases as the UK and Iran generated many tweets compared to other countries. As the COVID-19 case count increased, these governments escalated its warnings and the sharing of information with their populations. According to the results of social interaction, Saudi Arabia users were the most active engagers and distributors of social media content during the examined pandemic time frame. These findings suggests that there might be a positive correlation between the number of cases of COVID-19 and the number of generated tweets and interactions.

Using time-series analysis of COVID-19, we identified that there is a positive correlation between applying prevention measurements and the values of the reproduction number (R) over time. Among the different government polices, the widespread testing measure has the great impact in decreasing the value of the reproduction number (R) as in the case of South Korea. In future work, we will study the correlation between the daily number of public generated tweets with each governments' measures and actions to indicate the most polices and measures that attract the public. Further analysis will be conducted in the content of the posted tweets by investigating the public sentiment against each governmental measures and announcements.

References

1. Anderson, R.M., Heesterbeek, H., Klinkenberg, D., Hollingsworth, T.D.: How will country-based mitigation measures influence the course of the covid-19 epidemic? The Lancet **395**(10228), 931–934 (2020)
2. Bedford, J., Enria, D., Giesecke, J., Heymann, D.L., Ihekweazu, C., Kobinger, G., Lane, H.C., Memish, Z., Oh, M.d., Schuchat, A., et al.: Covid-19: towards controlling of a pandemic. The Lancet **395**(10229), 1015–1018 (2020)
3. Boccia, S., Ricciardi, W., Ioannidis, J.P.: What other countries can learn from italy during the covid-19 pandemic. JAMA internal medicine (2020)
4. Cha, M., Haddadi, H., Benevenuto, F., Gummadi, P.K., et al.: Measuring user influence in twitter: The million follower fallacy. Icwsm **10**(10-17), 30 (2010)
5. Clement, J.: Countries with most twitter users 2020 (Feb 2020), https://www.statista.com/statistics/242606/number-of-active-twitter-users-in-selected-countries/
6. Cohen, J., Kupferschmidt, K.: Countries test tactics in 'war'against covid-19 (2020)
7. Courtemanche, C., Garuccio, J., Le, A., Pinkston, J., Yelowitz, A.: Strong social distancing measures in the united states reduced the covid-19 growth rate: Study evaluates the impact of social distancing measures on the growth rate of confirmed covid-19 cases across the united states. Health Affairs pp. 10–1377 (2020)
8. Ding, H., Zhang, J.: Social media and participatory risk communication during the h1n1 flu epidemic: A comparative study of the united states and china. China Media Research **6**(4), 80–91 (2010)
9. Etlinger, S., Amand, W.: Crimson hexagon [program documentation]. Retrieved September **15**, 2016 (2012)
10. Khafaie, M.A., Rahim, F.: Cross-country comparison of case fatality rates of covid-19/sars-cov-2. Osong Public Health and Research Perspectives **11**(2), 74 (2020)
11. Linka, K., Peirlinck, M., Sahli Costabal, F., Kuhl, E.: Outbreak dynamics of covid-19 in europe and the effect of travel restrictions. Computer Methods in Biomechanics and Biomedical Engineering pp. 1–8 (2020)
12. Mboera, L.E., Akipede, G.O., Banerjee, A., Cuevas, L.E., Czypionka, T., Khan, M., Kock, R., McCoy, D., Mmbaga, B.T., Misinzo, G., et al.: Mitigating lockdown challenges in response to covid-19 in sub-saharan africa. International Journal of Infectious Diseases **96**, 308–310 (2020)
13. McGrail, D.J., Dai, J., McAndrews, K.M., Kalluri, R.: Enacting national social distancing policies corresponds with dramatic reduction in covid19 infection rates. PloS one **15**(7), e0236619 (2020)

14. Mourtada, R., Salem, F.: Citizen engagement and public services in the arab world: The potential of social media. Arab Social Media Report series, 6th edition, June (2014)
15. Organization, W.H.: Coronavirus disease 2019 (covid-19): situation report, 51 (2020)
16. Oxford: Epidemic forecasting: Covid-19 (2020), http://epidemicforecasting.org/country-rt-estimates
17. Prem, K., Liu, Y., Russell, T.W., Kucharski, A.J., Eggo, R.M., Davies, N., Flasche, S., Clifford, S., Pearson, C.A., Munday, J.D., et al.: The effect of control strategies to reduce social mixing on outcomes of the covid-19 epidemic in wuhan, china: a modelling study. The Lancet Public Health (2020)
18. Puri-Mirza, A.: Saudi arabia: Number of internet users 2023 (Feb 2019), https://www.statista.com/statistics/462959/internet-users-saudi-arabia/
19. Tang, B., Xia, F., Bragazzi, N.L., Wang, X., He, S., Sun, X., Tang, S., Xiao, Y., Wu, J.: Lessons drawn from china and south korea for managing covid-19 epidemic: insights from a comparative modeling study. medRxiv (2020)
20. Thomas, T.L., Schrock, C., Friedman, D.B.: Providing health consumers with emergency information: A systematic review of research examining social media use during public crises. Journal of Consumer Health on the Internet **20**(1-2), 19–40 (2016)
21. Wilder-Smith, A., Freedman, D.O.: Isolation, quarantine, social distancing and community containment: pivotal role for old-style public health measures in the novel coronavirus (2019-ncov) outbreak. Journal of travel medicine **27**(2), taaa020 (2020)
22. Zhang, L., Pentina, I.: Motivations and usage patterns of weibo. Cyberpsychology, Behavior, and Social Networking **15**(6), 312–317 (2012)
23. Zitek, T.: The appropriate use of testing for covid-19. Western Journal of Emergency Medicine **21**(3), 470 (2020)