Effectiveness of COVID-19 Pandemic Prevention: A cross-country Comparison of Digital Footprint of Google Search Data

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Abstract

The COVID-19 has been categorized as a pandemic on March 11, 2020, and caused tremendous damage to global health and economics. However, the situation of COVID-19 spread varied by country. With the features of high infectivity and uncertainty, earlier public perceptions of epidemic prevention play a vital role in combating the COVID-19. Thus, the study aims to capture the public epidemic awareness by using the digital footprint of public's searches for "face mask" on Google search engine as a real-time measurement and examine its effectiveness of epidemic prevention by comparing Taiwan, Singapore, Philippine, Italy, Spain, and South Korea. The data of Google search volume of face masks from Google Trend and confirmed cases of COVID-19 between December 31, 2019, and March 17, 2020, were collected. By tracing the digital footprints across countries, our findings indicated that public epidemic awareness varies by country. The early increasing and maintaining public epidemic awareness are crucial for epidemic prevention. Moreover, the study elaborated on how public epidemic awareness raises and keeps in Taiwan. The study highlighted the importance of using digital footprints for establishing an early warning system for the government by trancing the public's attitudes and response to emerging infectious diseases. The implication of the Google search volume index could be used for the government to implement health service management based on timely information. In the era of big data, countless online digital footprints are waiting to be gathered and analyzed to enhance an existing or create a new service.

Keywords: COVID-19, cross-country comparison, epidemic prevention, digital footprint, Google search volume, Taiwan.

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1. Introduction

1.1   Slowing down the global spread of COVID-19 pandemic is a necessity

Coronavirus disease 2019 (COVID-19) has spread worldwide. Since the World Health Organization declared the COVID-19 outbreak to be a global pandemic on March 11, 2020, the total numbers of the confirmed cases and the deaths of COVID-19 are growing exponentially (Roser, Ritchie, amd Ortiz-Ospina, 2020). According to the WHO COVID-19 situational report 71 (WHO, 2020), as of March 31, more than 170 countries and territories have been affected in less than three months, resulting in a total of 750,890 confirmed cases and 36,405 deaths. In addition to Asia, the pandemic in Europe and the Americas are becoming increasingly severe. This has a dramatic impact on the health of citizens worldwide and makes it more difficult for governments to prevent a pandemic. When pandemic prevention and the economy stand at opposite ends of the scale, finding a balance is the biggest challenge for governments.

All countries are in a race against time. Effectively reducing the "rapid" spread of the pandemic has become the primary goal due to the potential threats of high case fatality rate and the global economic crisis (Fernandes, 2020). As reported by the WHO situational report 71, the rapid increase in confirmed cases and relative high case fatality rate of COVID-19 were found in Italy (11.4%) and Spain (8.6%) (WHO, 2020). It implies that the rapid spread of the COVID-19 under limited medical resources is a serious threat to public health.

However, when facing the emerging infectious disease, the government's COVID-19 response plan often fails to catch up with the pandemic spread due to its uncertainty. Since the initial outbreak of COVID-19, we have repeatedly renewed our understanding of the infectivity and clinical features of COVID-19 (delRio and Malani, 2020), such as from no evidence to with evidence of human-to-human transmission. Additionally, asymptomatic or mild carriers have been recently found to be infectious (Gates, 2020). Considering these non-specific features of the disease, in addition to governmental measures, public epidemic awareness, and early preventive measures, play a critical role in initial infection prevention and control.

1.2   The digital footprints of public epidemic awareness with Google search volume index

Today, above half of the global population is using the Internet as of January 20, 2020 (Clement, 2020). Countless digital footprints were left behind by users consciously or unconsciously or on digital services such as IP addresses, browsing, and searching records, posting, and so on. These digital footprints provide valuable information about the individual's behaviors, characteristics, and preferences (Arakerimath and Gupta, 2015). In the literature on health care research, digital data have been widely applied to facilitate the current health services in multifaceted domains, including but not limited to detecting disease outbreak, clinical decision support, genomics and personalized care (Aiello, Renson, and Zivich, 2020; Saranya and Asha, 2019).

Regarding the infectious diseases, Google Trend has been recognized as a new method for surveilling the outbreak of disease and reflecting general population behaviors (Alicino et al., 2015; Cook, Conrad, Fowlkes, and Mohebbi, 2011; Nuti et al., 2014). Scholars have found that disease-related (Ebola) relative search volumes with the number of weekly and overall Ebola cases (Alicino et al., 2015). These findings imply that the Google search volume index data of disease information-seeking behavior can be utilized as an indicator of the prediction of influenza outbreaks. While traditional cross-sectional telephone survey for measuring public perceptions of infectious disease provided valuable information (DeZwart et al., 2009; Rubin, Amlôt, Page, and Wessely, 2009), this method might be unable to inform policies immediately and continuously due to the time-consuming process and cost-effectiveness. Therefore, more and more researchers started to extract valuable information from the digital footprint data underneath the vast database.

Given that the individual's motivation for self-protection behaviors is associated with one's perceived threat and risk perception (Witte and Allen, 2000), understanding the public's attention, attitudes or responses to emerging infectious disease is an essential reference for the government's formulation of emerging measures. In addition to the search term of the name of infectious diseases such as H1N1 and Ebola, which were used for the surveillance of disease outbreak, the study regarded the behavior of online searches for the word "face masks" to be an indicator of public epidemic awareness. While both search terms potentially reflect public epidemic awareness, to some extent, the motives for searching for "face masks" and the name of infectious disease are different. Driving people to search for face masks is the public perception of the threat of COVID-19 and a desire to understand how to protect themselves correctly. It seems that the former has stronger motivation for self-protection and provides more information on public epidemic prevention than the latter. Notably, as related treatment drugs and vaccines for COVID-19 are still under clinical trials (delRio and Malani, 2020), face masks have become necessary personal protective equipment for managing the COVID-19 pandemic (Feng et al., 2020).

Taiwan has demonstrated the resilience of epidemic prevention in the past three months. As of March 31, 2020, there were 322 confirmed cases of COVID-19 in Taiwan. Of the confirmed cases, 276 are imported, and 46 are indigenous (TCDC, 2000a), revealing that local transmission was effectively contained thus far. Regarding the total confirmed cases of COVID-19, Taiwan ranked 77th worldwide according to the Database of COVID-19 at Our World in Data website (Roser et al., 2020). Thus, this study aims to extend the literature by showing how the digital footprint of the public's web search behaviors for "face mask" could be treated as important information of public epidemic awareness and how it associates with the effectiveness of epidemic prevention during the course of COVID-19 spread in Taiwan. Additionally, the cross-country comparison data were also provided.

2. Methodology

The COVID-19 pandemic has caused tremendous damage to global health and economics. One of the purposes of the study is to see what we can learn from the past (before the world gets into a worse and uncontrollable situation) by measuring the public epidemic awareness and its effectiveness of epidemic prevention in the initial outbreak and spread of COVID-19. Thus, the research scope of time is between December 31, 2019 (the initial outbreak of COVID-19) and March 17, 2020 (one week after COVID-19 was recognized as a pandemic).

2.1   Sample selection

The study first opted for countries outside China and screened countries that had resisted the COVID-19 epidemic for more than 40 days from the date that the countries identified the first confirmed case of COVID-19 to March 17, 2020. Moreover, to select countries representing different epidemic spread conditions, the top three countries with the highest average daily confirmed cases were selected, including Italy (595), Spain (199), and South Korea (146) during the period. On the other hand, apart from Taiwan, the Philippines, and Singapore were selected due to their similar features of low average daily confirmed cases (below 5) and high population density (above 350 residents per square kilometer) with Taiwan during the period.

2.2   Data collection and analysis

The daily total confirmed cases of COVID-19 and the Google search volume of "face mask" were collected through the website of Our World in Data (Roser et al., 2020; https://ourworldindata.org/coronavirus) and Google Trend, respectively.

Google Trend, a free web online tool provided by Google Inc, was used to capture the public epidemic awareness in the study. Google Trend allows users to analyze the relative popularity of search queries for given topics or terms based on Google Search engine data across various regions and languages. To illustrate the relative popularity, each data point is divided by the total searches of the geography and time range it represents to compare relative popularity. The resulting numbers (i.e., Google research volume) are then scaled on a range of 0 to 100 based on a topic's proportion to all searches on all topics

(Google Trend, 2020; https://support.google.com/trends/answer/4365533?hl=zh-Hant&ref_topic=6248052).

In the study, the Google search volume of "face mask" from each country was collected separately by using its official language. Each data point is the query share of a particular term for a given country and time period. However, it is hard to easily compare each data point (within a country) across countries. For better illustration of comparison within and across countries, we rescaled each data point by dividing by the mean of Google search volume of "face masks" from December 31, 2019, to January 9, 2020 (the base). By doing so, it is easier to compare the change of searches within a country and across countries by looking at the multiples. After

this, a time-series graph (Figure 1) was provided to depict the growing number of confirmed cases and the change of Google search volume of face masks in those six countries. It should be noted that Figure 1 did not provide any information about the comparison of the total search volume of face masks among countries.

3. Results and Discussion

These are the main results of the paper.

Sections and subsections should be numbered as 1, 2, etc. and 1.1, 1.2, 2.1, 2.2 respectively. Capital letters should be used for the initial letter of each noun and adjective in the section titles, the section should be formatted as left, bold, times new roman, and 15pt font size. For subsection (left, bold, times new roman, and 14pt), the initial letter of first word should be capitalized. And also similarly for other sub-subsections (left, bold, times new roman, and 12pt).

3.1 Rapidly increasing and maintaining public epidemic awareness effectively prevents its spread

Figure 1 indicates that, after the first confirmed case was announced in the Philippines (1/30), Singapore (1/24), and Taiwan (1/21), the Google query volume of face masks soared on the same day (Figure 2). Moreover, the searches for face masks kept increasing and maintaining at a relatively high peak around ten times more than the base for a while. The three countries are also in the group of countries with low average daily confirmed cases. It implies that public epidemic awareness in the three countries raised, and people might take proper precautions to avoid infection.

While residents in South Korea reacted slowly comparing to the three countries in terms of the search for "face masks" (Figure 2), the COVID-19 epidemic seemed to slow down (from February 7 to 19; Figure 1) after a sharp increase in Google search volume of face masks and the maintenance of a relatively high peak for an extended period (since January 27; Figure 2).

In Italy, while a high peak appeared when the first confirmed cases of COVID-19 was found (January 31). The public's searches for face masks went back to the base quickly (Figure 2). By contrast, in Spain, it seemed that there was no significant increase in the Google search volume of face masks in the initial COVID-19 arrival (February 1). The two countries, in group of countries with high average daily confirmed cases, have been hit severely by the COVID-19. These findings shed light on the potential differences in how people or government responds to the occurrence of the first confirmed case.
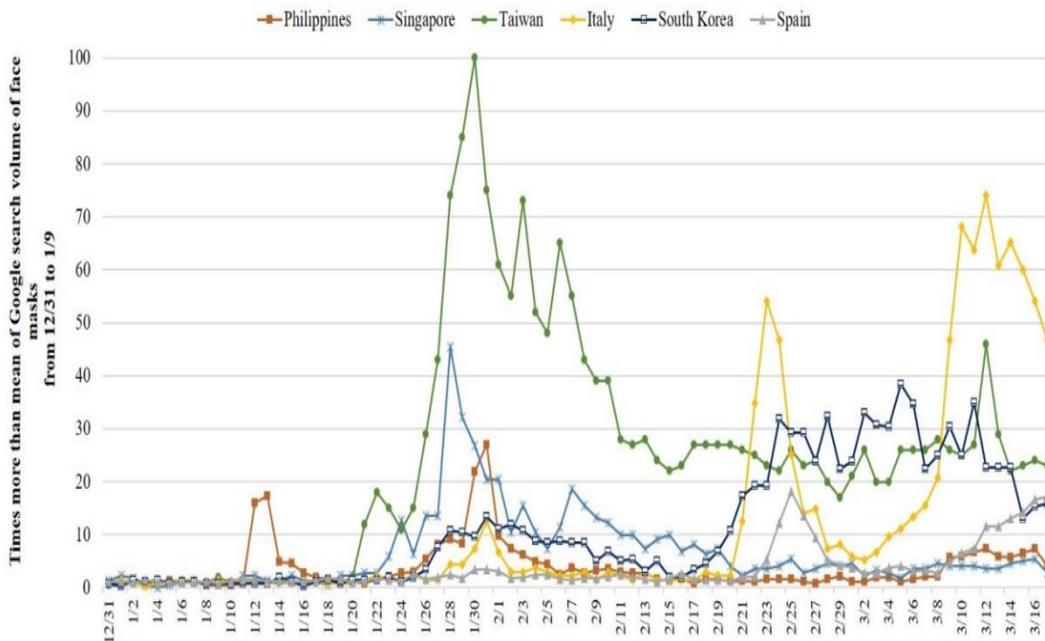
Figure 1: Trends of Google query volume of face masks in the Philippines, Singapore, Taiwan, Italy, South Korea, and Spain.
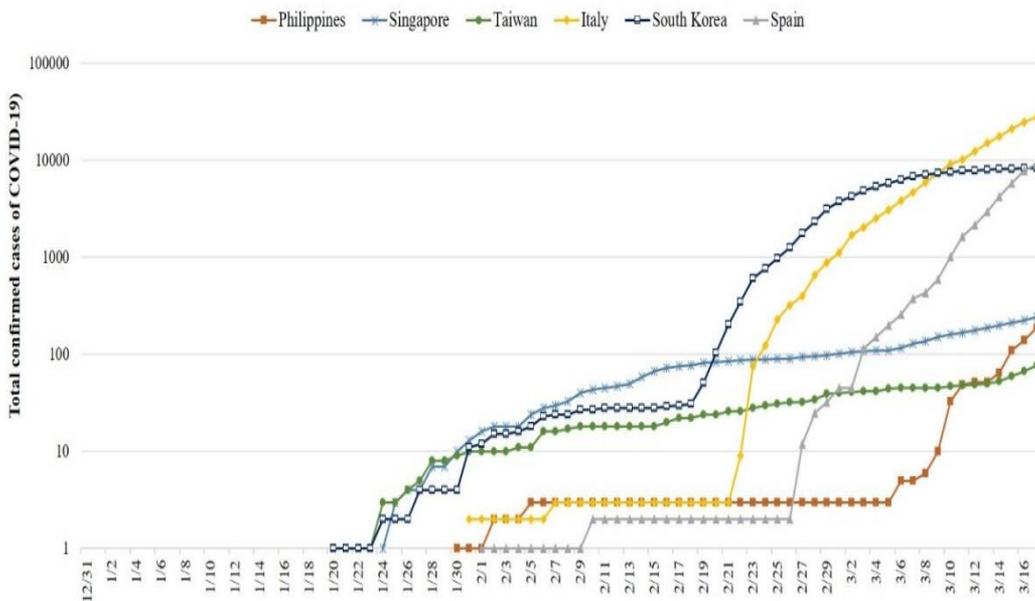

Figure 2: Trends of total confirmed cases of COVID-19 in the Philippines, Singapore, Taiwan, Italy, South Korea, and Spain.

3.2   A decline in Google search volume of face masks and the "re-outbreak" of COVID-19 pandemic

Not only is the earlier rise of public epidemic awareness substantial, but staying at a high level of it plays a crucial role in combating COVID-19. In South Korea, when Google query volume of face masks gradually reduced to a low point (February 17), large-scale confirmed cases reappeared (February 19). This turning point of the pandemic is related to the super-spreading event in the central city of Daegu, Korea. Moreover, a similar situation happened in the Philippines. The search for face masks soared after the first confirmed cases were founded, but it gradually dropped to a low point, and then a great number of confirmed cases of COIVD-19 has appeared. The two countries shared the same feature in the period that the public's search for face mask has dropped. That is no or minor increase of confirmed cases of COVID-19 during the time. This might also be the reason for the no enhancement of Google search volume of face masks in Italy and Spain in the initial stage of the COVID-19 epidemic. These findings hint us that public epidemic awareness seemed to be induced only when they receive the information of new confirmed cases. Previous findings also indicated that the correlation between disease-information seeking behaviors and new confirmed cases of emerging infectious disease (Alicino et al., 2015). However, no confirmed cases did not guarantee that there is no pathogen carrier in the country or no possibility of getting an infection. Our results indicated that once the public starts to relax and lose their alertness, the probability of the outbreak will increase.

The reported cases on a particular day do not necessarily represent new cases on that day. From the testing to the report, it requires several procedures, including but not limited to laboratory diagnoses, the communicating of results between the laboratory and the health departments of government, the investigation of a case such as the travel history or close contacts, and reporting by the government. Additionally, the delay between symptom onset and isolation played a critical role in determining whether the outbreak is controllable or not (Hellewell, 2020). Unfortunately, the information might not be understood by the public, and the response to COVID-19 varied by counties, depending on a government's attitudes toward the seriousness of the COVID-19.

3.3   The story behind the continuous and high public epidemic awareness in Taiwan and the effectiveness of epidemic prevention

In Figure 1, the trend of Google search volume of face masks in Taiwan was quite different from the other countries. In addition to the highest search volume reached one hundred times more than the base, the search volume of face mask has kept being relatively high level with at least around twenty times more than the base since January 26, 2020 . It indicated that the public in Taiwan had kept focusing on the topics of face mask, symbolizing that the high public epidemic awareness for the whole period. The dramatical face masks online information-seeking behaviors potentially reflect the Taiwanese public's fear and alertness to COVID-19. However,

what the reasons make Taiwan a special case with a continuously high search volume of face masks and effectiveness of epidemic prevention.

The initial massive searches for face mask might be related to the event of the severe acute respiratory syndrome (SARS) with a total of 346 confirmed cases of SARS and a high fatality rate of 10.7 percent (TCDC, 2004). The miserable memories of SARS potentially increase Taiwanese's risk perception of the severity of COVID-19. Previous findings have suggested that a person's perceived severity can affect one's protective behaviors (DeZwart et al., 2009; Rubin, Amlôt, Page, and Wessely, 2009; Witte and Allen, 2000). Another evidence to support this argument of the motives of buying face masks for Taiwanese is the face mask-related search term in Google engine. In the first two weeks since the arrival of COVID-19 (January 21), the related terms such as "where to buy," "surgical," and "n95" had appeared among the top five face mask-related queries. The perceived threats might be an explanation of the initial high public epidemic awareness in Taiwan.

Regarding the maintenance of high search volume, it might come from the government's great emphasis on ongoing responses to the COVID-19 since the government received the information of unknown pneumonia cases in China on December 31, 2020 (Wang, Ng, and Brook, 2020). For example, Government in Taiwan has successively formulated many face mask-related policies to respond to public's panic buying of face masks in Taiwan (Chang, Pan, Ku, and Joseph, 2020), including but not limited to enacting a month-long export ban on surgical and N95 masks (Yang, 2020), requisitioning of medical and surgical mask produced by domestic mask manufacturers (Everington, 2020a), expending the two former countermeasures (Chuan, Yeh, and Chiang, 2020), adding production lines of face masks (Lin, 2020), enactment, implement, and upgrade of name-based rationing system of face masks (Everington, 2020b; TCDC, 2020b), and cooperation with the public to create open data application such as Face Mask Maps (Lee, 2020).

By adopting the methods of unified collection, allocation, and price, and stipulated a purchase, these emergency measures effectively reduce the public's anxiety aroused by snapping up masks. Moreover, it also ensures that the Taiwanese are protected from other people's hoarding of goods and to avoid the more significant social burden caused by those who intend to drive up prices. The reduction of anxiety could be reflected by the decrease in Google search volume of face mask from one hundred times to near twenty times more than the base after the implementation of a name-based rationing system on February 6, 2020. Moreover, according to the change of top five face mask-related queries and rising queries, the related terms started to appear the term such as "name-based rationing system," "2.0 (means the new version of rationing system)," and "map". These terms are associated with government policies, indicating that the government's policy had successfully transmitted to the public and dominated the public's attention on the face mask, which indirectly maintained the public epidemic awareness. Therefore, Taiwan's success in pandemic prevention might be attributed to the citizen's self-discipline in epidemic prevention and willingness to comply with government policies. In short, proper risk communication by showing the government's attitudes

toward the COVID-19 plays a role in enhancing public epidemic awareness, which in turn, helps Taiwan to prevent infection effectively.

4. Conclusion

Making a policy or strategic decision for a government must rely on sufficient scientific evidence to make it more effective. In the face of an emerging infectious disease such as COVID-19, the challenge for the government's ability to deal with crisis management is even tough since decision making must be valid and fast. As COVID-19 pandemic rapidly spread worldwide with the features of high infectivity and uncertainty, the public involvement in combating the COVID-19 is urgently needed. Hence, the rise of global epidemic awareness plays a vital in containing the rapid spread of COVID-19 and pandemic prevention, especially in an earlier stage. Our findings suggested that the Google search volume index might be one of the excellent indicators which should be embedded in an early warning system for a country when the outbreak of emerging infectious diseases. Such digital footprints of public Internet activity provide a real-time measurement for the public epidemic awareness, primarily associated critical keywords for epidemic prevention such as face masks in the study. It seems that the traceable digital footprint provided new insight into measuring the level of the public epidemic awareness, which might enable the government to manage the health service efficiently by getting immediate feedback or information. In the age of big data, countless online digital footprints are waiting to be gathered and analyzed to enhance an existing or create a new service.

However, the study acknowledged that the Google search volume of "face masks" did not directly reflect the actual behavior of wearing face masks. Additionally, the study recognized that the attitudes toward face mask used in the epidemic or pandemic context would vary by country. In fact, the study is not to advocate that everyone should wear a face mask to prevent the spread of the pandemic. Instead, the study encourages us to find out the specific digital footprint of public epidemic awareness in a given scenario for a region or a country. The digital footprint is not limited to Google search engine data. Any form and record of online activity log are worthwhile to explore in the future. By doing so, the real-time information could be effectively used by governments to provide robust risk communication at proper timing and location. However, the issues of privacy of data might be another issue since most of the time, data is collected without the user's awareness or permission.

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