

# Why do you wear a face mask? Taiwanese public epidemic awareness of COVID-19 from social media behavior

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## Research article

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# Abstract

## Background

Facing the COVID-19 epidemic, Taiwan has demonstrated resilience at the initial stage of epidemic prevention and effectively slowed down its spread. This study aims to capture public epidemic awareness toward the COVID-19 through collecting social media- and Internet-based data and elaborate on how the public epidemic awareness rose and played a role in the epidemic prevention in Taiwan during the initial course of COVID-19 spread.

## Methods

Using the Google search query volume of COVID-19 and face mask as indicators of public epidemic awareness, we collected the volume of news reports and the mentions on social media about COVID-19 and face masks between December 31, 2019, and February 29, 2020, through big data analysis and sorted the daily total confirmed cases of COVID-19 worldwide and in Taiwan as well as critical mask-related measures implemented by the Taiwanese government to plot the trends in this information and conduct correlation analysis. Additionally, the content analysis was adopted to analyze the transmission of different types of fear information of COVID-19 between December 31, 2019, and March 29, 2020, and their effects on the public.

## Results

The Google search query volume of COVID-19 and face mask was significantly correlated with the number of confirmed cases in Taiwan, the number of news reports on COVID-19 (correlation coefficient: .74–.90). Since the first confirmed cases of COVID-19, public epidemic awareness has increased rapidly, prompting the government to formulate relevant emergency measures. Additionally, the findings from content analysis suggested that the fear of the loss of control best explains why panic behavior occurs in public.

## Conclusions

Confronting the highly infectious COVID-19, public epidemic awareness is vital. While fear is an inevitable product when an emerging infectious disease occurs, the government can convert resistance into assistance by understanding why fear arises and which fear factors cause excessive panic in public. Moreover, online social media promptly reflect public epidemic awareness, which can be used as a reference for epidemic prevention; this urges the government to deal with the crisis in the form of public opinion.

## Background

The coronavirus disease 2019 (COVID-19) epidemic broke out in December 2019 in Wuhan, Hubei, China, and then spread worldwide. So far, the spread of COVID-19 can be generally split into two phases. In the initial course of the COVID-19 epidemic, China, and other Asian countries such as Korea, Japan, and Iran were regarded as highly hazardous area due to the large number of confirmed cases of COVID-19. However, the development of the COVID-19 epidemic seems to enter a new phase in March. In addition to Asian countries, the high speed of transmission and a vast number of confirmed cases of the COVID-19 started to occur in European countries, the United States.<sup>1</sup> Additionally, On March 3, 2020, WHO director-general, Tedros Adhanom, said that “In the last 24 hours there were almost nine times more cases reported outside China than inside China.”<sup>2</sup> Given the global spread, the COVID-19 has been declared as a worldwide pandemic on March 11, 2020. As of March 31, approximately 750,890 people worldwide were infected, and more than 170 countries have been affected.<sup>3</sup> COVID-19 has become the world’s leading threat; therefore, implementing effective strategies to prevent the spread of COVID-19 has become a topic of discussion and research by governments and academia worldwide.

Owing to its geographical location and historical background, Taiwan is closely associated with China. Most arrivals in Taiwan come from China, reaching 2.71 million per year.<sup>4</sup> Taiwan was expected to be the second-highest risk for COVID-19 outside China.<sup>5</sup> As of March 31, there were 322 confirmed cases of COVID-19 in Taiwan. Of the confirmed cases, 276 are imported, and 46 are indigenous.<sup>6</sup> Regarding the total confirmed cases of COVID-19, Taiwan ranked 77th worldwide<sup>1</sup>, suggesting that the Taiwanese government achieved early control of imported or indigenous cases.<sup>7</sup> As COVID-19 is more contagious than severe acute respiratory syndrome (SARS) and is infectious even through asymptomatic carriers<sup>8</sup>, earlier public epidemic awareness may be another key to comprehensive prevention apart from government measures.

Since public epidemic prevention may provide simple, low-cost, and effective ways of reducing the transmission and impact of the COVID-19 epidemic,<sup>9</sup> it is necessary to understand how the public perceives the threat of COVID-19 and the reasons which cause COVID-19 to be threatening. A previous study proved that fear could arouse vigilance against threats to an individual. This leads the individual to employ measures to protect themselves from harm.<sup>10</sup> Many public health information campaigns often use fear to improve health management in public.<sup>11</sup> However, excessive anxiety in society in the face of emerging infectious diseases or major disasters may lead to more social and

economic problems. For example, during the SARS epidemic, US citizens stigmatized certain races or regions, erecting a barrier between people.<sup>12</sup>

Moreover, fear also decreases the willingness for human-to-human interactions, thereby affecting economic activity.<sup>13</sup> Shortages in medical supplies or other supplies may even cause panic buying.<sup>14</sup> In this case, the idiom, “the same knife cuts bread and fingers,” is truly applicable. Effective control over fear of the COVID-19 epidemic to improve the public’s infection control awareness while avoiding excessive panic, which may result in external effects on the society and economy, is an important matter that the government must consider during epidemic control.<sup>15</sup>

Given that, how the government monitors public epidemic awareness of emerging infectious diseases is particularly important. Previously, cross-sectional telephone surveys were used to measure public awareness of diseases.<sup>16</sup> While it provided valuable information about public perceptions at the time, it is hard to survey continuously throughout epidemic spread due to cost-effectiveness. With the development of the Internet and information communication technology, a web-based methodology has been used to capture public awareness promptly. Browsing, commenting, and various online behaviors represent free thoughts as the user’s online activities can be tracked and recorded. Different online actions are evaluated to explore public awareness of diseases, thereby providing new perspectives to monitor public health.<sup>17</sup> Researchers have used the methodology to observe correlations between public anxiety and flu-related information-seeking behavior<sup>18</sup> or between the number of confirmed influenza cases and disease information-seeking behavior to examine whether influenza outbreaks can be detected early through disease information-seeking behavior.<sup>19</sup> To detect the social response to emerging infectious diseases, these online behaviors not only capture public opinion in a timely manner but also reveal changes in public attention and attitudes to disease-related issues. The collection and interpretation of such information are helpful to governments managing public crises.

This naturalistic study aims to capture public epidemic awareness toward the COVID-19 through collecting social media- and Internet-based data and elaborate on how the public epidemic awareness rose and played a role in the epidemic prevention in Taiwan during COVID-19 spread. Given that related treatment drugs and vaccines for COVID-19 are still under clinical trials,<sup>20</sup> face masks have become necessary personal protective equipment for managing infectious diseases.<sup>21,22</sup> Moreover, increasing face mask use indicates that the public is aware of the threat and reflect other positive hygiene practices.<sup>23,24</sup> Thus, we reviewed changes in the confirmed cases of COVID-19 worldwide and Taiwan, the number of news reports on COVID-19, the volume of the mentions of COVID-19 and face masks on social media, and the Google search volume index of COVID-19 and face masks during the first stage of COVID-19 epidemic (between December 31, 2019, and February 29, 2020). Additionally, this study attempted to analyze the transmission of different types of fear information of COVID-19 from December 31, 2019, to March 29, 2020, and their effects on the public by conducting a content analysis. By doing so, the purpose of the study is to obtain valuable experience based on Taiwan’s response to COVID-19 to aid the government or public in overcoming the COVID-19, or infectious diseases that may emerge in the future.

## Methods

### *Study one: Data collection*

While the development of the COVID-19 epidemic has entered a new phase in March, the first study aims to address the issue of how the earlier public epidemic rise and change in the first stage of the COVID-19 epidemic spread. Thus, we continuously collected data of the following seven indicators between December 31, 2019, and February 29, 2020: total global confirmed cases, total confirmed cases in Taiwan, number of news reports on COVID-19, volume of the mentions of COVID-19 on social media, volume of the mentions of face masks on social media, Google search query volume of COVID-19, and Google search query volume of face masks.

The total global confirmed cases data were mainly collected through the real-time global cases website of System Science and Engineering Center, Johns Hopkins University<sup>25</sup>. Because the site was not completed until January 20, the number of confirmed cases between December 31 and January 19 was based on the source from Wikipedia<sup>26</sup>. The total confirmed cases in Taiwan was based on the daily press conference convened by TCDC and simultaneous press releases<sup>27</sup>.

Data on the number of news reports on COVID-19, the volume of the mentions of COVID-19 on social media, and the volume of the mentions of face mask on social media were collected through KEYPO Big Data Analytics Engine<sup>28</sup>, Taiwan’s well-known online public opinion system. The former represents the number of news reports on COVID-19, whereas the latter two represent the number of mentions of COVID-19 and face mask in posts and comments on social media. A higher number of mentions on social media indicate a higher degree of discussion.

The Google search query volume of COVID-19 and Google search query volume of face masks were acquired through the Google Trends search service, with the search area set to Taiwan and the search time set within the research period. Google Trends provides a normalized value according to the set time range, with a scale of 0–100. A daily search volume of 100 is the highest value for the keyword within that time range.

To compare the above indicators in a trend chart with the same scale, other indicators were normalized using the same method, with the scale ranging from 0 to 100.

#### *Study one: Statistical analysis*

Apart from plotting the trend chart to depict the synchrony among the seven indicators by trend chart, the Pearson product-moment correlation was used to measure how two continuous variables co-vary over time and indicate the linear relationship as a number between -1 (negatively correlated) to 0 (not correlated) to 1 (perfectly correlated).

#### *Study two: Data collection*

To further investigate what types of fear were imbedded in COVID-19-related popular events in Taiwan and how these types of fear have an impact on public epidemic awareness across the whole periods of epidemic spread from December 31, 2019, to March 29, 2020 (the date of latest data collected in the study), a content analysis was adopted in the study.

To select representative popular events among the past 90 days, we screened COVID-19-related popular daily events by using KEYPO Big Data Analytics Engine.<sup>28</sup> The time range for popular event samples was from 31 December 2019 to 29 March 2020, and the total sample size was 359 events.

The function of categorization is to classify the content of the study subjects into groups, in order to endow symbolic meaning. Regarding the categorization of fear, although there are various differences in an individual's ability to determine whether an event is a threat, many researchers who study risk perception and fear believe that people tend to fear similar things due to similar factors based on human instinct.<sup>10,29,30,31</sup> After reviewing these studies and examining collected events, the study constructed "fear type" categories, including *mistrust*, *severity*, *loss of control*, *uncertainty*, *susceptibility*, and *without fear*. For details, please refer to additional file 1.

#### *Study two: Statistical analysis*

In order to examine the associations between different types of fear events and public fear behavioral markers, Google search volume of face masks was gathered, and one-way ANOVA was used. This was done to analyze whether there were differences in the Google search volume of face masks on a day when different types of fear events occurred. Scheffé's method was used for post hoc multiple comparisons. Since Levene's test for equality of variances was found to be violated for the present analysis,  $F(5,353) = 12.14, p < .05$ , the study used the bootstrap method, a resampling method, to derive parameter estimates of standard errors and confidence intervals, and correct biases.<sup>32</sup>

Additionally, to extend our analysis to the correlation between mask search volume at different periods and the number of various types of fear events, we used a threshold value of 25 for Google mask search volume, which was used to divide the period of this study into three stages. These periods are namely: the first stage (2019/12/31–2020/1/26, 27 days), the second stage (2020/1/27–2/22, 27 days), and the third stage (2020/2/23–3/29, 36 days). There are significant differences in the Google face mask search volume among the three stages by One-way ANOVA (Additional file 2). The first stage is the low search volume group ( $M = 4.33, SD = 6.87$ ), the second stage is the high search volume group ( $M = 45.19, SD = 21.47$ ), and the third stage is the medium search volume group ( $M = 25.55, SD = 5.20$ ). After differentiating these three stages, the Chi-square test and multinomial logistic regression were used to examine differences in the number of different types of fear events among the different stages.

## Results

### *Imported overseas cases in the early stage: the rise of public epidemic awareness*

Table 1 shows the correlations among total global and Taiwanese confirmed cases, the volume of the mentions on social media, number of news reports, and Google search query volume from the official press release on COVID-19 issued by the government (December 31) to the implementation of a new mask rationing system (February 6). The correlation coefficients among the seven variables were between .55 and .97. In the early stage of the epidemic spread, the correlation coefficients between the total Taiwanese confirmed cases and number of news reports ( $r = .92$ ), volume of the mentions of COVID-19 on social media ( $r = .92$ ), the volume of the mentions of face masks on social media ( $r = .92$ ), Google search query volume of COVID-19 ( $r = .76$ ), and Google search query volume of face masks ( $r = .90$ ) were significant and high, suggesting that the news media and the public attached great importance to the imported cases of COVID-19 in Taiwan.

Table 1. Pearson correlation coefficients among the seven variables

<i>N</i> = 38	2	3	4	5	6	7
1. Global total confirmed cases of COVID-19	.94	.79	.80	.81	.55	.74
2. Total confirmed cases of COVID-19 in Taiwan	-	.92	.92	.92	.76	.90
3. Volume of the mentions of COVID-19 on social media		-	.91	.97	.91	.88
4. Volume of the mentions of face masks on social media			-	.93	.81	.95
5. Number of news reports on COVID-19				-	.84	.89
6. Google search query volume of COVID-19					-	.83
7. Google search query volume of face masks						-

Note: All values are significant at the .05 level.

Data collected between December 31 and February 6 were used.

Figure 1 shows that when Taiwan announced its first confirmed case on January 21, it aroused the first wave of news media reports and attention to COVID-19 on social media and prompted the public to search for COVID-19 and mask-related information on social media. After two more cases were added on January 24, the news media and the volume on social media climaxed again. The attention of the news media toward COVID-19 continued to increase, as did the volume of discussion on COVID-19 on social media. Thus, social media rapidly promoted discussion of the topics in news reports, and there was a high correlation between the number of news reports and the volume of the mentions of COVID-19 on social media ( $r = .97$ ). Since the spread of COVID-19 to Taiwan, its Google search query volume peaked in less than five days (January 25), and the number of news reports and the volume of mentions on social media also peaked on January 28 when the first confirmed local case in Taiwan was identified as a household infection.

#### *The new form of public epidemic awareness*

Although the correlation between the Google search query volume of COVID-19 and face masks ( $r = 0.83$ ) was quite high, the trend chart showed that the rising period and time of reaching a peak were not the same.

Figure 1 shows that the volume of the mentions of face masks on social media and Google search query volume of face masks increased on January 24 after the government implemented the export ban on face masks and reached peaks on January 28 and January 31, respectively. In this period, the government released 6 million epidemic prevention face masks for sale in convenience stores daily on January 28–30, with a purchase limit of three face masks per person at a price of NT \$8 per face mask. The second local case of household transmission occurred on January 31, and the WHO declared the outbreak to be a public health emergency of international concern on the same day. Furthermore, in the week of January 24–31, among the top 25 keywords of rising searches on Google Trends, seven were related to face masks, especially “medical face masks,” “where to buy,” and “names of each face mask shop.” This implies that public epidemic awareness began to increase in just a few days, from the perception of the importance of COVID-19 (Google search for COVID-19) to the perception of its threat and the adoption of protective measures (Google search for face masks).

It shows that new local cases, the government’s emergency release of face masks, and lax purchase restrictions on face masks have aroused a public sense of insecurity and anxiety created by the increased chance of potential infection and the public quickly buying face masks. The phenomenon of panic buying of face masks was reported by news media during that period.<sup>33</sup>

#### *The implement of name-based rationing system for face masks*

Public complaints also prompted the government to increase the allocation of resources for mask-related epidemic prevention materials. The government took emergency measures on January 31, including the daily collection of 4 million face masks from manufacturers, of which 2.6 million were for the public and sold through convenience stores, drugstores, and related chain stores, with a purchase limit of three face masks per person per day at a unified price of NT \$6 per face mask on February 1.<sup>34</sup> Subsequently, the government launched a name-based rationing system for face masks on February 6. Based on the principles of prioritizing healthcare workers and ensuring equal purchase opportunities for all, the government adopted the method of unified collection, allocation, and price, and stipulated a purchase limit. Each person is allowed to

buy two masks per National Health Insurance card (for identification) at a price of NT\$5 per face mask in a week.<sup>35</sup> The response measure is to ensure 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. After the policy was put in place, the government and the public worked together to create open data applications such as Face Mask Maps to enable the public to quickly find sales locations and inventory, thereby improving the efficiency of buying face masks, reducing the negative impact of long queues and inability to buy face masks, and making proper use of information technology to achieve epidemic prevention.<sup>36</sup>

After the implementation of the new mask rationing system, the government also successively put forward some face mask countermeasures such as increasing collection, extending the export ban, adding production lines, and increasing the purchasing limit of face masks to three face masks per person per week (TCDC, 2020 March 2),<sup>37,38</sup> which were expected to enable everyone to have face masks and protect themselves. Such positive actions have reduced public anxiety about not being able to buy face masks; accordingly, the volume of the mentions and search query of face masks have dropped significantly and become less affected by new cases of infection. More recently, a "name-based rationing system for face masks new version 2.0" was implemented in which the online ordering mechanism was added on March 12.<sup>39</sup> The purpose of this new mechanism is to ensure even distribution better and make it more convenient to obtain face masks for people such as office workers and students who lack time to go to pharmacies and public health centers. From the perspective of crisis management, these face mask countermeasures not only achieve a cogent allocation of medical resources and reduce the possibility of infection but also take into account the panic of the public so that the people have sufficient control over the purchase of face masks, thus preventing the epidemic of fear.

*The period of highest Google search query volume of face masks and the loss of control*

According to the results of the ANOVA (Table 2), the types of fear had a significant effect on Google search query volume of "face masks" [ $F(3,358) = 5.67, p < .05$ ]. Moreover, the results from post hoc comparisons using the Scheffé test with bootstrap method (Table 3) indicated that only the mean score for the *loss of control* group ( $M = 42.65, SD = 26.12$ ) was significantly different from the other groups ( $M = 26.73, SD = 14.61$ , for *mistrust*;  $M = 24.65, SD = 18.38$ , for *severity*;  $M = 22.08, SD = 21.20$ , for *uncertainty*;  $M = 26.12, SD = 12.10$ , for *susceptibility*;  $M = 25.77, SD = 8.67$ , for *without fear*).

Table 2. The result of one-way analysis of variance

	Sum of squares	df	Mean square	F	p
Between groups	6163.83	5	1232.77	5.67	<.05
Within groups	76726.75	353	217.36		
Total	82890.58	358			

Table 3. Post hoc Scheffé test with the bootstrap method

	Descriptive statistics			Multiple comparison <sup>a</sup>				
	N	Mean	SD	2 <sup>b</sup>	3 <sup>b</sup>	4 <sup>b</sup>	5 <sup>b</sup>	6 <sup>b</sup>
1. Mistrust	48	26.73	14.61	2.08 (3.31)	<b>-15.92* (3.92)</b>	4.65 (3.18)	0.62 (2.49)	0.96 (2.65)
2. Severity	34	24.65	18.38	-	<b>-18.00* (4.16)</b>	2.57 (3.46)	-1.47 (2.84)	-1.12 (2.98)
3. Loss of control	20	42.65	26.12	-	-	<b>20.57* (4.06)</b>	<b>16.54* (3.54)</b>	<b>16.88* (3.66)</b>
4. Uncertainty	39	22.08	21.20	-	-	-	-4.04 (2.69)	-3.69 (2.84)
5. Susceptibility	131	26.12	12.10	-	-	-	-	0.34 (2.04)
6. Without fear	87	25.77	8.67	-	-	-	-	-

Note. Values in parentheses are bootstrap standard error.

<sup>a</sup> Post hoc Scheffé test with the bootstrap method was used.

<sup>b</sup> The reference group for the multiple comparisons of mean

\* The mean difference in bold is significant at the .05 level.

*Changes in the number of different fear events at different periods*

A Pearson chi-square test was performed to examine the change in the proportion of events in different types of fear across various time periods. The proportion differs by the time periods [ $\chi^2 (10) = 41.16, p < .05$ ]. A cross-table (Table 4) showed the counts and expected counts of events in different categories.

Table 4. Crossable for Sample characteristics with Chi-square analysis

Types of fear	Untrustworthy	<i>n</i>	Time periods			$\chi^2$ (df)
			First stage	Second stage	Third stage	
			( <i>N</i> = 47)	( <i>N</i> = 105)	( <i>N</i> = 207)	
			6	17	25	41.16* (10)
	( <i>N</i> = 48)	Expected <i>n</i> 6.3	14.0	27.7		
Dread	<i>n</i>	<b>8<sup>a</sup></b>	11	15		
	( <i>N</i> = 34)	Expected <i>n</i> 4.5	9.9	19.6		
Loss of control	<i>n</i>	2	<b>10<sup>a</sup></b>	8		
	( <i>N</i> = 20)	Expected <i>n</i> 2.6	5.8	11.5		
Uncertainty	<i>n</i>	<b>15<sup>a</sup></b>	10	<i>14<sup>b</sup></i>		
	( <i>N</i> = 39)	Expected <i>n</i> 5.1	11.4	22.5		
Vulnerability	<i>n</i>	<i>11<sup>b</sup></i>	34	86		
	( <i>N</i> = 131)	Expected <i>n</i> 17.2	38.3	75.5		
Other	<i>n</i>	<i>5<sup>b</sup></i>	23	59		
	( <i>N</i> = 87)	Expected <i>n</i> 11.4	25.4	50.2		

Note. <sup>a</sup> The counts are 1.5 times greater than expected counts were in bold.

<sup>b</sup> The counts are 1.5 times less than expected counts were in *Italic*.

\* The Pearson chi-square value is significant at the .05 level

To further ascertain which types of events in terms of fear have relatively large ratios compared to different periods, multinomial logistical regression was used (Table 5). We used the second stage as a reference group since it had the highest Google search query volume of face masks. The odds ratio for *uncertainty* (6.90) in the First stage is significant, indicating that the probability of *uncertainty* event happening in the First stage is 6.90 times higher than that in the Second stage, relative to the *without fear* group. On the other hand, the probability of the *loss of control* event happening in the Second stage is 3.23 (1/0.31) times significantly higher than that in the Third stage, relative to the *without fear* group.

Table 5. Results of the multinomial logistic model

Time periods <sup>a</sup>		<i>B</i>	<i>SD</i>	Wald	<i>df</i>	Odds ratio	95% Confidence Interval	
							for odds ration	
							Lower Bound	Upper Bound
First stage	Intercept	-1.53	0.49	9.56	1	.00		
	Mistrust	0.48	0.68	0.50	1	.48	1.62	.42
	Severity	1.21	0.68	3.17	1	.07	3.35	.89
	Loss of control	-0.08	0.92	0.01	1	.93	.92	.15
	Uncertainty	1.93*	0.64	9.10	1	.00	6.90	1.97
	Vulnerability	0.40	0.60	0.43	1	.51	1.49	.46
	Without fear <sup>b</sup>	-	-	-	-	-	-	-
Third stage	Intercept	0.94	0.25	14.69	1	.00		
	Mistrust	-0.56	0.40	1.94	1	.16	.57	.26
	Severity	-0.63	0.47	1.83	1	.18	.53	.21
	Loss of control	-1.17*	0.53	4.76	1	.03	.31	.11
	Uncertainty	-0.61	0.48	1.58	1	.21	.55	.21
	Vulnerability	-0.01	0.32	0.00	1	.96	.99	.53
	Without fear <sup>b</sup>	-	-	-	-	-	-	-

<sup>a,b</sup> The reference categories are Second stage for time periods and Other for types of risk characteristic.

\* The parameter estimate is significant at the .05 level.

## Discussion

The current situation of the COVID-19 pandemic is quite severe. In addition to Asia, the pandemic in Europe, 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 the epidemic. When epidemic prevention and the economy stand at opposite ends of the scale, finding a balance is the biggest challenge for governments. The study provided an insight into how to measure national public epidemic awareness through social media- and Internet-based data and how the public plays a role in infection prevention and control.

### *Rapidly increasing public epidemic awareness effectively prevents its spread*

When it comes to infection prevention and control, the basic reproduction number ( $R_0$ ) is a marker of epidemic transmission intensity under a specific spatiotemporal background. This number represents the number of people around every infected person that could possibly get infected as well. During the early stages of the epidemic, scientists estimate that if  $R_0$  is less than 1.5, contact tracing of patients can be used in theory to identify potential targets for control. However, during the actual outbreak of the COVID-19 epidemic, controlling the same was difficult because of the substantial increase in the number of patients and asymptomatic transmission.<sup>40</sup> In past cases,  $R_0$  was found to be more than 2 in Wuhan during the early stages of the epidemic and in Europe and the Americas from March onwards.<sup>41,42</sup> This shows that it is essential to lower  $R_0$  in the early stage of the epidemic spread.

As of March 31, the data showed that the total confirmed cases of COVID-19 in per million in people in Taiwan is considerably lower than most of the countries<sup>1</sup> even though Taiwan had resisted the COVID-19 epidemic for more than 70 days and have high population density (673 people/km<sup>2</sup>). So far, the  $R_0$  of Taiwan was still lower than one, and the epidemic was within the controllable range.<sup>41</sup> This might be attributed to the government's super-early deployment<sup>7</sup> as well as fear-induced infection control awareness in public.

In terms of disease information-seeking behavior, previous findings suggested that seeking behaviors for epidemic diseases could be an indicator of the influenza outbreaks. However, the relationship varied by counties.<sup>19</sup> We argued that the variation might be explained by the

various public epidemic awareness. In Taiwan, the public's COVID-19 online information-seeking behavior appeared quite early, with a large amount of query volume. When the media began to report on the epidemic on a large scale, the discussion of COVID-19 continued to increase on social media, and the public started seeking information about COVID-19 through Google to reduce their sense of insecurity caused by uncertainty about the unknown. Such rapid growth of public epidemic awareness is immensely significant for public health. Realizing the importance of COVID-19 and understanding COVID-19 is the crucial first step in combating COVID-19.

#### *The story behind the face masks information-seeking behavior during epidemics*

While the search for diseases can be viewed as a form of public epidemic awareness, we argued that the behavior motivation between information-seeking for COVID-19 and face masks are different. Driving the search of the former was the feeling of ignorance about the emerging disease by the public, who sought knowledge to reduce the uncertainty and potential threat to themselves. By contrast, face masks are crucial personal protection equipment.<sup>22</sup> and driving their search is the public perception of the threat of COVID-19 and a desire to understand how to protect themselves correctly. Despite the ongoing debates on the effectiveness of face masks in epidemic transmission,<sup>43</sup> previous research found that people wearing a face mask tended to have positive hygiene practices such as maintaining social distancing, washing hands as well as avoiding crowds frequently, and regularly avoiding close contact with an infected person.<sup>23</sup> Thus, the face masks information-seeking behavior might be viewed as an indicator of public epidemic awareness.

#### *The role of fear in stimulating public epidemic awareness*

In the history of infectious diseases, fear is almost always the first intuitive emotion and response of humans.<sup>15</sup> Among the five types of fear in this study, the most common fear factor embedded in popular events across the whole period was found to be *susceptibility*. The content of these events includes new cases throughout the world and the events in which people who didn't obey the rules of home quarantine. From changes in the proportion of various types of fear in popular COVID-19 topics with time, different fear elements play different roles at different time periods. This also properly shows the public response towards COVID-19.

Before COVID-19 entered Taiwan up until the first case occurred in the same (First stage: 31 December 2019 to 25 January 2020), the types of fear embedded in popular events that were discussed by the public were mainly the *uncertainty* and *severity* caused by COVID-19. The number of these types of events was higher than the expected value by 1.5 times. The event content included discussion on the possibility of human-to-human transmission of COVID-19 and where suspected patients were located. Additionally, as studies during this period provided that COVID-19 is caused by the severe acute respiratory syndrome coronavirus two, the public in Taiwan was concerned with the possibility of severe harm or even death caused by SARS in the past. These uncertain events and consideration of the immense threat of COVID-19 to individual health have sown the seeds of fear in the population for days to come.

As the epidemic gradually spread, the number of popular events related to *loss of control* started to increase in the second stage (26 January to 21 February). These types of events accounted for a higher proportion compared to other stages. While findings have suggested that individuals are more likely to wear a face mask due to the perceived susceptibility and perceived severity,<sup>22</sup> we argued that the *loss of control* best explains why the panic behavior occurs in public in Taiwan<sup>33</sup>, as the event involves an individual's body. This causes individuals to lose control over self-protection and feel uneasy when they are unable to buy masks, toilet paper, and other protective and essential supplies. An emerging infectious disease has a considerable impact on the public, as it involves social and livelihood issues.

Several limitations of the study ought to be mentioned here. First, the Google search query volume of "face masks" did not directly reflect the actual behavior of wearing face masks. To some extent, the Google search query volume represents the public perception of the COVID-19 threat and an attempt to take self-protection measures. Second, while our results suggested Google search query volume of face masks could be an indicator of the public epidemic awareness, the indicator might not be applicable for every country due to cultural differences in attitudes toward using face masks during the epidemic.<sup>44</sup>

## **Conclusions**

Facing the threat of COVID-19, the government's crisis risk management and public epidemic awareness are at the core of this campaign. In addition to the government's early maneuvers and precautions, the study highlights that the importance of early public vigilance against COVID-19 and the timely detection of public epidemic awareness is the key to effective epidemic prevention, and the news media also play a role in disseminating information between the government and the public. The volume of mentions and search query behaviors on social media represents many implications in the anti-epidemic stage. These online behaviors can be regarded as indicators for the government to observe public epidemic awareness and for the public to monitor the government's response to crisis risk management. While fear is an inevitable product when an emerging infectious disease occurs, by understanding why fear arises in public and which fear factors cause excessive panic in public, the government and society can convert resistance into assistance. Additionally, these online behaviors can be regarded as indicators for the government to observe public epidemic awareness and for the public to monitor the government's response to crisis risk management. In

a society where the Internet and science and technology are booming, the application of big data in the fight against epidemics will be more diverse in the future.

## List Of Abbreviation

COVID-19: coronavirus disease 2019

## Declaration

*Ethics approval and consent to participate*

Not applicable

*Consent for publication*

Not applicable

*Availability of data and materials*

The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

*Competing interests*

The authors declare that they have no competing interests

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*Authors' contributions*

CCY conceived and designed the study through observing social media behaviors, and drafted the work. LCP provided professional advice on the domain of emerging infectious diseases. WCL implemented data acquisition and analysis. All the authors contributed to interpreting results and revising the manuscript. All authors read and approved the final manuscript.

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Not applicable

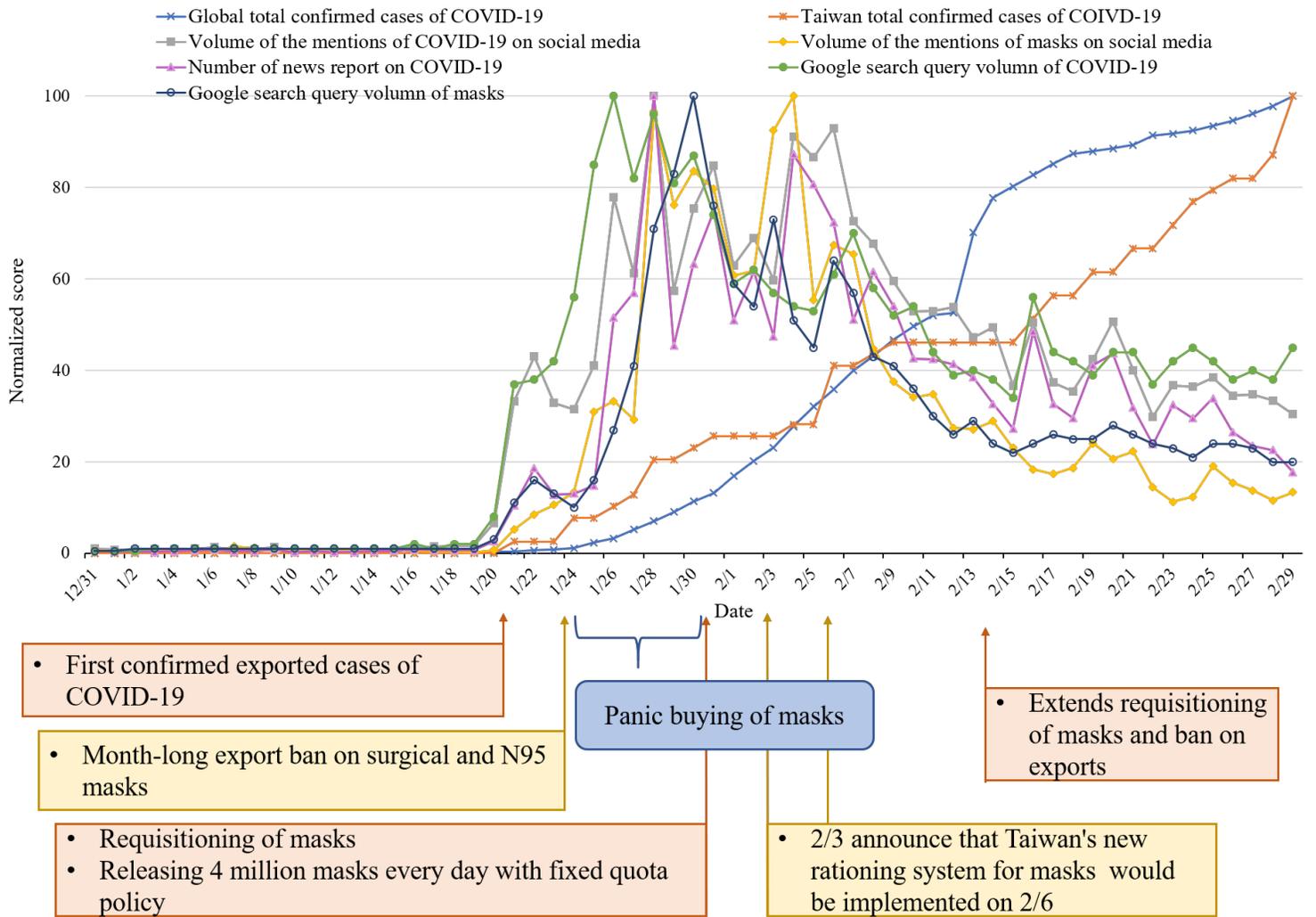
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## Figures



**Figure 1**

The trend chart between December 31, 2019, and February 29, 2020 for seven indicators . Trends of the total confirmed cases worldwide and in Taiwan, the numbers of news reports on COVID-19, the volume of the mentions of COVID-19 and face masks on social media, and the Google search query volume of COVID-19 and face masks between December 31, 2019, and February 29, 2020.

## Supplementary Files

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