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Article

Patterns of public interest in infectious diseases in South Korea, five other major countries, and worldwide: A Google trends analysis

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Abstract: Background: Various studies have demonstrated the usefulness of Google search data for public health-monitoring systems. The aim of this study is to be estimated interest of public in infectious diseases in infectious diseases in South Korea, the five other countries. **Methods:** We conducted cross-country comparisons for queries related to the H1N1 virus and Middle East respiratory syndrome coronavirus (MERS-CoV). We analyzed queries related to the novel coronavirus disease (COVID-19) from 20 January to 13 April 2020, and performed time-descriptive and correlation analyses on trend patterns. **Results:** Trends in H1N1, MERS-CoV, and COVID-19 queries in South Korea matched those in the five other countries and worldwide. The relative search volume (RSV) for the MERS-CoV virus increased as the cumulative number of confirmed cases in South Korea increased and decreased significantly as the number of confirmed cases decreased. The volume of COVID-19 queries dramatically increased as South Korea's confirmed COVID-19 cases grew significantly at the community level. However, RSV remained stable over time. **Conclusions:** Google Trends provides real-time data based on search patterns related to infectious diseases, allowing for continuous monitoring of public reactions, disease spread, and changes in perceptions or concerns. We can use this information to adjust their strategies of the prevention of epidemics or provide timely updates to the public.

Keywords: infectious diseases; COVID-19; MERS-CoV; N1H1; health communication; Google

1. Background

Recently, cases of infectious disease have shown that no country is safe from new infectious diseases. South Korea has historically faced infectious diseases, and although it has improved its ability to respond to them through health policies, information technology, and social cooperation in the 21st century, it still prepares for the introduction and spread of new infectious diseases.

Various infectious diseases have threatened South Korea since 2000, including severe acute respiratory syndrome coronavirus (SARS-CoV) in 2003, influenza A virus subtype H1N1 (H1N1) in 2009, highly pathogenic avian influenza A (H7N9) in 2013, Ebola virus in 2014, Middle East respiratory syndrome coronavirus (MERS-CoV) in 2015, and Zika virus in 2016 (Lee, 2016).

In response, South Korea strengthened its infectious disease response system to prevent the spread of SARS-CoV. In 2015, the MERS-CoV was introduced into South Korea. At that time, MERS-CoV spread through hospital infections, prompting the government to implement measures to close and isolate affected hospitals. The MERS-

CoV outbreak revealed vulnerabilities in the South Korean health system and led to calls for improvements in the infectious disease response system. And four years later, in February 2020, a South Korean patient was confirmed to have coronavirus disease-19 (COVID-19) (Ki, 2020). South Korea initially implemented a fast and efficient inspection and tracking system, but early communication with the public showed some vulnerabilities.

The SARS, H1N1, MERS-CoV, and COVID-19 outbreaks can all be characterized as either cases in which an infectious disease from the past has reappeared or as cases in which a powerful new virus has emerged. Infectious diseases such as SARS, MERS-CoV, and COVID-19, that have prompted emergencies, have the potential to be transmitted by respiratory or human-to-human contact (Lee and Hsueh, 2020; Riou and Althaus, 2020), reported different propagation patterns than conventional infectious diseases.

Infectious diseases have been found to have a high probability of spreading through social contact (Eames et al., 2012; Horby et al., 2011; Leung et al., 2017). New infectious diseases have a fast infection rate and a high mortality rate, adding to public confusion and anxiety (Zhang, 2020). For example, the lack of public understanding and awareness, poor attitudes, and risky practices are among the factors that aggravate the situation (Balkhy et al., 2010).

Several countries have reported on the public's understanding and interest in infectious diseases using Google Trends (GTs) (Husain et al., 2020; Knipe et al., 2020; Kurian et al., 2020; Ming et al., 2021; Saegner and Austys, 2022; Yousefinaghani et al., 2021). The United States, Australia, New Zealand, Canada, and the United Kingdom have used GTs to report on trends in infectious diseases among the public. Husain et al. (2020) highlighted that GTs is vital for effective containment and mitigation strategies. Kurian et al. (2020) found it to be the most efficient method for analyzing Internet search behavior. Ming et al. (2021) reported that GTs enhance public health surveillance and understanding of public emotions. Previous studies reported that search patterns reflected the public's response to the pandemic. Data generated by GTs has proven useful for assessing correlations and developing prediction models for several infectious diseases, including influenza, MERS-CoV, and the Zika virus (Bragazzi et al., 2017; Ginsberg et al., 2009; Shin et al., 2016). Therefore, GTs show potential as a tool for monitoring public reactions to infectious disease threats. We need to strengthen public health risk communication and understand the public's concerns about new infectious diseases.

A systematic review of studies using GTs saw a sevenfold increase in these studies from 2009 to 2013 (Nuti et al., 2014). Most studies that examined health trends using GTs focused on population monitoring, followed by infectious diseases, mental health, and chronic diseases (Nuti et al., 2014). Studies have reported that it may be possible to monitor health-searching behavior and predict flu outbreaks through analysis of search engine queries (Ginsberg et al., 2009; Lazer at al., 2014; Olson et al., 2013). Nontraditional data sources have also been used in research on the Zika (Majumder et al., 2016) and Ebola (Alicino et al., 2015) viruses. One study suggested that GTs can potentially be used to predict the outbreak of various diseases (Bousquet et al., 2017).

2. Purpose

This study aimed to answer the following questions: (1) What were the query trends for H1N1-related keywords from 2008 to 2010 and MERS-CoV-related keywords from 2014 to 2016 in South Korea, five countries included in the study, and worldwide? (2) How do query trends for MERS-CoV-related keywords and confirmed cases and deaths compare from 20 May to 11 July 2015? (3) What were the query trends for COVID-19-related keywords in South Korea, five countries, and worldwide from 20 January to 13 April 2020? (4) What were the query trends for infectious disease- and epidemic-related keywords in South Korea, five countries included in the study, and worldwide from 2009 to 2019?

This study can potentially strengthen public health risk communication to enhance the prevention and management of infectious diseases and to focus public attention on emerging infectious diseases.

3. Methods

3.1. Study design

Retrospective study analyses the South Korean public's interest in, and trends related to the outbreak of infectious diseases and identifies correlations with countries. This study examines the infectious diseases and related keywords that occurred in South Korea from January 2008 to April 2020 using GTs data and explores the correlation with trends in the five other countries.

3.2. Study data

GTs is a free tool that tracks and visualizes how often a specific search term is queried over time, based on Google search data. GTs is useful for understanding public interests and trends by showing changes in search volume for particular keywords. This is described by the relative volume known as search interest, which corresponds to the relative search volume (RSV) (Shariatpanahi et al., 2017). RSV describes the popularity of a topic in a specific area during a particular time period. Therefore, GTs is a powerful tool for understanding public concerns and search patterns. The analysis units of GTs are query, time, location, category, and search type. GTs is a tool that shows how often a particular query is searched over time, allowing you to compare the relative interest in a search term. The numbers in GTs do not represent the absolute number of searches. Instead, they compare the RSV during the analysis period on a relative scale. These numbers are calculated as a percentage, meaning the higher the RSV, the larger the number.

3.3. Materials

This study analyzed data from GTs (https://trends.google.co.kr/trends/). Since 2008, domestic infectious disease search queries have been conducted both in South Korean and in English and have been analyzed as optimal search algorithms using Medical Subject Headings (MeSH) terms and abbreviations. The following search terms were used to search for MeSH terms: "influenza A virus or influenza human" and "influenza or H1N1" for the influenza A virus, "MERS-CoV or MERS virus" for

the Middle East respiratory syndrome coronavirus, and "2019 novel coronavirus disease or COVID-19" and "Coronavirus or 2019-nCoV" for COVID-19. We finally selected the "influenza A virus subtype H1N1" as the H1N1 keyword, "Middle East respiratory syndrome coronavirus" as the MERS-CoV keyword, and "2019 novel coronavirus" as the COVID-19 keyword.

We collected additional data on the cumulative number of confirmed cases and fatalities in MERS-CoV outbreaks in South Korea. South Korea has reported data on daily new cases, cumulative cases, and cumulative deaths of MERS-CoV through the Korea Centers for Disease Control and Prevention. We created a new MERS-CoV dataset by combining data from the Korea Centers for Disease Control and Prevention Infectious Disease Portal (https://dportal.kdca.go.kr/pot/index.do).

3.4. Study population

The search periods used in the study were from January 2008 to December 2010 for H1N1; January 2014 to December 2016 for MERS-CoV; 20 January 2020, to 13 April 2020, for COVID-19, and January 2009 to December 2019 for epidemic and infectious diseases. The before and after dates for the H1N1 (15 August 2009) and MERS-CoV outbreaks in South Korea were considered to be the date of the first confirmed case (MERS-CoV, 20 May 2015) and the date of the announcement of the end of the epidemic in South Korea (MERS-CoV, 11 July 2015). In the case of COVID-19, we considered the period from the date of the first confirmed case (20 January 2020) to the date of data access (13 April 2020). The country selection criteria were determined by reviewing previous article that included the subject of this article. Data on South Korea, the United States, France, Australia, Canada, the United Kingdom, and the world in general were analyzed, and averages for the five others included countries were calculated.

3.5. Analysis

Data collection for the GTs analysis was determined on 13 April 2020. The search began on 13 April 2020, and ended on 15 April 2020. We accessed the GTs website (https://trends.google.co.kr/trends/), downloaded the data as a ".csv" file, and selected the queries, countries, and extraction dates to collect the data. For GTs, RSV refers to the relative number of queries over a period of time. The graph's x-axis indicates the period, and the y-axis indicates the level of interest in the query searched. However, it was noted that in GTs, higher values indicate a relative proportion of the absolute query count. Descriptive and Pearson correlation coefficient analyses were performed on trend patterns using SPSS version 21.0 (IBM Corp., Armonk, NY, USA). Significance was set at $p < 0.05$.

The correlation analysis examines whether the public search volume is correlated with trends in South Korea, other respective countries, and worldwide for queries related to 'H1N1', 'MERS-CoV', 'COVID-19', 'infectious disease', and 'epidemic'. We aim to determine whether the results of the correlation analysis represent a unique phenomenon in South Korea or reflect similar trends in other countries. Additionally, the MERS analysis explores whether the cumulative MERS-CoV cases and deaths in South Korea are correlated with GTs interest.

4. Results

4.1. RSV of Google query trends for the keyword "infectious diseases" in South Korea, the five other countries, and the world

This result presents the RSV for public interest in infectious disease queries from 2009 to 2019, by country. Although the RSV for infectious disease queries has generally decreased, South Korea's RSV has increased since 2012, with the highest RSV recorded dramatically in 2015. The year 2015 coincided with the introduction of MERS-CoV in South Korea, a period marked by high public anxiety due to the significant number of deaths caused by the infection (**Table 1**).

Table 1. RSV of Google query trends for the keyword "infectious diseases" in South Korea, the five other countries, and the world.

Year	South Korea (min–max)	United States (min–max)	France (min–max)	Australia (min–max)	Canada (min–max)	United Kingdom (min–max)	Average of 6 countries (min–max)	Worldwide (min–max)
2009	28 (10–51)	82 (64–100)	56 (17–100)	57 (31–100)	72 (51–100)	73 (43–100)	61 (46–79)	87 (69–100)
2010	19 (4–46)	73 (49–100)	56 (15–98)	53 (21–80)	68 (41–92)	67 (44–94)	56 (42–69)	77 (64–90)
2012	13 (6–26)	64 (44–83)	35 (0–75)	38 (6–58)	60 (37–85)	61 (41–86)	45 (31–65)	68 (55–82)
2012	6 (4–13)	53 (36–64)	45 (19–89)	47 (28–73)	57 (40–81)	62 (37–82)	45 (35–53)	61 (47–73)
2013	13 (5–36)	50 (31–64)	40 (17–66)	41 (14–55)	53 (42–62)	58 (41–70)	42 (35–49)	57 (48–66)
2014	19 (11–43)	51 (37–77)	36 (8–60)	42 (16–63)	57 (41–83)	63 (49–80)	45 (36–60)	58 (47–73)
2015	25 (11–100)	52 (38–65)	42 (8–76)	43 (24–55)	62 (49–81)	64 (35–97)	48 (34–58)	55 (43–63)
2016	16 (11–28)	45 (30–62)	38 (7–70)	41 (7–61)	51 (26–80)	57 (42–75)	41 (28–54)	53 (37–65)
2017	16 (12–22)	46 (33–60)	24 (0–43)	43 (29–53)	55 (28–86)	50 (38–72)	39 (28–49)	52 (42–63)
2018	15 (11–21)	45 (32–54)	27 (14–50)	40 (21–52)	45 (29–77)	48 (37–61)	37 (31–46)	50 (41–58)
2019	14 (11–19)	43 (29–55)	21 (7–47)	40 (23–57)	44 (34–50)	45 (33–56)	34 (25–42)	49 (42–58)

4.2. Comparison of Google query trends for the keyword "H1N1" in South Korea, the five other countries, and the world

During the H1N1 outbreak in South Korea in 2009, similar search patterns for H1N1-related queries were seen in South Korea, the five other countries in the study (r = 0.863, p = 0.001), and worldwide (r = 0.811, p = 0.001). There were correlations among the United States (r = 0.709, p = 0.001), France (r = 0.617, p = 0.001), Australia

(r = 0.563, p = 0.001), Canada (r = 0.583, p = 0.001), and the United Kingdom (r = 0.702, p = 0.001) (**Table 2**) (**Figure 1**).

Table 2. Google query correlation for H1N1 and MERS-CoV keywords in South Korea and the five other countries and around the world**.**

Keyword	United States	France	Australia	Canada	United Kingdom	Average of 6 countries	Worldwide
H1N1	0.709*	0.617*	0.563*	0.583*	0.702*	0.863*	0.811*
MERS-CoV	0.423*	0.866*	0.857*	0.767*	0.676*	0.848*	0.678*

Note: * < 0.05.

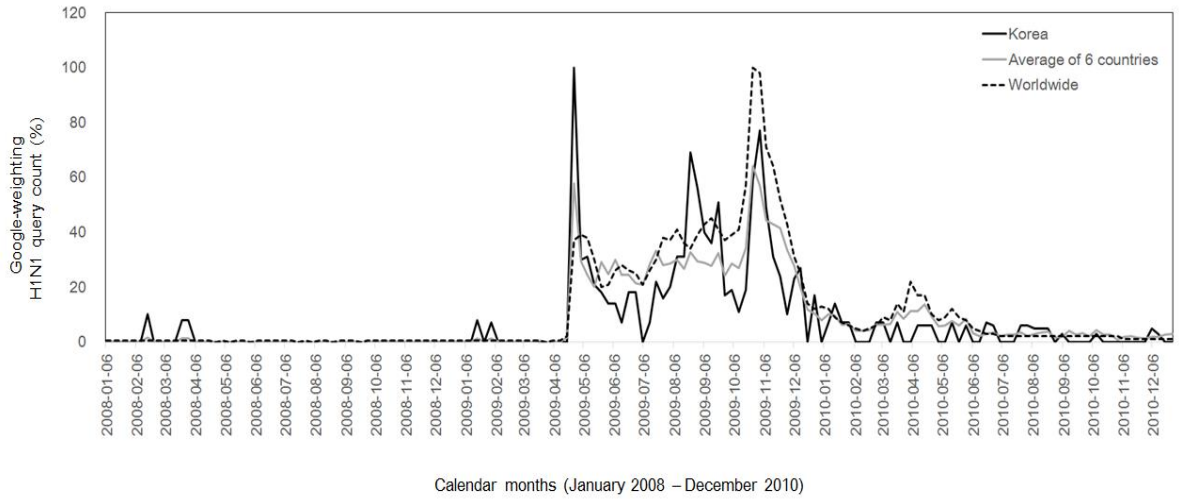

Figure 1. Comparison of Google query trends for the keyword "H1N1" in South Korea, the five other countries, and the world (January 2008–December 2010).

4.3. Comparison of Google query trends for the keyword "MERS-CoV" in South Korea, the five other countries, and the world

From April to May 2014, the five other countries included in the study and the world showed high peaks for MERS-CoV-related queries. However, South Korea did not show a high peak. From May to July 2015, South Korea, the five other countries in the study (r = 0.848, p = 0.001), and the world (r = 0.678, p = 0.001) showed high peaks in MERS-CoV. There were correlations among the United States (r = 0.423, p=0.001), France (r = 0.866, p = 0.001), Australia (r = 0.857, p = 0.001), Canada (r = 0.767, p = 0.001), and the United Kingdom (r = 0.676, p = 0.001) (**Table 2**) (**Figure 2**).

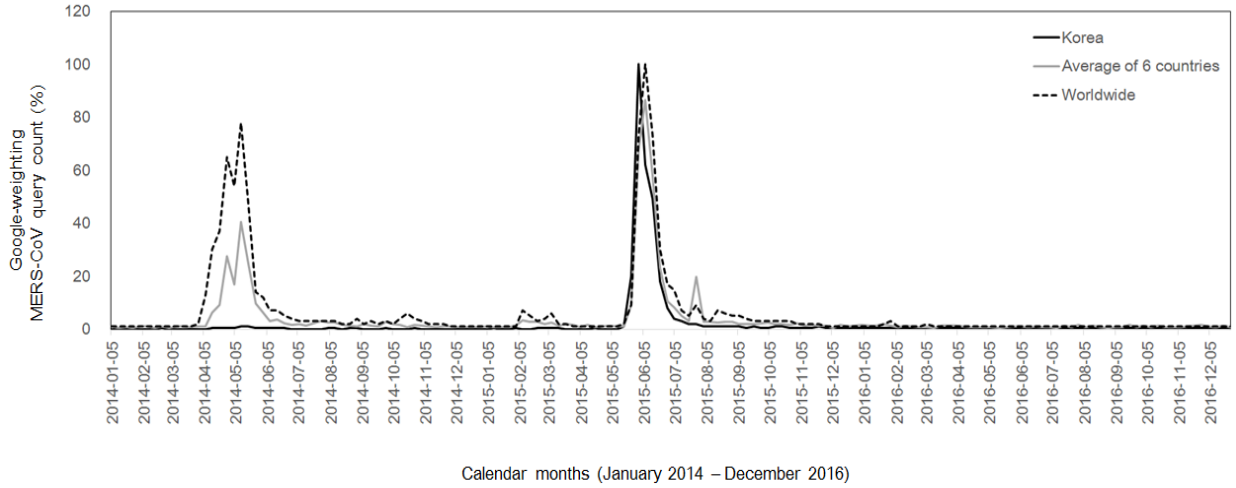

Figure 2. Comparison of Google query trends for the keyword "MERS-CoV" in South Korea, the five other countries, and the world (January 2014–December 2016).

4.4. Comparison of Google query trends for the keyword "MERS-CoV" and the cumulative number of confirmed cases and deaths

We compared query trends for the keyword "MERS-CoV" in South Korea, from 20 May to 11 July 2015 (from the first confirmed case of MERS-CoV in South Korea to the reported end of the outbreak), with the cumulative number of confirmed cases and number of deaths. On 24 May 2015, the number of confirmed cases of MERS-CoV began to increase, and the query volume for the keyword "MERS-CoV" began to increase dramatically. However, the number of queries for the keyword "MERS-CoV" decreased on 19 June 2015, and the cumulative number of confirmed cases (r = −0.289, p = 0.036) and number of deaths (r=−0.048, p = 0.001) also decreased. On 11 July 2015, the day of the announcement of the end of the MERS outbreak, the query volume for MERS-CoV was very low (**Figure 3**).

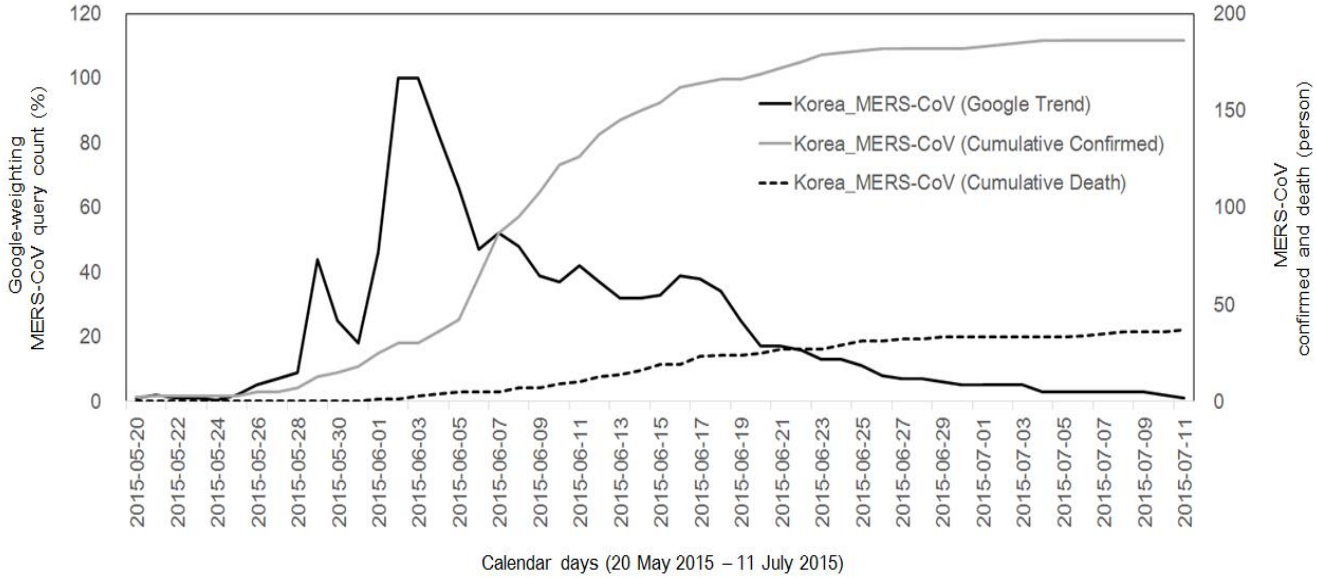

Figure 3. Comparison of Google query trends for the keyword "MERS-CoV" and the cumulative number of confirmed cases and deaths (May 20, 2015–July 11, 2015) in South Korea.

4.5. Comparison of Google query trends for the keyword "COVID-19" in South Korea, the five other countries, and the world

From 20 January to 13 April 2020, query trends for the keyword "COVID-19" correlated with the progression of the outbreak in South Korea, the five other countries included in the study (r = 0.880, p = 0.001), and around the world (r = 0.860, p = 0.001). After the first case of COVID-19 was confirmed in South Korea, the number of queries repeatedly increased and decreased in the country. However, since 18 February 2020, which was around the time of the first reports of the spread of community-based infections in Daegu metropolitan city and Gyeongsangbuk-do province, the number of queries has increased. Since the number of confirmed COVID-19 cases in Italy, Spain, and the United States rapidly increased in early March, the number of COVID-19 queries has increased in the five other countries included in the study and around the world (**Figure 4**).

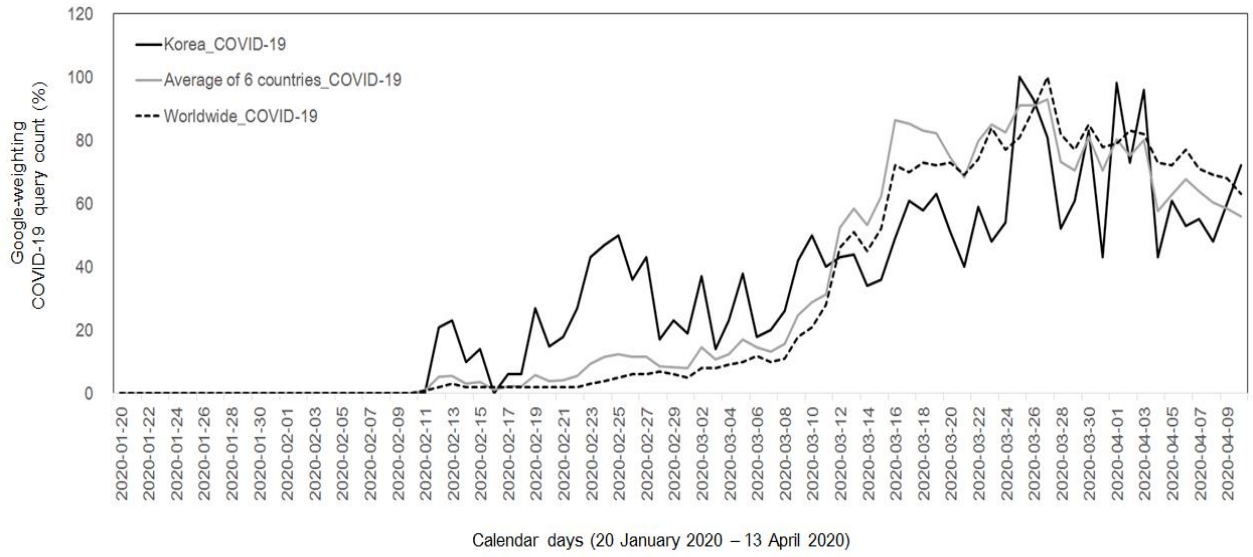

Figure 4. Comparison of Google query trends for the keyword "COVID-19" in South Korea, five others countries, and the world (20 January 2020–13 April 2020).

4.6. Comparison of Google query trends for the keyword "infectious diseases" in South Korea, the five other countries, and the world

We compared query trends for the keyword "infectious diseases" in South Korea, the five other countries included in the study, and the world from 2009 to 2019. South Korea showed small peaks during the H1N1 outbreak in 2009, the H7N9 outbreak in 2013, and the Ebola virus outbreak in 2014. In 2015, South Korea had the highest query volume during the MERS-CoV outbreak. However, the query volume has decreased significantly since the end of the MERS-CoV outbreak (**Figure 5**).

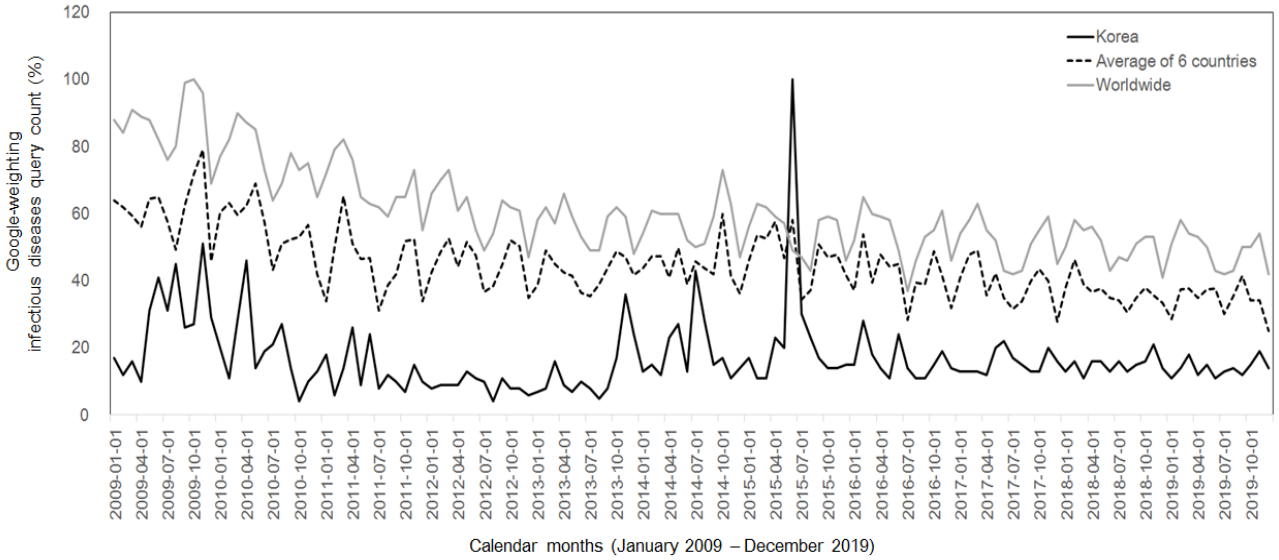

Figure 5. Comparison of Google query trends for the keyword "infectious diseases" in South Korea, the five other countries, and the world (January 2009–December 2019).

4.7. Comparison of Google query trends for the keyword "epidemic" in South Korea, the five other countries, and the world

From January 2009 to December 2019, there were no correlations in query trends for the keyword "epidemic" in South Korea, the five other countries included in the study ($r = 0.146$, $p = 0.096$), and the world ($r = 0.106$, $p = 0.228$). South Korea showed the highest peak when the H1N1 outbreak occurred in 2009, and when the MERS-CoV outbreak occurred in 2015. However, after the end report of each outbreak, it showed a low peak (**Figure 6**).

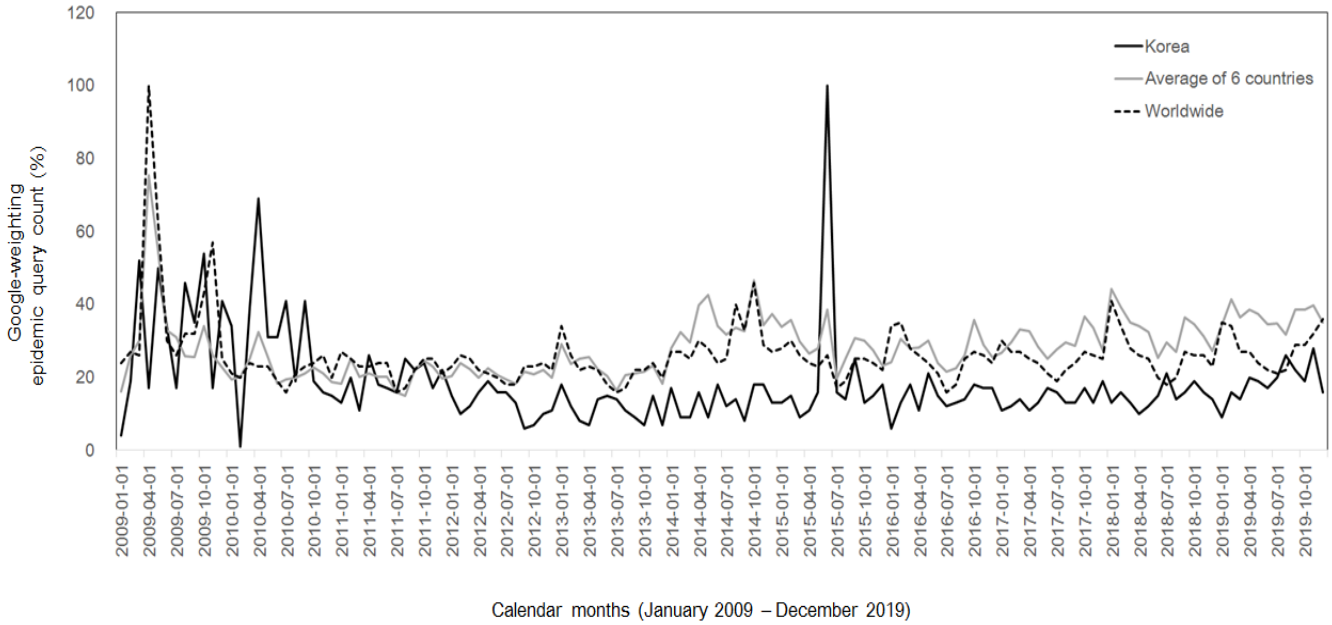

Figure 6. Comparison of Google query trends for the keyword "epidemic" in South Korea, the five other countries, and the world (January 2009–December 2019).

5. Discussion

This study used GTs to show the public's interest in infectious diseases in South Korea, the five other countries (the United States, France, Australia, Canada, and the United Kingdom), and the world.

This study reported four main findings. First, similar trends were seen in South Korea, the five other countries included in the study, and around the world for H1N1, MERS-CoV, and COVID-19-related RSV. South Korea and France and Australia showed high correlation in Google query trends for MERS-CoV. Particularly, H1N1 and MERS-CoV showed high RSV among South Koreans at the onset of the infectious disease outbreaks. These results were similar to those reported in studies from other countries (Husain et al., 2020; Shin et al., 2016). Second, during the outbreak of MERS-CoV in South Korea, the RSV correlated with increase in the cumulative number of confirmed cases and number of deaths. These results were similar to those reported in SARS and COVID-19 studies from the United States and eight countries (Cinarka et al., 2021; Husain et al., 2020; Ming et al., 2021). Third, after the MERS-CoV outbreak, South Korean interest in MERS-CoV was very low. These results were similar to the previous reported (Ming et al., 2021). Finally, H1N1, MERS-CoV, and COVID-19 the trends reflected the public's emotions. Therefore, we found that the timing of the reporting on H1N1 and MERS-CoV and the patterns of interest, as determined with GTs, were similar.

South Korea has implemented strong quarantine measures to minimize the spread of pandemics like SARS, MERS-CoV, and COVID-19, and government prevention have sparked increased public interest. The U.S. government in COVID-19 have led to aggressive travel restrictions and extensive media coverage, driving public attention to its peak (Husain et al., 2020). The United Kingdom study has observed a rise in searches for 'quarantine' and 'lockdown' due to the increased prevalence of RSV, reaching record highs (Ming et al., 2021). Some GTs studies observed a pattern in which RSV peaked at the onset of an infectious disease epidemic, or shortly after the first confirmed case was reported, before gradually decreasing to baseline levels. Asian countries were more interested in COVID-19 searching than the United States (Husain et al., 2020; Ming et al., 2021). In this study, it has been observed that RSV levels rise at the onset of infectious disease outbreaks and then decrease rapidly over a short period of time. Public interest in the early stages of an infectious disease tends to be higher, as the uncertainty surrounding the COVID-19 pandemic suggests that the public may not have been fully informed at first (Ming et al., 2021). On the other hand, after some time, RSV began to decline, possibly due to public desensitization to infectious diseases. The decrease was attributed to ongoing and widespread news coverage, according to the previous study (Collinson et al., 2015; Towers et al., 2015).

South Korea has seen a significant increase in RSV following the rise in MERS-CoV cases. The increase in search interest was linked to a rise in positive MERS-CoV tests or stronger epidemic control measures. Previous studies have reported a strong correlation between SARS-CoV-2 positive cases and an increase in RSV (Husain et al., 2020). Another study found that the search terms with the largest increase during the pre-lockdown period were directly related to the MERS-CoV (Ginsberg et al., 2009; Shin et al., 2016). We represented finding that GTs could complement early

health surveillance and provide valuable insights into the public's reactions and emotions during the pandemic (Kurian et al., 2020). These measures helped raise awareness of new threats and relevant health information quickly, enhancing public sensitivity and alertness to COVID-19 through effective health communication. This underscores the importance of digital surveillance and suggests that it can be a valuable tool in monitoring emerging pandemic outbreaks (Kurian et al., 2020).

Information communication through social networking sites during the MERS outbreak in South Korea greatly contributed to prevention efforts, demonstrating the importance of social networking services in the response to public health risks around new infectious diseases (Yoo et al., 2016). The COVID-19 outbreak has taught us the importance of communication, particularly health risk communication (Cowper, 2020; Heymann and Shindo, 2020). Public interest in infectious diseases is a reference for understanding the trend of the public health (Fagherazzi et al., 2020; Santangelo et al., 2020). GTs data on the public's interest in infectious diseases can reflect the level of health risk communication in a country.

Despite a high possibility of spreading the disease through human-to-human contact during the SARS-CoV and MERS outbreaks, the Korean government encountered difficulty in its initial response (Oboho et al., 2015). In the case of MERS-CoV, public confusion and anxiety were high because there was conflicting evidence regarding the cause of the virus.

Researching digital behavior patterns can provide a better understanding of the public's situation and effective immediate response strategies (Fagherazzi et al., 2020). Data on digital behavioral patterns can improve our ability to accurately estimate the spread of infectious diseases, assisting in the proactive monitoring of public reactions to infectious diseases and the development of countermeasures against them (Wong et al., 2019; Santangelo et al., 2020). It is essential to share information to quickly identify and respond to the spread of new infectious diseases (Ki, 2020).

GTs have not been validated for accuracy as a tool to measure public interest, and the search criteria used are not standardized, potentially omitting some search terms. Additionally, while Google is widely used in the United States, it may not be representative of all countries, particularly in regions with limited internet access, where vulnerable populations may be underrepresented. Finally, GTs do not provide actual search volume data, making it unclear to what extent search behavior has changed. However, since Google data reflect honest public opinion, it is possible to identify trends and other information on new infectious diseases in real time. Identifying digital behavioral patterns in population groups using web-based surveillance tools such as digital transformation allows scientists and policy makers to promote better decision-making and proactive responses to new infectious diseases (Budd et al., 2020).

6. Conclusions

In the context of a public health crisis, an increase in RSV related to specific topics or terms concerning an infectious disease can be seen as a public demand. Based on GTs, reasonable measures can be implemented for a rapid response in the early stages of the disease. Furthermore, building public trust is crucial during times of crisis,

making effective communication between the media and the government essential. Therefore, greater emphasis on health risk communication is needed to ensure public health and safety.

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Conflict of interest: The authors declare no conflict of interest.

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