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Original Research Article

Prediction of the Spread of the COVID-19 Pandemic with Google Searches: An Infodemiological Approach

Google Aramaları ile COVID-19 Pandemisinin Yayılımının Tahmini: İnfodemiyolojik Yaklaşım

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ABSTRACT

Aim: In outbreaks, public concern is reflected in search behavior. Examining the health literacy of the population and predicting before the diagnosis of cases may benefit the outbreak management. This study aims to evaluate the association of search behavior with the number of new confirmed cases in the affected countries by the Coronavirus disease 2019 (COVID-19) pandemic. This retrospective study is based on monitoring search behavior with an infodemiology and infoveillance approach.

Materials and Method: Google Trends™ was used to investigate Internet search behavior related to COVID-19 for 10 countries from February 15, 2020, to November 10, 2020. Spearman's rank correlation and time-lag correlation were used to determine the correlation with a delay of -30 days to +30 days between public interest and new daily confirmed cases.

Results: The level of COVID-19-related interest peaked about 33 days before the first peak in the number of cases. The correlation gradually decreased in seven countries towards the peak of cases. Spearman's rank correlations between Google searches and the number of new confirmed cases showed a negative correlation in Argentina, Brazil, India, and the United Kingdom ($p<0.001$), and a positive correlation in Italy, Turkey ($p<0.001$), and Russia ($p=0.017$). Eight countries had negative correlations in the increasing phase ($p<0.001$), and eight countries had strong to moderate positive correlations in the decreasing phase ($p<0.001$).

Conclusion: The findings showed that searches on Google Trends™ increased before new cases in the countries.

Keywords: COVID-19; Google Trends; Health information; Internet; Pandemic; Search interest

ÖZET

Amaç: Salgınlarda, halkın endişesi internet arama davranışına yansır. Nüfusun sağlık okuryazarlığının incelenmesi ve vakalara tanı konulmadan önce tahmin yapılması ülkelerin salgın yönetimine fayda sağlayabilir. Bu çalışma Koronavirüs hastalığı 2019 (COVID-19) pandemisinden etkilenen ülkelerdeki doğrulanmış yeni vaka sayısı ile arama davranışı arasındaki ilişkiyi değerlendirmeyi amaçlamaktadır. Bu retrospektif çalışma, arama davranışının bir infodemiyoloji ve bilgi gözetimi yaklaşımıyla izlenmesine dayanmaktadır.

Gereç ve Yöntem: On ülke için 15 Şubat 2020 tarihinden 10 Kasım 2020 tarihine kadar COVID-19 ile ilgili internet arama davranışını araştırmak için Google Trends™ kullanıldı. Halkın ilgisi ile günlük doğrulanmış yeni vakalar arasındaki -30 gün ila +30 gün gecikmeli korelasyonu belirlemek için Spearman rank korelasyonu ve zaman gecikmesi korelasyonu kullanıldı.

Bulgular: COVID-19 ile ilgi düzeyi, vaka sayısındaki ilk zirveden yaklaşık 33 gün önce zirve yaptı. Korelasyon yedi ülkede vakaların zirvesine doğru kademeli olarak azaldı. Google aramaları ile doğrulanmış yeni vaka sayısı arasındaki Spearman sıralama korelasyonları; Arjantin, Brezilya, Hindistan ve Birleşik Krallık'ta negatif bir korelasyon ($p<0.001$), İtalya, Türkiye ($p<0.001$) ve Rusya'da pozitif bir korelasyon gösterdi. ($p=0.017$). Sekiz ülke artan fazda negatif korelasyon vardı ($p<0.001$), sekiz ülke ise azalan fazda güçlü ila orta derecede pozitif korelasyon vardı ($p<0.001$).

Sonuç: Bulgular, ülkelerdeki yeni vakalardan önce Google Trends™'deki aramaların arttığını gösterdi.

A**nahtar Kelimeler:** COVID-19; Google Trends; Sağlık bilgisi; İnternet; Pandemi; Arama ilgisi

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INTRODUCTION

On the 12th of December 2019, the first case of coronavirus was detected in China[1] and it was temporarily called the 2019 novel coronavirus (2019 n-CoV) on the 31st of December 2019.[2] The virus spread to other countries due to its high virulence, it attracted worldwide attention.[3] The International Committee on Taxonomy of Viruses (ICTV) officially named the novel coronavirus the "Severe Acute Respiratory Syndrome Coronavirus 2" (SARS-CoV-2), and the disease the "Coronavirus Disease 2019" (COVID-19).[4] On March 11, the WHO announced that COVID-19 can be considered to be a pandemic.[5]

Infodemiological studies, such as analysis of Google queries to predict outbreaks, investigate the determinants and distribution of electronic information to benefit public health and public policy.[6] These studies are also crucial for presenting a preliminary picture of outbreaks[7] and avoiding infodemic, which is defined as "the misinformation phenomena during the management of virus outbreaks".[8] More than half of the global population had internet access in 2019,[9] and the general population searches for their health concerns online using Google Search with the increase in Internet access.[10]

When COVID-19 spread worldwide, the public concern may have been reflected in Google searches. As the global number of cases increased, people sought information online about the symptoms of the disease and how to protect themselves from the disease.[6,11,12] Even when anosmia was not recognized as a potential symptom by the WHO, search interest in anosmia was highly correlated with the number of COVID-19 cases.[12] Besides, in 2009, a study reported that Google searches provide an effective evaluation of the prediction of the influenza epidemic.[13] Since then, the application of Google search engine data to population health research has increased significantly. Several studies[14-15] were published regarding the early detection of many infectious diseases. Concerning the COVID-19 outbreak, it was also used for the forecast of the national outbreak.[1,11] Thus, statistics of Google searches about COVID-19 may be beneficial for rapidly spreading outbreaks.

According to the best of our knowledge, there is no published study on health literacy in the ten most affected countries by COVID-19 pandemic. This infodemiological study aims to compare Google searches on COVID-19 and the number of newly infected cases in the ten most affected countries from February 15, 2020, to November 10, 2020. The following was the null hypothesis: There is no correlation between the rate of the disease spreading and the online searches of Internet users in the ten countries most affected by the COVID-19 pandemic.

MATERIALS AND METHOD

The Search Terms and the Analysis of Google Trends™

This study obtained real-time data from Google searches for COVID-19 related terms from the public portal Google Trends™. Google Trends™ enables users to determine the pattern of search behavior, and provides the search volume relative to the total search volume of terms in a selected period.[10] It also normalizes the data according to the total search volume to make accurate comparisons on queries. Additionally, it filters recurrent searches made by the same user in a short time and gives daily data in Relative Search Volume (RSV). In other words, it gives the normalized value of the number of searches on the examined day compared to all searches in the evaluated period. On this relative scale, 100 refers to the most searched query while 50 refers to half of the searched queries (https://support.google.com/trends/).

The search queries were obtained by filtering the period between 15 February 2020 and 10 November 2020. The search terms were chosen by assessing the definitions announced by WHO on December 31, 2019. Google Trends™ provides data on a weekly basis when searches involve a period of more than approximately 10 months.[16] For retrieval of daily data, a period of about 10 months was chosen. Before February 15, three of the selected countries had only 10-15 cases, while other countries had only a few cases.[17] After November 10, as the public became familiar with COVID-19, the level of interest dropped and remained at a steadily low level on Google Trends™. Before selecting the keywords to be examined, all nomenclatures and abbreviations were searched in each country. Long

nomenclatures containing ‘‘2019’’ were searched with and without date using the compare function of Google Trends™ to see if they were searched with the year or not (such as ‘‘2019 novel coronavirus’’ and ‘‘novel coronavirus’’). The terms ‘‘Coronavirus disease 2019’’ and ‘‘Novel coronavirus’’ were the most used terms, so these terms were selected to be analyzed. Queries for India in English and Hindi were compared. Hindi queries seemed to be relatively nonexistent compared to English. Therefore, keywords for India were searched in English. In French and Portuguese, the terms with and without accents were compared. The term with the accent in French and the term without the accent in Portuguese were searched for in higher volumes. French terms with the accent and Portuguese terms without the accent were selected. When the terms are used without quotations, they include words in any order and combination; for example, instead of ‘‘coronavirus disease 2019’’, ‘‘the increase in diseases in 2019 and the coronavirus...’’.[16] Therefore, terms were queried with the double quotation. Six keywords, “Coronavirus, Coronavirus disease 2019, COVID-19, SARS-CoV-2, Novel coronavirus, and 2019-nCoV” were searched with the ‘‘web search’’ option of Google Trends™ for 10 countries in their languages. The plus sign (+) meaning ‘‘or’’ was used among all the terms to evaluate the combination of the terms. Since the COVID-19 related terms were recently recognized, “all query categories” were used in the filter option of Google Trends™. Terms with RSVs less than 1 were considered to be 0. This analysis obtained all data on December 16, 2020.

The selection of countries may result in the exclusion of data for countries with different outcomes due to selection bias.[18] Therefore, the ten most affected countries by the COVID-19 pandemic were evaluated in the present study. According to the 16th of December data of John Hopkins University[19], the top ten countries with the highest number of cases were determined. They were in descending order of the number of cases: The United States (US), India, Brazil, Russia, France, Turkey, the United Kingdom (UK), Italy, Spain, and Argentina. Considering that there were eight different national languages in these ten countries, all the terms have been translated into those eight languages (https://translate.google.com/). The list of the translated terms in the target languages is shown in Table 1. We used a framework specified by Mavragani and Ochoa[16] to obtain query data from Google Trends™. In the presentation of the data, the checklist of Nuti *et al*.[20] was also followed.

Table 1. The list of COVID-19-related terms searched in Google Search

English	Coronavirus	Coronavirus Disease 2019	COVID-19	SARS-CoV-2	Novel coronavirus	2019-nCoV
Portuguese	Coronavirus	Doença do coronavirus 2019	COVID-19	SARS-CoV-2	Novo coronavirus	2019-nCoV
Russian	коронавирус	коронавирус заболевание 2019	COVID-19	SARS-CoV-2	Новый коронавирус	2019-nCoV
French	Coronavirus	Maladie à coronavirus 2019	COVID-19	SARS-CoV-2	Nouveau coronavirus	2019-nCoV
Turkish	Koronavirüs	Koronavirüs hastalığı 2019	COVID-19	SARS-CoV-2	Yeni koronavirüs	2019-nCoV
Italian	Coronavirus	Malattia da coronavirus 2019	COVID-19	SARS-CoV-2	Nuovo coronavirus	2019-nCoV
Spanish	Coronavirus	Enfermedad por coronavirus 2019	COVID-19	SARS-CoV-2	Nuevo coronavirus	2019-nCoV

The Number of Daily New Cases in the Ten Most Affected Countries

The daily numbers of new cases and deaths by country were retrieved from ‘‘Our World in Data’’,[17] a public portal. This database updates data from John Hopkins University daily. The daily numbers of new cases and deaths in ten countries included in our study were filtered within the dates that match the specified period of time.

Statistical Analysis

This analysis used the Shapiro-Wilk test to determine whether the continuous variables were normally distributed. Spearman's rank correlation test was used to analyze the relationship between non-normal variables. Data were recorded at the first global peak with a delay of -30 days to +30 days and the correlation between RSV and the number of new cases was examined. Data analysis was performed with the SPSS (Statistical Package for the Social Sciences) for Windows version 22.0, and the statistical significance level was 0.05.

RESULTS

The search behavior of the population was examined to predict and associate with outbreaks. Figures 1 and 2 show the daily number of new cases and RSVs for the first 5 and the second 5 countries most affected by COVID-19 by February 15. All countries, except Italy, reached the highest level of interest (RSV=100) in Google searches between 12 and 31 March. Public search interest in the ten countries peaked for about 33 days (20 – 41 days) before they reached the peak of the first fluctuation in the number of cases. Later, as the number of cases continued to increase, the relative search volume did not exceed half of the maximum searched query in any country. The daily new confirmed cases and public interest are compared between February 15 to November 10 in Table 2. The increasing and decreasing phases of the first peak for each country were also analyzed by Spearman's rank correlation. In the increasing phase, there were negative correlations in eight countries ($p<0.001$), while the correlation was positive in the US ($p<0.001$). When the decreasing phase was examined, there was a strong to moderate positive correlation in eight countries ($p<0.001$), other than France ($p=0.642$) and Argentina ($p=0.315$).

Figure 3 shows the time-lag correlations between the RSVs and daily new confirmed COVID-19 cases and deaths of the ten affected countries by COVID-19 pandemics. In seven countries other than the European countries of France, Italy, and Spain, the correlation gradually decreased towards the peak of cases and then continued at a steady rate. However, the correlation increased towards the peak of cases in European countries. The correlation of public interest with the number of new deaths for each country was similar to the correlation with the number of cases.

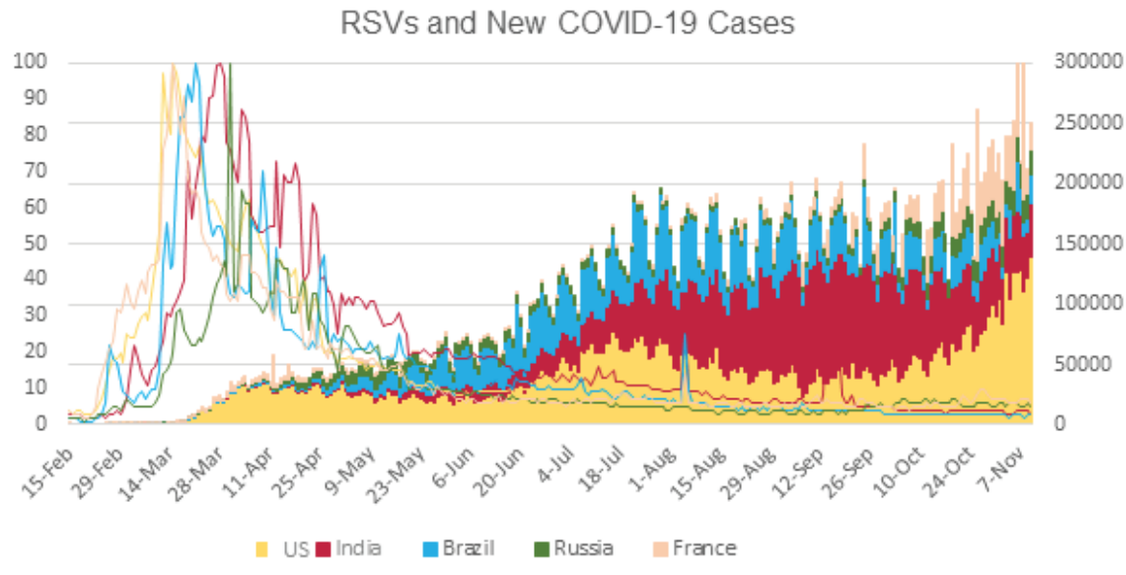

Figure 1. The Relative Search Volume (RSV) and daily new confirmed cases in the US, India, Brazil, Russia, and France between February 15, and November 10, 2020

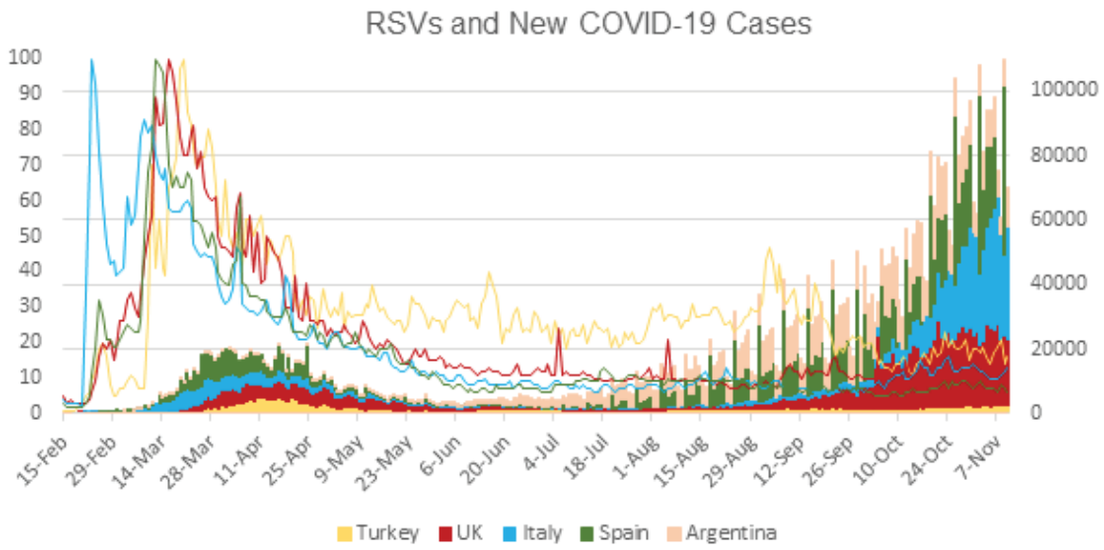

Figure 2. The Relative Search Volume (RSV) and daily new confirmed cases in Turkey, the UK, Italy, Spain, and Argentina between February 15, and November 10, 2020

Table 2. Spearman's rank correlations between Google searches (RSVs) and the number of new cases for ten countries between February 15, and November 10, 2020

	Feb 15 - Nov 11			Increase phase			Decrease phase		
	ρ-value	p-value	n	ρ-value	p-value	n	ρ-value	p-value	Peak date
US	0.009	0.877	34	0.659	<0.001*	58	0.774	<0.001*	07.16.2020
India	-0.505	<0.001*	92	-0.754	<0.001*	55	0.751	<0.001*	09.16.2020
Brazil	-0.330	<0.001*	85	-0.760	<0.001*	99	0.462	<0.001*	07.29.2020
Russia	0.145	0.017*	33	-0.780	<0.001*	106	0.964	<0.001*	05.11.2020
France	-0.022	0.723	41	-0.601	<0.001*	21	0.108	0.642	04.19.2020
Turkey	0.229	<0.001*	33	-0.597	<0.001*	51	0.513	<0.001*	04.16.2020
UK	-0.498	<0.001*	45	-0.693	<0.001*	71	0.913	<0.001*	04.22.2020
Italy	0.439	<0.001*	26	-0.005	0.979	67	0.950	<0.001*	03.26.2020
Spain	0.084	0.170	20	-0.836	<0.001*	29	0.685	<0.001*	04.01.2020
Argentina	-0.678	<0.001*	155	-0.888	<0.001*	18	-0.251	0.315	10.21.2020

ρ: Spearman's rank correlation coefficients, *p<0.05

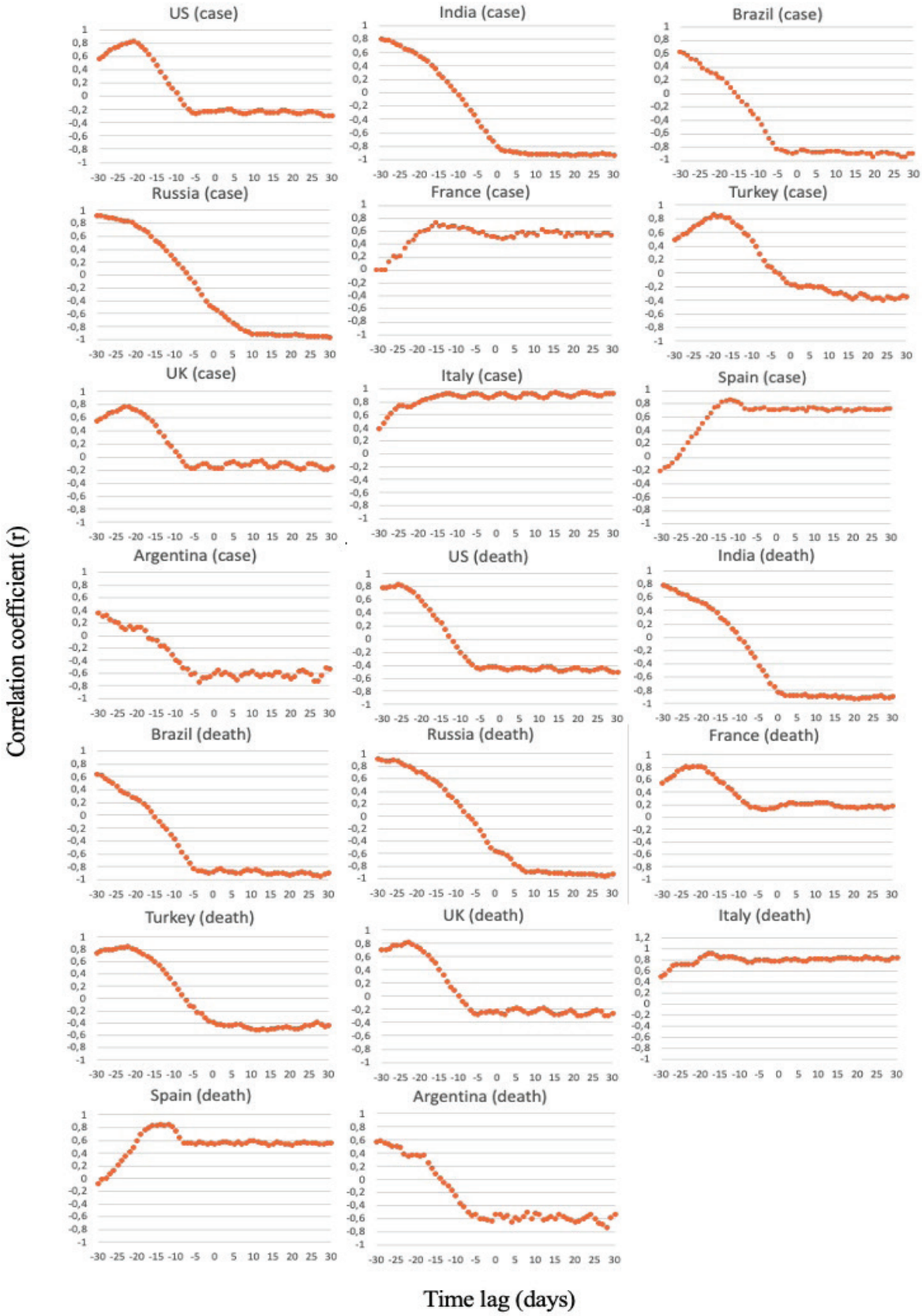

Figure 3. Time-lag correlation between RSVs and daily new confirmed COVID-19 cases/deaths of the ten most affected countries between February 15, and November 10, 2020

DISCUSSION

The total number of confirmed COVID-19 cases in the world has reached 80 million and the global number of deaths is now over 1.7 million in one year.[19] It is important to predict rapidly rising outbreaks as early as possible to prevent spread. In this infodemiological study, the beginning of interest in the investigated countries of COVID-19 was about a month before the number of new confirmed cases reached a peak. Similarly, Carneiro and Mylonakis[21] reported that Google Trends™ data could predict the influenza outbreak 7-10 days before the Centers for Disease Control and Prevention. Moreover, several studies showed that it predicts different infectious outbreaks such as Ebola14 and H1N1 influenza (swine-origin influenza A).[15] These epidemics have supported the use of Internet searches for outbreak surveillance.

There may be several reasons for the earlier increase in public interest. First, because it was a newly recognized disease, it might have attracted more attention than familiar epidemics such as influenza. Furthermore, the public may be more concerned due to faster spread rates and higher deaths. Secondly, people searching the Internet may have searched not only because they were infected, but also because they were curious about the symptoms and ways of protection from COVID-19.[11] Finally, it takes several days for patients or suspected cases to be tested and to be identified as newly infected cases, which extends the lag period. On the other hand, Walker *et al*. thought that as a result of the study they published, Google Search Trends™ could also be used to identify minor symptoms that would not require seeking medical attention.[12] Although there were some problems in using Google Flu for predictions in the past, the improved Google Trends™ can now be used with more confidence.[22]

The highest level of attention in all countries was between 12 and 31 March. The reason for this may be the declaration of the WHO on March 11, 2020 that COVID-19 can be considered a pandemic.[5] Then, the level of interest in all countries but Turkey declined below 25% of the RSV in 1-1.5 months. In Turkey, however, it took 3 months. The reason for this may be the government's strategy of lockdown in Turkey. Lockdown was applied for weekends only in Turkey and these lockdowns were announced weekly. This may have kept the public's interest in COVID-19 at high level. Although the number of cases increased in the latter period of the pandemic, Google searches decreased about 2 months after reaching the peak. Rovetta and Castaldo[23] stated that although the searches of Italian Internet users related to COVID-19 decreased significantly at the beginning of the pandemic about 2 months after the peak, their search related to hygiene and protection remained stable at a certain level despite a slight decrease. The reason may be that, as Bults *et al*.[24] pointed out for the 2009 Influenza A pandemic, the general concern about the pandemic may decrease, even if the concern of becoming personally infected increases over time. Another reason could be educational programs and awareness campaigns about COVID-19 in the media and on the Internet.[3]

When the lag correlation with -30 to +30 days delay was calculated, there were different correlation patterns in the countries. There was a positive correlation from high to moderate in France, Italy, and Spain for almost two months. The spread of the outbreak might be similar, as European countries have similar levels of economic development and high movement between countries.[22] In addition to tracking the number of local cases, European countries may also be tracking the number of cases worldwide and in their own region.

In Argentina, there was a correlation only between -30 and -27 days. Google Trends™ data may have detected COVID-19 cases more than 30 days prior to the recognition of the pandemic in Argentina. To understand the reason, the lag correlation could be evaluated over a longer period in further studies. In other countries, positive correlations continued for about 3 weeks. Besides, the highest correlation was 20-22 days ago or 30 days ago for 7 countries except for the European countries. Although the highest correlation values were similarly -12 and -18 days for Spain and France, respectively, it was +22 days for Italy. One reason may be that Italy was one of the first countries where the outbreak spread after China. While the highest public attention in other countries occurred after the WHO's pandemic announcement, it occurred in Italy on 23 February, in the early period of the outbreak. Another reason why Internet searches were fewer at the beginning may be the educational programs made via televi-

sion in the country. Zanin *et al*.[25] reported that the rate of television watching was 44% and internet search was below 10% as a source of information on COVID-19 in Italy, in March 2020. The rate of Internet users accessing health information online in other countries was reported between 75%-92%.[26,27] As noted in a previous study,[18] COVID-19-related queries may be influenced by international news reports and WHO announcements. As distinct from these studies, Sousa-Pinto *et al*.[28] stated that the media has some effect on searches about ‘‘anosmia’’, but not on ‘‘coronavirus’’ searches. On the other hand, Bento *et al*.[29] reported that the 36% increase in interest after the announcement of the first local case was short-lived. However, since announcements associated with COVID-19 were related to the number of cases, it is difficult to separate the influence of the media from the number of cases.

Spearman’s rank correlation between the number of new confirmed cases and the RSV of each country was evaluated. There was a positive correlation in Italy, Russia, and Turkey, while a negative correlation in Argentina, Brazil, India, and the UK. Countries with negative correlations, and Russia with a very low correlation, were the countries with the earliest increase in RSV. The public in these countries started online research much earlier than the outbreak spread. In the increasing phase, RSV in most countries was negatively correlated with the number of cases, while in the decreasing phase, they were positively correlated.

Since the present study is the first to evaluate the association between the search behavior of the population and the number of cases in the ten most affected countries by COVID-19 pandemic, this country-based analysis can be considerably useful in determining community and public health policies. After it was reported in 2009 that Google search engine data detected the influenza epidemic early, Google Trends data began to be used in public health policies, such as the early detection of outbreaks like syphilis, Zika virus infection, Lyme disease, and AIDS.[10] In addition, it has been utilized for health policies, such as monitoring drug usage and tracking interest in topics like electronic cigarettes or abortions.[10] To the best of our knowledge, this study is more comprehensive in many respects than previously published studies. To reach larger data, instead of a few terms,[1,3,28] 6 keywords containing all the definitions related to COVID-19 were used. To reach unbiased data, the 10 countries most affected by COVID-19 were examined, and the present study included almost 50 million of the 76 million global cases at the time of analysis. Moreover, instead of countries where a single language was used,[1,11] 10 countries with different structures in which 8 different official languages are used were examined. This provides a more global view.

It is also the longest time frame of study on COVID-19 ever published. Other studies[3,18,22] that analyze short time frames do not include the peak of Google searches or the late period when public interest decreases. The study has shown that the public interest at the beginning of the pandemic and in the later period of the pandemic was different. Three studies[3,11] used time-lag correlations to assess the association between Google search and newly confirmed cases of COVID-19. However, two of these studies analyzed a single country.

Since Google Trends™ data was affected by the number of cases announced by countries, this may cause different search outputs in surveillance studies. Moreover, it should be kept in mind that the data of new cases and deaths reported by countries are dependent on the test policies of the particular countries.[30]

The present study has several limitations. First, in the evaluation of search trends, only Google Trends™ was used. Second, there is no clear standardization yet for Google Trends™ data analysis.[20] However, this study followed the conventions used in two articles published on this subject.[16,20] Third, the sample of the study includes only the literate public who can access the Internet in ten countries, as it is an online surveillance study.

CONCLUSION

In conclusion, these results confirm that Google Trends™ in the COVID-19 outbreak, as in other outbreaks, could be used for prediction. When the size of the outbreak was large, it could predict its size and spread much earlier than other outbreaks. Therefore, the null hypothesis of this study was rejected. However, it should not be forgotten that these forecast times may vary, as the management and direc-

tion of the epidemic may differ in each country, and public interest in the outbreak may decrease over time. When analyzed correctly, Google Trends™ data can help countries manage their health policies. By examining the data, public health information campaigns could be carried out in the period when public anxiety and curiosity are the highest. Furthermore, Internet users' activities on Google Trends™ may be monitored to prevent misinformation and in informing the public about diseases and preventive measures.

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