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Silver lining of COVID-19: Heightened global interest in pneumococcal and influenza vaccines, an infodemiology study

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ABSTRACT

Background: Health-seeking behaviors change during pandemics and may increase with regard to illnesses with symptoms similar to the pandemic. The global reaction to COVID-19 may drive interest in vaccines for other diseases.
Objectives: Our study investigated the correlation between global online interest in COVID-19 and interest in CDC-recommended routine vaccines.
Design, settings, measurements: This infodemiology study used Google Trends data to quantify worldwide interest in COVID-19 and CDC-recommended vaccines using the unit search volume index (SVI), which estimates volume of online search activity relative to highest volume of searches within a specified period. SVIs from December 30, 2019 to March 30, 2020 were collected for "coronavirus (Virus)" and compared with SVIs of search terms related to CDC-recommended adult vaccines. To account for seasonal variation, we compared SVIs from December 30, 2019 to March 30, 2020 with SVIs from the same months in 2015 to 2019. We performed country-level analyses in ten COVID-19 hotspots and ten countries with low disease burden.
Results: There were significant positive correlations between SVIs for "coronavirus (Virus)" and search terms for pneumococcal ($R = 0.89$, $p < 0.0001$) and influenza vaccines ($R = 0.93$, $p < 0.0001$) in 2020, which were greater than SVIs for the same terms in 2015–2019 ($p = 0.005$, $p < 0.0001$, respectively). Eight in ten COVID-19 hotspots demonstrated significant positive correlations between SVIs for coronavirus and search terms for pneumococcal and influenza vaccines.
Limitations: SVIs estimate relative changes in online interest and do not represent the interest of people with no Internet access.
Conclusion: A peak in worldwide interest in pneumococcal and influenza vaccines coincided with the COVID-19 pandemic in February and March 2020. Trends are likely not seasonal in origin and may be driven by COVID-19 hotspots. Global events may change public perception about the importance of vaccines. Our findings may herald higher demand for pneumonia and influenza vaccines in the upcoming season.

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1. Introduction

In December 2019, a novel coronavirus caused a cluster of cases of severe pneumonia in Wuhan, China. The World Health Organization (WHO) has since named the disease "coronavirus disease 2019" (COVID-19) and the etiologic agent "severe acute respiratory syndrome-coronavirus-2" (SARS-CoV-2). On January 30, 2020, the first human-to-human transmission of this infection was confirmed, and the WHO declared COVID-19 a Public Health Emergency of Concern. By March 2020, there were more than 400,000 recorded cases of COVID-19 worldwide, prompting the WHO to declare a global pandemic [1].

With the current dearth of approved therapeutic agents, the management of COVID-19 is primarily supportive and preventative. The Centers for Disease Control and Prevention (CDC) recommends hand washing and social distancing to the general public. Though there are ongoing trials of Bacillus Calmette-Guerin (BCG) vaccine [2] and SARS-CoV-2 mRNA vaccine [3] for use on COVID-19, no vaccine for the prevention of COVID-19 has been approved for public use.

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Public interest in vaccinations and health-seeking behavior generally increase during outbreaks, particularly with regard to illnesses that manifest with symptoms similar to those of the pandemic [4–7]. A study in Spain documented a higher volume of phone calls for flu-like symptoms and influenza vaccinations during the flu season and during awareness campaigns [6]. Among patients with influenza like illness, there were higher health-seeking rates or patient visits during the H1N1 pandemic than during non-pandemic periods [4,5,7].

With over 3 billion Internet users around the world, Internet search trends have been used in the past to reflect public interest and awareness in diseases and as a proxy for public health risk perception [8–16]. Such type of research falls under the field of infodemiology, the study of distribution and determinants of information, specifically in the Internet, with the primary goal of informing public health or policy [17]. Prior infodemiology studies modeled outbreaks of influenza based on internet search queries [18–20]. Similar attempts were subsequently made to predict outbreaks of SARS, foodborne illnesses, and dengue [21]. Infodemiology studies on vaccination interest or demand are lacking. Our study describes search trends for various vaccines and assesses the association between a pandemic (COVID-19) and public interest in vaccines made for other diseases. We hypothesized that heightened public awareness about a global pandemic would galvanize health information-seeking behavior, as reflected in online interest in vaccinations.

2. Methods

Our study investigated whether or not a correlation exists between online interest in COVID-19, as reflected by search volume index (SVI), and interest in routine vaccinations recommended by the CDC from December 30, 2019 to March 30, 2020. December 30, 2019 was chosen as the initial date of data collection because it coincided with the first report of Chinese health officials to the WHO regarding clusters of an acute respiratory illness among patients in Wuhan, China [25]. If positive correlations were demonstrated, we further investigated whether or not the recent search trend for the vaccine in 2020 was attributable to a seasonal pattern by comparing 2020 search trends to those from the same months of 2015–2019.

Online interest was analyzed using Google Trends, an online activity data analysis tool that reports search trends in the unit search volume index (SVI) [22]. SVIs do not report the absolute volume of searches for a specified search term, but rather provide an estimate of the search activity relative to the highest volume of searches recorded within a specified time period and geographic location. SVIs are normalized to the time period and geographic location in which the search phrase was searched most frequently (assigned SVI = 100), and is collected by Google as a random sample of historical data [22]. SVIs have been used previously to assess population interest in health-related topics [9,10,23]. We used Google Trends to collect SVIs for the search phrases "coronavirus", "COVID-19", "COVID", "nCoV", and "nCoV-19" from January of 2004, the earliest period with available data from Google Trends, to March 30th of 2020. The search term "coronavirus" yielded the highest SVIs compared to the other search terms and was therefore the most commonly searched phrase related to the pandemic. We opted to use "coronavirus (Virus)" instead of "coronavirus (search term)" as the former encompasses all search activity related to the coronavirus and not just search queries with the actual text "coronavirus" [24].

We collected the worldwide SVIs from December 30, 2019 to March 30, 2020 of routine vaccines recommended by the CDC to all non-pregnant adults (Table 1). To evaluate associations between interest in COVID-19 and interest in vaccines, Pearson correlation was used to correlate the worldwide SVIs of "coronavirus (Virus)" from December 30, 2020 to March 30, 2020 with the SVIs of the search terms for routine vaccines in the same period.

To determine whether global trends remained consistent between COVID-19 hotspots and countries with less disease burden, we collected the SVIs for vaccines whose SVIs demonstrated a positive correlation with "coronavirus (Virus)" from ten countries with the highest number of COVID-19 cases as of March 30, 2020 and ten other countries with the least number of COVID-19 cases in the same period and with available Google Trends data. Pearson correlation was used to correlate the SVIs of "coronavirus" from the corresponding country from December 30, 2019 to March 30, 2020 with the local SVIs of the search terms for vaccines in the same period (Supplementary Table 2).

Among the vaccines with SVIs demonstrating a significantly positive correlation with the term "coronavirus (Virus)", we investigated whether or not the search trend followed a seasonal pattern. Furthermore, we added more specific search terms for these vaccines to compare with the SVIs of "coronavirus (Virus)" (Table 1). The Student's T-test was used to compare the vaccine SVIs from December 30, 2019 to March 30, 2020 to the SVIs between the same period from the years 2015 to 2019.

Statistical significance was defined as a two-sided P-value of less than 0.05. All analyses were performed using Stata 16.1 I/C (StataCorp, College Station, TX). No funding was used in the preparation of this work; the Harvard Medical School Institutional Review Board deems this work exempt from review as it does not constitute research on human subjects.

3. Results

Search volume indices for "coronavirus (Virus)" and search terms for influenza and pneumococcal vaccines showed a marked peak in March of 2020 (Fig. 1).

Table 1
Vaccine search terms used in comparison with "coronavirus".

Disease	Vaccine search terms used	Added search terms after demonstrating positive correlation
Influenza	"flu vaccine"	"influenza vaccine", "Fluarix", "Flublok", "Fluzone", "Flucelvax"
Streptococcal pneumonia	"pneumonia vaccine"	"pneumococcal vaccine". "Pneumovax", "Prevnar". "PCV13", "PPSV23"
Tetanus, diphtheria, pertussis	"Tdap" "tetanus vaccine"	
Measles, mumps, rubella	"MMR" "measles vaccine"	
Varicella-zoster	"varicella vaccine", "zoster vaccine", "shingles vaccine", "chickenpox vaccine"	
Haemophilus influenza B	"Haemophilus vaccine", "HiB vaccine"	
Human papillomavirus infection	"HPV vaccine"	
Hepatitis	"hepatitis A vaccine", "hepatitis B vaccine"	
Meningococcemia	"meningococcal vaccine"	

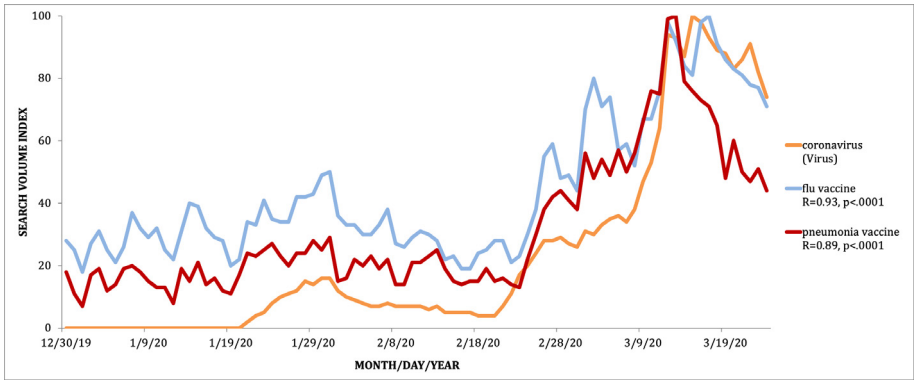

Fig. 1. Search volume indices for the terms "coronavirus (Virus)", "flu vaccine", and "pneumonia vaccine" in the year 2020. SVIs were calculated separately for each search term such that SVIs are normalized within each term.

Table 2
Positive correlations between SVIs for "coronavirus" and SVIs for pneumoccocal and influenza vaccine search terms.

Disease	Search Term	R value	p-value
Influenza			
	"influenza vaccine" "flu vaccine"	0.36	<.001
		0.93	<.0001
	"Fluarix"	0.71	<.001
Streptococcal pneumonia			
	"pneumococcal vaccine"	0.58	<.0001
	"pneumonia vaccine"	0.89	<.0001
	"PPSV23"	0.50	<.0001
	"Pneumovax"	0.87	<.0001

Table 3
P-values after comparing 2020 search volume indices with those from 2015 to 2019

Disease	Search Term	p-value
Influenza		
	"influenza vaccine"	<.0001
	"flu vaccine"	<.0001
	"Fluarix"	0.004
Streptococcal pneumonia		
	"pneumococcal vaccine"	<.0001
	"pneumonia vaccine"	<.0001
	"PPSV23"	0.001
	"Pneumovax"	<.0001

SVIs for "coronavirus (Virus)" were positively correlated with the SVIs for numerous search terms related to vaccines for influenza and streptococcal pneumonia (Table 2). SVIs for "coronavirus (Virus)" were negatively correlated with those of the following search terms: "Tdap vaccine", "varicella vaccine", "HPV vaccine", "HiB vaccine", "shingles vaccine", "Hepatitis A vaccine", "Hepatitis B vaccine", and "meningococcal vaccine" (Supplementary Table 1).

Eight in the ten countries with the highest incidence of COVID-19 on March 30, 2020 demonstrated a positive correlation between the local SVIs for the influenza vaccine and coronavirus, and between the pneumococcal vaccine and coronavirus. In contrast, three and four in the ten countries with the lowest number of cases of COVID-19 and with available Google Trends data demonstrated significantly positive correlations when comparing local SVIs for coronavirus with the local SVIs for the influenza vaccine and the pneumococcal vaccine, respectively. In the correlation of local SVIs for the influenza vaccine and coronavirus, the range of significant Pearson coefficients (R) of the 10 COVID-19 hotspots and the 10 countries with low incidence were 0.35–0.73 and 0.22–0.46, respectively. When correlating local SVIs for the pneumococcal vaccine and coronavirus, the range of significant R values of the countries with the highest and lowest incidence were 0.37–0.91 and 0.29–0.39, respectively (Supplementary Table 2).

Among the vaccines with significant positive correlations, SVIs of respective search terms from December 30, 2019 to March 30, 2020 were compared to those from the same months of the years 2015–2019. SVIs from the year 2020 of most related search terms for influenza and pneumococcal vaccines were significantly different from those from the years 2015–2019 (Table 3, Fig. 2). Exceptions were the search terms "Prevnar", "PCV13", "Flublok", "Fluzone", "Flucelvax".

4. Discussion

Our findings point to increased worldwide interest in the pneumococcal and influenza vaccines that is coincident to current events surrounding the COVID-19 pandemic in February and March of 2020. The World Health Organization (WHO) declared COVID-19 a Public Health Emergency of Concern on January 30, 2020 and then a pandemic on March 11th. On March 13th, the WHO designated Europe as the new epicenter of the infection and then two weeks later, the United States confirmed more COVID-19 cases than any other country in the world [26,27]. By March 31st, there were more than 850,000 confirmed cases worldwide [27]. All of these events may explain the peak in global interest in COVID-19 in February and March 2020 that is reflected by the SVIs for "coronavirus".

Online interest in the influenza and pneumococcal vaccines follows a seasonal pattern, typically highest during the months of September to November (Fig. 2), just before the flu season, when both vaccines are typically administered in the same visit [28–30]. Therefore, the significant difference between the SVIs for influenza and pneumococcal vaccine-related search terms in February and March 2020 and the SVIs for the same months in the years 2015–2019 suggests that the sudden peak in interest for these two vaccines is unlikely seasonal in origin.

Heightened interest in pneumococcal and influenza vaccines during the COVID-19 pandemic may have a number of plausible explanations. The first is an increase in health-seeking behavior throughout the world, with regard to illnesses that manifest with symptoms similar to those of the pandemic [4–7]. Previous experience with influenza infections, particularly the H1N1 pandemic, demonstrated an increased number of visits for influenza-like illnesses during the pandemic vs. non-pandemic times [7]. In the setting of COVID-19, use of various non-COVID-related medical services ranging from emergency room visits to surgical proce-

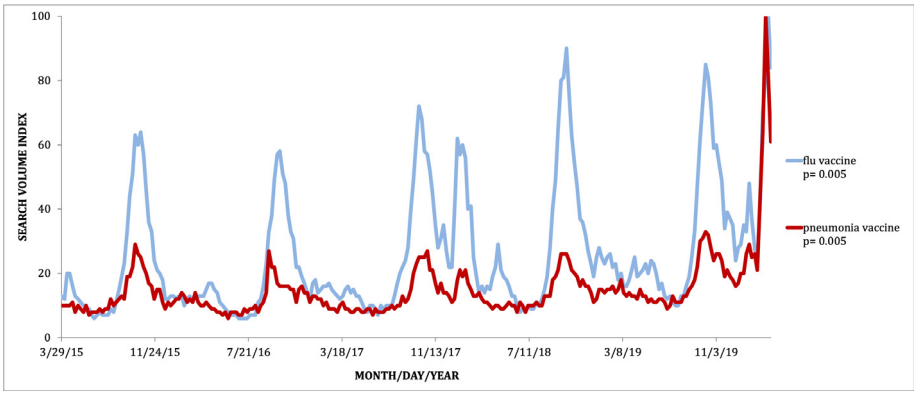

Fig. 2. Seasonal pattern of search volume indices for "flu vaccine", and "pneumonia vaccine" with SVIs from January 30th to March 30th 2020 significantly different from SVIs between the same months and days in 2015–2019. SVIs were calculated separately for each search term such that SVIs are normalized within each term.

dures decreased, possibly due to fear of contracting COVID-19 in the hospital [31,32]. Online interest in elective orthopedic procedures decreased with the advent of the COVID-19 pandemic [33]. It is possible therefore that the public's interest in health during the pandemic may be specific to COVID-19 and conditions with symptoms that may be perceived similar to those of COVID-19, such as influenza and pneumococcal pneumonia, and their vaccines. This hypothesis may also explain why an increase in interest in vaccines for conditions such as tetanus and viral hepatitis was not demonstrated. Although online health information seeking does not fully encompass health-seeking behavior, it may be an important component [4,6,7,34–37].

Second, towards the latter end of February 2020, the Centers for Disease Control (CDC) called for all adults to be vaccinated for the flu as a way to decrease hospital admissions for influenza and subsequent COVID-19 exposure, and to aid in the diagnosis of patients presenting with flu-like symptoms. However, the CDC did not specifically highlight the need for the pneumococcal vaccine during this period [38].

Third, COVID-19 may be changing perceptions about the importance of preventing pulmonary infections through vaccinations. There is evidence that a previous history of influenza vaccination is associated with pneumococcal vaccination among high-risk groups [39]. Patient perception and knowledge about other vaccines are significant drivers in increasing vaccination coverage for the pneumococcal vaccine [40,41]. Perceived severity of pneumonia, in particular, is significantly associated with successful pneumococcal vaccinations [39]. It is possible that the anxiety surrounding the severity of COVID-19 may be carried over to other causes of pneumonia, like the influenza virus and S. pneumoniae.

Focused analyses of COVID-19 hotspots and of countries with low COVID-19 incidence demonstrated findings consistent with the global trend. However, the larger proportion of positive correlations and the higher range of Pearson coefficients among the ten COVID-19 hotspots suggest that this global trend is largely driven by countries with higher disease burden. The most intuitive explanation for this finding is that countries which were more affected by the pandemic would likely have greater interest in preventative measures for diseases of similar symptomatology. Another possible explanation for this finding is the higher penetration of the Internet in the ten COVID-19 hotspots, which were mostly developed countries [42]. Collection of SVIs from a specified territory allows us to analyze the trends within countries having less search volumes that would have otherwise been overshadowed by global trends.

We found negative correlations between the SVIs for "coronavirus (Virus)" with those of search terms of vaccines for diseases not generally thought to be associated with pneumonia. These include hepatitis A, hepatitis B, meningitis, chickenpox, and shingles. More data on vaccine surveillance and coverage is needed to conclude that the general public possibly lost interest in these vaccines.

Our findings may foreshadow changes in vaccination rates in the near future. Though vaccine coverage is largely a function of the health care system, public perception of vaccines may lead to massive changes in immunization rates. For example, public distrust that stemmed from the premature introduction of a new dengue vaccine in the Philippines led to low immunization rates and the 2019 measles outbreak in the region [43,44]. What we hope for in this case is the corollary in which the widespread demand for the COVID-19 vaccine would influence vaccination uptake around the world [45].

Prior studies have also used an infodemiology approach to study various aspects of COVID-19. One study found correlations between online interest in "coronavirus" and the number of cases and deaths in various European countries, an association that was strongest in the early stages of the pandemic [46], consistent with our study's demonstrated SVI uptick in early March 2020. Another infodemiology study found strong positive correlations between online interest in symptoms associated with COVID-19 (e.g. shortness of breath, chest pain, dysgeusia) and daily new cases and deaths using both Google Trends and the Baidu Index [47]. The authors conclude that digital epidemiology may be used in surveillance of disease outbreaks [47]. Our study adds to the literature and suggests increased interest in vaccines for conditions that manifest with pulmonary symptoms potentially similar to those classically associated with COVID-19 [48]. Other studies have warned against potential online misinformation, and have encouraged careful curation of online health information [49,50]. As in other areas of medicine [11,37,51,52], care must be taken in the provision of accurate and accessible online health information that may influence the health behaviors of many.

Previous studies validate Internet search patterns as a proxy for population interest of different diseases [9,10,53–55]. Some studies have also shown promise in anticipating influenza and varicella outbreaks using Google search trends [34,55,56]. Our demonstration of associations between the increasing search trends of COVID-19 with those of influenza and pneumococcal vaccines may suggest an increase in the perceived need for these vaccines and may ultimately signal an increasing demand in the near future. Furthermore, increased interest in vaccines for pulmonary illnesses may allow providers to open the conversation about and encourage adherence to guidelines regarding vaccines for non-pulmonary illnesses. [57,58].

One limitation of this study is the use of search volume index from Google Trends as a surrogate for population interest for COVID-19 and vaccines. Thus, people who use other search engines or lack Internet access are not included in the investigation. However, since more than 3 billion individuals around the world use the Internet and Google is the most widely used search engine, Google Trends is still a useful tool to estimate public interest [10,59]. Another limitation of the study is that Google Trends does not show absolute search volumes, which could have been used for more in-depth and precise studies; however, analysis of data normalized to time and geography allow for useful study of change in health information-seeking behavior. The study is also limited by the finite number of search terms used. However, "coronavirus" has been demonstrated in other infodemiology studies to be correlated with incidence and mortality in various settings [46,47]. The study is similarly limited by the study of the initial months of the pandemic. Further analyses may explore trends over longer periods of time and using a wider array of search terms. There is lack of demographic data about who are actually conducting the searches represented by the SVIs. Searches may be conducted for research, education, or other purposes. SVIs include searches conducted by children, who may have different rates of Internet use compared to adults. Lastly, it is still unclear whether changes in online activity translate to changes in health behavior. Future studies may assess the associations between online interest in vaccines and actual vaccination rates. Studies may also assess the role of online health information – with online activity as a barometer for access to online health information – in mitigating sociodemographic and global disparities in vaccination rates.

5. Conclusion

The study found a significant correlation between interest in COVID-19 and interest in influenza and pneumococcal vaccines. This could be driven by the general increase in health information-seeking behavior during a pandemic, the CDC recommendation for the annual influenza vaccination, and a changing perception about preventing pulmonary infections because of COVID-19. This could present as an opportunity for further studies into approximating vaccine demand and improving health education that could mitigate future disease outbreaks and possibly impact other aspects of public health. Success of these measures could be reflected in Internet search patterns.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2020.06.069.

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