Utilizing Google trends to monitor coronavirus vaccine interest and hesitancies

Emily Merrick [a], Joshua P. Weissman [a], Sameer J. Patel [a,b,*]

[a] Northwestern University Feinberg School of Medicine, Chicago, IL, USA
[b] Division of Infectious Diseases, Department of Pediatrics, Ann & Robert H. Lurie Children's Hospital of Chicago, Chicago, IL, USA

ABSTRACT

Introduction: Vaccine hesitancy remains a serious challenge for ending the coronavirus disease 2019 (COVID-19) pandemic. Digital media has played an immense role in the spread of information during the pandemic. One method to gauge public interest in COVID-19 related information is to examine patterns of online search queries.

Methods: Google Trends (GT) was used to analyze results for search terms relating to COVID-19 vaccine misinformation, information, and accessibility from October 1st, 2020 to May 27th, 2021. GT allows you to compare multiple queries at one time. The resultant relative search volumes (RSVs) range from 0 to 100. The search term and point in time on the graph that has the greatest search volume is given a score of 100 and all other terms and times are given values relative to that maximum. Search interest peaks were analyzed by subgroups (misinformation, information seeking, and access seeking) and across key time points throughout the pandemic.

Results: GT analysis revealed that search interest related to vaccine misinformation, general information, and access seeking changed in relation to events taking place throughout the pandemic. The most commonly searched terms in each subgroup were: "Covid vaccine infertility", "Covid vaccine side effects", and "Covid vaccine appointment". Searches related to misinformation peaked in December 2020. Search terms in the general information category peaked in April 2021. RSVs for access seeking terms peaked in March 2021 and have decreased since April 2021.

Conclusion: Misinformation RSVs were highest after FDA authorization and have multiple repeated spikes after subsequent vaccine announcements. General information seeking terms peaked concurrently with increased vaccination uptake in the United States. Search interest has decreased with wider vaccine availability, despite many individuals in the United States remaining unvaccinated. GT can be used to monitor trends in public attitudes and misinformation regarding COVID-19 vaccines and further target education.

1. Introduction

Numerous vaccines have been developed at an extraordinary pace to combat the coronavirus disease 2019 (COVID-19) pandemic [1,2]. In December 2020, the Food and Drug Administration (FDA) issued emergency use authorization (EUA) for COVID-19 vaccines produced by Moderna and Pfizer-BioNTech [2]. Though criteria varied slightly by states and cities, vaccines were made available in a staged approach: healthcare workers and residents and staff of long-term care facilities in December 2020 and January 2021; elderly patients and those with high-risk medical conditions and occupations in February and March 2021; and universal eligibility for persons $\geq$ 16 years in April 2021 [1].

Ensuring widespread distribution and uptake of vaccines is vital. Despite adequate supply since April 2021, the United States narrowly missed a national target to have 70% of the adult population fully vaccinated by July 4, 2021 [3,4]. Equitable access has been a barrier, particularly for Black and Hispanic populations, and vaccine rollout strategies have included inclusive messaging to target these populations [5]. However, vaccine hesitancy remains a significant challenge across demographic groups to limit hospitalizations and mortality from COVID-19 [6,7]. Common reasons for vaccine hesitancy include concerns about rushed vaccine development, use of novel messenger RNA (mRNA) technology,

* Corresponding author at: Division of Infectious Diseases, Department of Pediatrics, Ann & Robert H. Lurie Children's Hospital of Chicago Ann & Robert H. Lurie Children's Hospital of Chicago, Box 20 225 E Chicago Avenue, Chicago, IL 60611, USA.

E-mail address: sjpatel@luriechildrens.org (S.J. Patel).

misinformation, inadequate communication with patients and providers, and general mistrust of vaccines [6,8–9].

Digital media has played an immense role in the spread of information during the COVID-19 pandemic [10,11]. Unfortunately, these online platforms can also spread substantial misinformation. One way to gauge public interest in COVID-19 related information is to examine patterns of online search queries. Google Trends (GT) is a website that analyzes the popularity of search queries in Google Search and search volumes over time [12,13]. GT has been used to forecast disease outbreaks and measure interest in public health measures such as cancer screenings [14–16].

The purpose of this paper is to use GT to understand the United States public's interest in vaccine misinformation, general information, and accessing the vaccine and how they were influenced by events throughout the pandemic. By better understanding information seeking behavior, public health organizations may be able to target education to encourage vaccination.

2. Methods

2.1. Data source

GT analyzes the popularity of specific search terms by allowing users to input up to five queries that track search interest over time in relation to time, region, and other inputted search terms [12,13]. The graph does not represent actual search volume. Instead, these graphs utilize relative search volumes (RSVs) that range from 0 to 100, representing search interest relative to the greatest search interest on the chart. The search term and point in time on the graph that has the greatest search volume is given a score of 100 and all other geographic areas and times are given values that quantify interest relative to that maximum. This method of acquiring search demand provides anonymized, open-source data that controls for population size.

2.2. Study design

Three different GT analyses were conducted for search terms related to the COVID-19 vaccine 1) misinformation, 2) general information, and 3) access seeking in the United States. The time period of the GT analysis was from October 1st, 2020 - May 27th, 2021. This time-period was chosen to span the time just before first vaccine distribution until data analysis for this study was performed. Search parameters were set to "United States,", "All categories", and "Web search" to capture national Google searches pertaining to the novel COVID-19 vaccine.

2.3. Search terms

The Center for Disease Control and Prevention's (CDC) "Myths and Facts" webpage was used to identify search terms related to misinformation on June 1st, 2021 [8]. The following search terms were used to evaluate vaccine misinformation: "Covid vaccine infertility", "Covid vaccine changes DNA", "Can you get covid from the vaccine", "Covid vaccine microchips", and "Covid vaccine fetal tissue". Terms that related to information seeking behavior included: "Covid vaccine side effects", "Covid vaccine safe", "Covid vaccine effective", "Who should not get the covid vaccine", and "Covid vaccine risks". Finally, to analyze vaccine access seeking trends, the following terms were used: "Covid vaccine appointment", "Covid vaccine finder", "Covid vaccine eligibility", "How to get covid vaccine", and "Where to get covid vaccine".

To determine search terms for each category, the first author chose at least three versions of the same search term concept to input into Google Trends to determine the most popular one. For

example, for the search term "Covid vaccine safe", "Is the covid vaccine safe?", "Safety of covid vaccine", "Covid vaccine and safety", and "Covid vaccine safe" were all inputted into GT. "Covid vaccine safe" was determined to be the most searched version.

Since GT does not provide absolute values, but instead relative values for search trends, the most searched term from each category was graphed alongside two non-covid vaccine search terms to better understand the search terms in the context of larger national search trends. The first was a major contemporaneous event (the riot at the United States capitol on January 6th, 2021) and the second is a recurrent seasonal event (Tax Day when United States federal taxes are due) [17,18].

2.4. Timepoints

Key events during the pandemic were obtained, and search trends were graphed against these events, including FDA authorizations, vaccine manufacturer press releases, and CDC guidance announcements [1,2].

3. Results

3.1. Misinformation

Fig. 1 represents national trends in searches related to common vaccine misinformation from October 2020 until May 2021. Of the five search terms relating to misinformation, "Covid vaccine infertility" was the most commonly searched term with an average RSV of 22. "Can you get covid from the vaccine" was the second most popular with an average RSV of 10. "Covid vaccine fetal tissue" and "Covid vaccine changes DNA" had average RSVs of 4 and 2, respectively. "Covid vaccine microchips" was the least popular search term with an average RSV of 1.

Most peaks for the misinformation related search occurred early during the defined search period. "Covid vaccine fetal tissue" was the first search to peak on November 19th, one day following the release of clinical trial data demonstrating 95% vaccine efficacy to prevent symptomatic infection [19]. Searches then shifted to "Covid vaccine infertility" in December with increased activity, between December 8th and December 18th, 2020 coinciding with FDA approvals for the Pfizer and Moderna vaccines [20–24]. Another peak was seen on March 4th, two days after President Biden announced that vaccines will be available for all Americans by May 2021 [25]. Additional peaks in searches occurred toward the end of March and the beginning of April. These peaks coincided with major announcements related to vaccines such as Pfizer's release of vaccination data for adolescents, safety information for vaccine administration during pregnancy, and reports of the clotting complications with the Johnson & Johnson vaccine and subsequent pause [26–28].

3.2. Information seeking

Fig. 2 represents national trends in searches related to information seeking in regard to the COVID-19 vaccine from October 2020 until May 2021. Of the five search terms relating to information seeking, "Covid vaccine side effects" had the highest search volume (average RSV of 37). "Covid vaccine safe" and "Covid vaccine effective" were the second and third most popular searches with RSVs of 6 and 5, respectively. "Covid vaccine risks" had an average RSV of one and "Who should not get covid vaccine" had an average RSV of zero.

In mid-December 2020, there was a period of sustained increased search volume for "Covid vaccine side effects" coinciding with the announcement and approval of the Pfizer and Moderna
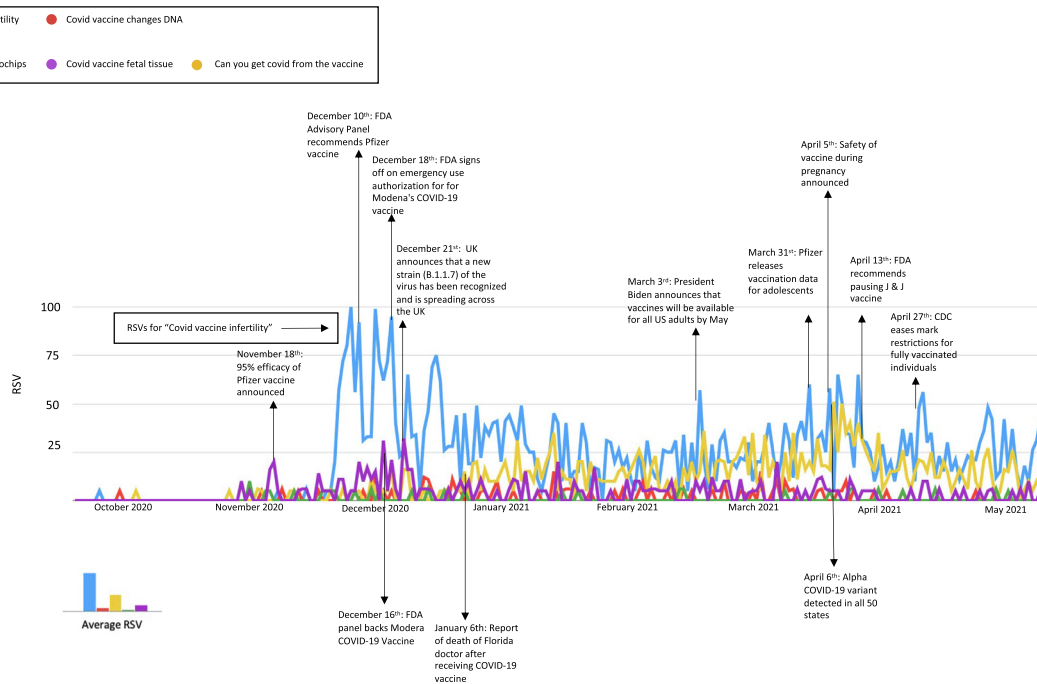
Fig. 1. Relative search volumes (RSVs) for COVID-19 vaccine related misinformation terms from October 1, 2020 - May 27th, 2021. A score of 100 represents the time point with the greatest volume of searches. Data source: Google Trends (https://www.google.com/trends).
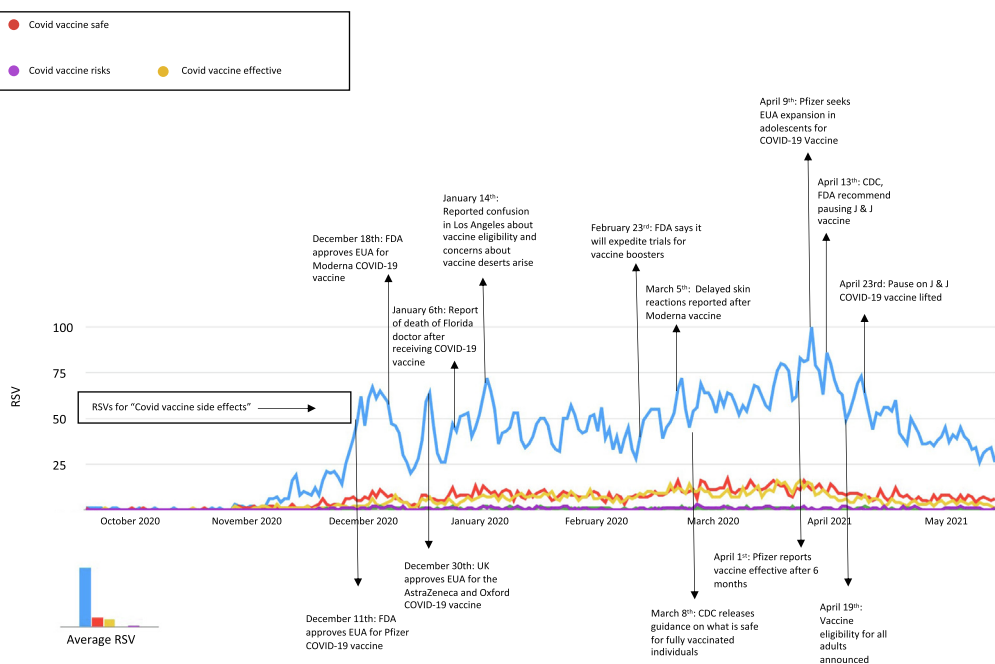
Fig. 2. Relative search volumes (RSVs) for COVID-19 vaccine related information terms from October 1, 2020 - May 27th, 2021. A score of 100 represents the time point with the greatest volume of searches. Data source: Google Trends (https://www.google.com/trends).

vaccine [20–24]. Another peak was seen on December 30th, when the United Kingdom approved the EUA for the AstraZeneca vaccine [29]. RSV decreased from mid-January until the end of February where they began to rise again. This coincided with a rapidly increasing moving average of doses administered [30]. "Covid vaccine side effects" RSVs continued to rise and had its highest peak on April 9th, the same day that Pfizer sought EUA expansion for adolescent use of their vaccine [1]. An additional peak was seen on April 13th, 2021, the same day that the CDC and FDA recom-

mended pausing the Johnson & Johnson vaccine due to concerns for clotting [28]. A rapid decrease occurred on April 23rd, 2021 the day that the pause on the Johnson & Johnson vaccine was lifted, and continuously decreased after that date [31]. RSVs for all other search terms remained fairly steady throughout this studied time period. There was a slight increase in January 2021 and March 2021. RSVs related to information seeking decreased after April.

3.3. Access seeking

Fig. 3 represents national trends in searches related to vaccine access seeking from October 2020 until May 2021. Of the five terms relating to access seeking, "Covid vaccine appointment" had the greatest average RSV of 26. "How to get covid vaccine" and "Where to get covid vaccine" had RSVs of nine and eight, respectively. Covid vaccine eligibility had an average RSV of five and "Covid vaccine finder" had an average RSV of three.

The search terms "How to get covid vaccine," "Where to get Covid vaccine," and "Covid vaccine appointment" all experienced rapid increases in RSV beginning on January 10th. "Covid vaccine eligibility" and "Covid vaccine finder" did not show this early increase but instead gradually rose until peaking in mid to late March 2021.

"Covid vaccine appointment" continued to rise substantially in January, with highest RSVs in March and early April. The largest peak in RSV occurred on March 9th, one day after the CDC released its initial guidance on what is safe for fully vaccinated individuals [32]. Another peak was seen on March 30th, a day after real world data was published highlighting 90% effectiveness in the prevention of COVID-19 infection for the Pfizer and Moderna vaccines [33]. On April 6th, the same day the Alpha variant was announced to be present in all 50 states and a day after data was released announcing the vaccine to be safe for pregnant women, RSV for "covid vaccine appointment" also peaked [1,27]. All RSVs related to access seeking have decreased since early April 2021.

3.4. Comparison to other search topics

Fig. 4 also demonstrates the top search term from each category in relation to each other and two non-COVID-19 related search terms. Overall, the misinformation term "covid vaccine infertility" was much less commonly searched in relation to the access and information seeking terms. There was a major peak in searches for "capitol riot" on January 7th, the day after a riot took place in the United States capitol [17]. In addition, there were two peaks in searches for "tax day" that were comparable to 'capitol riot': one on April 15th (the typical United States tax day) and another on May 17th (the extended 2021 tax day due to COVID-19) [18]. The peak of vaccine appointment searches was nearly as high as the peak of "capitol riot", while the peak in vaccine side effects generally ranged from 25 to 60% of that value. Searches for "Covid vaccine infertility" were much less common compared to the other search terms.

4. Discussion

In 2019, the World Health Organization (WHO) included "vaccine hesitancy" as one of the top ten threats to global health [34]. Despite widespread availability of COVID-19 vaccines, vaccine hesitancy has been an intractable challenge in the United States [6,35–37]. A national survey in March 2021, indicated that less than half of Americans intended to receive a COVID-19 vaccination [37]. While the total proportion of fully-vaccinated individuals is approaching 66% as of May 2022, pace of vaccination has fallen, despite emergence of more transmissible variants of concern and recommendations for booster doses [3]. This paper adds to the growing utility of GT as a public health tool that can characterize public attitudes towards COVID-19 vaccines and help public health officials adapt messaging to improve education, counter misinformation, and encourage vaccine uptake. For example, if misinformation around COVID-19 vaccines causing infertility begins to circulate, GT can easily and cheaply identify this through an increase in search interest. Education can then be provided and even targeted by geographic region as GT provides data on RSVs by state, subregion, metro area, and city. GT is a promising way to
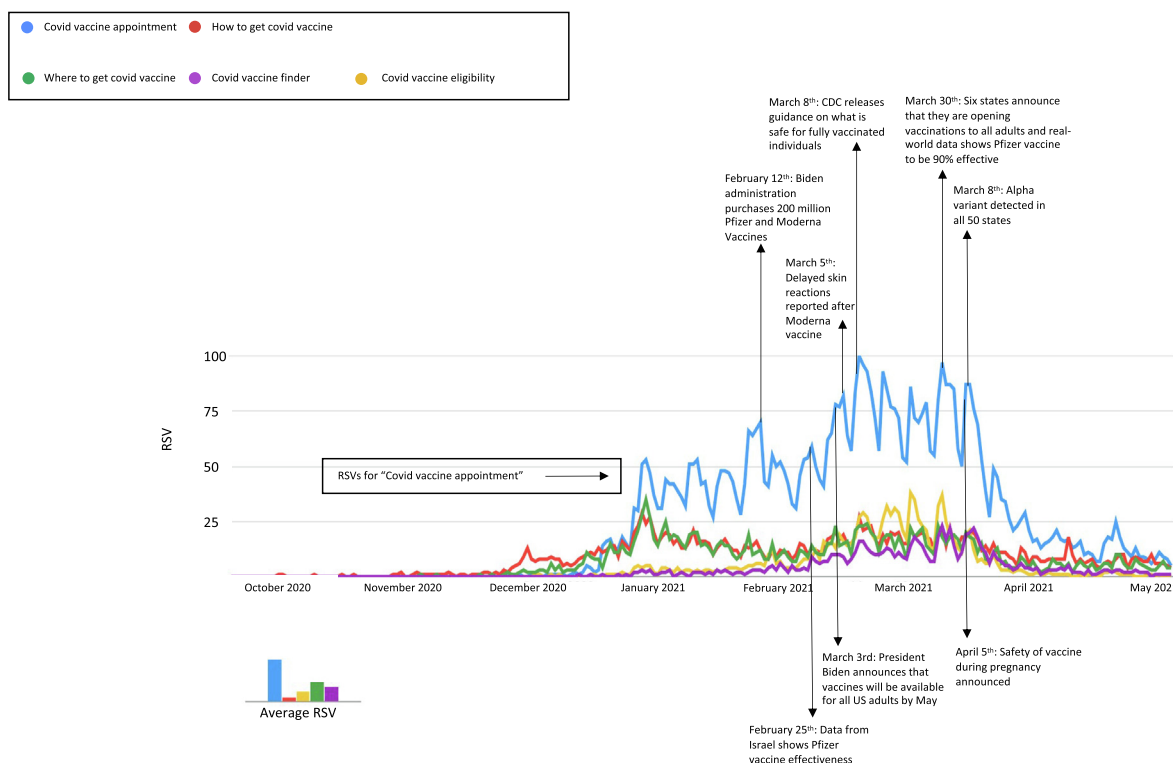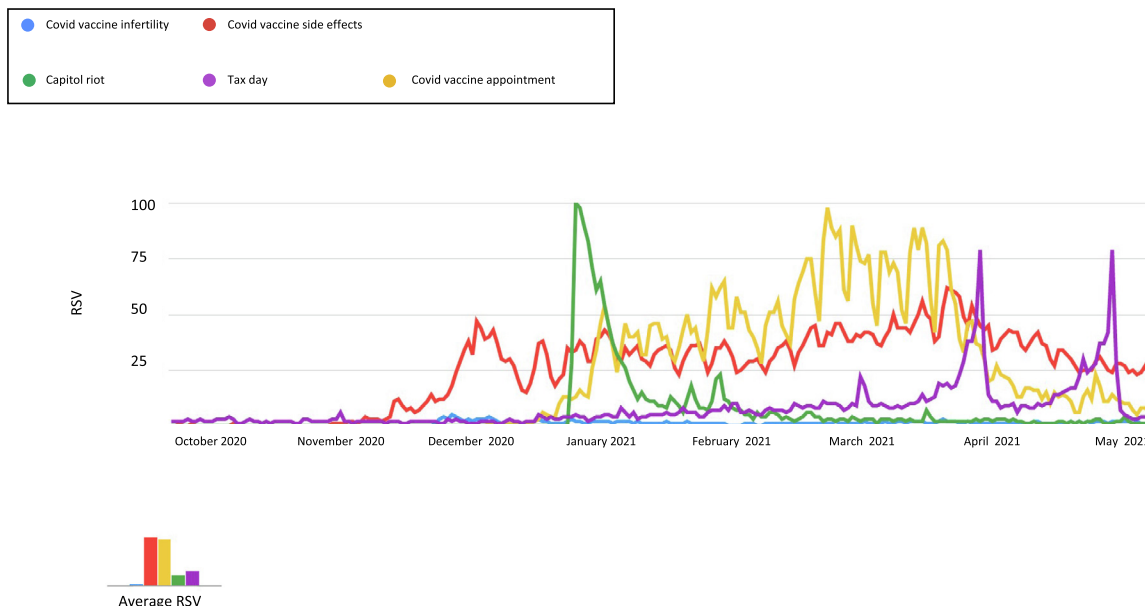

Fig. 3. Relative search volumes (RSVs) for COVID-19 vaccine related accessibility terms from October 1, 2020 - May 27th, 2021. A score of 100 represents the time point with the greatest volume of searches. Data source: Google Trends (https://www.google.com/trends).

Fig. 4. Relative search volumes (RSVs) for the most commonly searched term related to misinformation, information, and accessibility from October 1, 2020 - May 27th, 2021 compared to a major contemporaneous event and a recurrent seasonal event. Data source: Google Trends (https://www.google.com/trends).

ascertain between actual and perceived hesitancy by tracking search trends to understand concern.

4.1. Vaccine misinformation

Based on our longitudinal data throughout the COVID-19 pandemic, RSVs for terms related to vaccine misinformation have overall decreased since the development and announcement of the COVID-19 vaccine. This is presumably due to increasing acceptance and uptake of the vaccines since FDA authorization.

"Covid vaccine infertility" was the most commonly searched term in this subgroup of misinformation terms. We can conclude that infertility is a more common misconception than the other search terms such as 'changing DNA' or 'microchips'. Infertility related terms specifically peaked in demand throughout the beginning months of the pandemic, coinciding with the initial announcements and approvals of the first two COVID-19 vaccines. Early vaccine skepticism related to infertility may have been an initial response to vaccine announcements. It is also important to specifically highlight the significant secondary peaks in infertility searches seen around April 5th, the same day that a study was published announcing that the vaccine was safe for pregnant and breastfeeding women [27]. These secondary peaks were likely in response to safety updates related to pregnancy and breastfeeding.

For the COVID-19 vaccine and future vaccines developed, GT can be used to cost-effectively monitor trends in circulating misinformation and target educational content before false claims gain traction. For example, "Covid vaccine fetal tissue" was more commonly searched in November and December than "Can you get covid from the vaccine", which increased in early January. Spikes in RSV for vaccine misinformation terms, particularly at the state and local level, could inform the timing of public health messaging.

The second increase in misinformation related searches occurred in late March and early April, a time where the moving average daily doses administered had rapidly increased to its peak on April 8th [30]. Our data suggest that the United States public was more exposed to vaccine misinformation as vaccine eligibility broadened. Staged deployment of vaccines are opportunities to enforce vaccine safety. This is particularly important for future

COVID-19 booster vaccines. It is particularly noteworthy that misinformation peaks seen later in the pandemic coincided with federal guidance and vaccine manufacturer's press releases. Thus, even release of positive information about vaccine safety and efficacy was associated with increased searches for misinformation.

4.2. Vaccine information

In addition to identifying patterns of searches for vaccine misinformation, it is important to understand general vaccine information seeking behavior regarding eligibility, effectiveness, and safety. Unlike vaccine misinformation based searches that peaked within the first few months of the pandemic, most general vaccine information searches peaked much later in the pandemic in April 2021. This latter pattern was concurrent with increasing nationwide vaccine uptake, likely reflecting searches about adverse events immediately prior to and following receipt of the vaccine.

The largest peak for "Covid vaccine side effects" searches coincided with the request made by the FDA to expand their EUA to 12–15 years old, likely reflecting concern by parents about vaccine adverse effects for their children [1]. Our findings suggest that future announcements of vaccine eligibility for younger children, represent opportunities to reinforce messaging about vaccine safety.

Of note, there was an additional spike in searches for vaccine information seen on the day that the Johnson & Johnson vaccine was paused. Nevertheless, once the Johnson & Johnson pause was lifted, a sustained decrease in searches was seen. Interestingly, long-term searches for vaccine misinformation terms did not increase with the Johnson and Johnson pause.

4.3. Access seeking

Among the five selected vaccine accessibility terms, "Covid vaccine appointment" had consistently the highest search demand. While vaccine appointment searches may have been constrained by limited vaccine availability to the general population prior to April 2021, it is important to note that the highest peak in demand for appointments was on March 9th, 2021, just after the CDC

released safety guidelines for fully vaccinated individuals. This spike in search activity may have reflected vaccine access seeking behavior following the announcement. Additional spikes in "Covid vaccine appointments" and "Covid vaccine eligibility" were seen on March 30th when real world Pfizer vaccine effectiveness data were published. This again could have reflected public reaction to the information.

After April 6th, RSVs for all vaccine access seeking terms decreased substantially. However, at this point, only 19% of the United States population was fully vaccinated [3]. The decrease in access seeking searches may be due to increased appointment availability to those seeking vaccines as well as lower interest among the remaining proportion of unvaccinated people. Our GT analysis suggests a drop in RSV may be an inflection point where more active measures beyond ensuring vaccine supply and appointment availability are needed to target unvaccinated persons.

There are several limitations to the use of GT. First, GT does not provide absolute counts of searches which makes it more difficult to understand search trends in the context of larger information-seeking trends. Further, while GT holds the majority (74%) of all Internet searches, it does not account for smaller search engines which may introduce a source of bias [38]. Sampling bias may also exist as data analyzed is only from people with internet access who are actively searching for one of the designated terms in our analysis. Relationships between search spikes and events during the pandemic can only be inferred. With a plethora of keywords relating to this pandemic, potential search terms may have been missed in our study. Finally, while GT provides valuable information about one's interest and behavioral intent, it may not correlate with actual vaccination behavior. We aimed to mitigate these limitations by choosing search terms based on the CDC website and choosing the most searched version of each search term for our final analysis.

5. Conclusion

GT is useful to assess COVID-19 vaccine hesitancy and interest. We described national trends in vaccine misinformation, general information, and access seeking at key timepoints during the pandemic. GT analysis can be potentially used to dynamically guide public health messaging and education based on search interest for vaccine-related terms.

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.

References

[1] A Timeline of COVID-19 Vaccine Developments in 2021. Accessed June 1, 2021. https://www.ajmc.com/view/a-timeline-of-covid-19-vaccine-developments-in-2021.

[2] A Timeline of COVID-19 Developments in 2020. Accessed June 1, 2021. https://www.ajmc.com/view/a-timeline-of-covid19-developments-in-2020.

[3] US COVID-19 Vaccine Progress Tracker | Vaccinations by State | USAFacts. Accessed July 11, 2021. https://usafacts.org/visualizations/covid-vaccine-tracker-states/.

[4] FACT SHEET: President Biden to Announce Goal to Administer at Least One Vaccine Shot to 70% of the U.S. Adult Population by July 4th | The White House. Accessed July 11, 2021. https://www.whitehouse.gov/briefing-room/statements-releases/2021/05/04/fact-sheet-president-biden-to-announce-goal-to-administer-at-least-one-vaccine-shot-to-70-of-the-u-s-adult-population-by-july-4th/.

[5] Latest Data on COVID-19 Vaccinations by Race/Ethnicity | KFF. Accessed May 23, 2022. https://www.kff.org/coronavirus-covid-19/issue-brief/latest-data-on-covid-19-vaccinations-by-race-ethnicity/.

[6] Momplaisir F, Haynes N, Nkwihoreze H, Nelson M, Werner RM, Jemmott J. Understanding Drivers of COVID-19 Vaccine Hesitancy Among Blacks. Clin Infect Dis. Published online February 9, 2021. doi:10.1093/cid/ciab102.

[7] MacDonald NE. SAGE Working Group on Vaccine Hesitancy. Vaccine hesitancy: definition, scope and determinants. Vaccine 2015;33(34):4161–4. https://doi.org/10.1016/j.vaccine.2015.04.036.

[8] Myths and Facts about COVID-19 Vaccines | CDC. Accessed June 1, 2021. https://www.cdc.gov/coronavirus/2019-ncov/vaccines/facts.html.

[9] Wheelock A, Ives J. Vaccine confidence, public understanding and probity: time for a shift in focus? J Med Ethics March 2021. https://doi.org/10.1136/medethics-2020-106805.

[10] Di Gennaro F, Murri R, Segala FV, et al. Attitudes towards Anti-SARS-CoV2 vaccination among healthcare workers: results from a national survey in Italy. Viruses 2021;13(3). https://doi.org/10.3390/v13030371.

[11] Radwan E, Radwan A, Radwan W. The role of social media in spreading panic among primary and secondary school students during the COVID-19 pandemic: an online questionnaire study from the Gaza Strip, Palestine. Heliyon 2020;6(12):. https://doi.org/10.1016/j.heliyon.2020.e05807e05807.

[12] FAQ about Google Trends data - Trends Help. Accessed March 12, 2021. https://support.google.com/trends/answer/4365533?hl=en. [12]

[13] Google Trends. Accessed March 12, 2021. https://trends.google.com/trends/?geo=US.

[14] Teng Y, Bi D, Xie G, et al. Dynamic forecasting of zika epidemics using google trends. PLoS ONE 2017;12(1):. https://doi.org/10.1371/journal.pone.0165085e0165085.

[15] Schootman M, Toor A, Cavazos-Rehg P, et al. The utility of google trends data to examine interest in cancer screening. BMJ Open 2015;5(6):. https://doi.org/10.1136/bmjopen-2014-006678e006678.

[16] Tijerina JD, Morrison SD, Nolan IT, Parham MJ, Richardson MT, Nazerali R. Celebrity influence affecting public interest in plastic surgery procedures: google trends analysis. Aesthetic Plast Surg 2019;43(6):1669–80. https://doi.org/10.1007/s00266-019-01466-7.

[17] U.S. Capitol riot - HISTORY. Accessed May 23, 2022. https://www.history.com/this-day-in-history/january-6-capitol-riot.

[18] Tax Day for individuals extended to May 17: Treasury, IRS extend filing and payment deadline | Internal Revenue Service. Accessed May 23, 2022. https://www.irs.gov/newsroom/tax-day-for-individuals-extended-to-may-17-treasury-irs-extend-filing-and-payment-deadline.

[19] Pfizer and BioNTech Conclude Phase 3 Study of COVID-19 Vaccine Candidate, Meeting All Primary Efficacy Endpoints | pfpfizeruscom. Accessed July 10, 2021. https://www.pfizer.com/news/press-release/press-release-detail/pfizer-and-biontech-conclude-phase-3-study-covid-19-vaccine.

[20] Coronavirus (COVID-19) Update: FDA Holds Advisory Committee Meeting to Discuss Authorization of COVID-19 Vaccine Candidate as Part of Agency's Review of Safety and Effectiveness Data | FDA. https://www.fda.gov/news-events/press-announcements/coronavirus-covid-19-update-fda-holds-advisory-committee-meeting-discuss-authorization-covid-19. Accessed July 21, 2021.

[21] FDA Takes Key Action in Fight Against COVID-19 By Issuing Emergency Use Authorization for First COVID-19 Vaccine | FDA. https://www.fda.gov/news-events/press-announcements/fda-takes-key-action-fight-against-covid-19-issuing-emergency-use-authorization-first-covid-19. Accessed July 11, 2021.

[22] FDA Panel Recommends Emergency Use for Pfizer, BioNTech COVID-19 Vaccine. Accessed July 11, 2021. https://www.ajmc.com/view/fda-advisory-panel-recommends-pfizer-biontech-covid-19-vaccine.

[23] FDA Panel Backs Moderna COVID-19 Vaccine; EUA Expected Next. Accessed July 11, 2021. https://www.ajmc.com/view/fda-panel-backs-moderna-covid-19-vaccine-eua-expected-next.

[24] FDA Takes Additional Action in Fight Against COVID-19 By Issuing Emergency Use Authorization for Second COVID-19 Vaccine | FDA. https://www.fda.gov/news-events/press-announcements/fda-takes-additional-action-fight-against-covid-19-issuing-emergency-use-authorization-second-covid. Accessed July 11, 2021.

[25] Biden Says U.S. Will Have Vaccine Supply For All Adults By May, Prioritizes Teachers : Coronavirus Updates : NPR. Accessed July 10, 2021. https://www.npr.org/sections/coronavirus-live-updates/2021/03/02/973030394/biden-says-u-s-will-have-vaccine-supply-for-all-adults-by-may-prioritizes-teache?

[26] The Pfizer-BioNTech Vaccine Is Said to Be Powerfully Protective in Adolescents - The New York Times. Accessed July 10, 2021. https://www.nytimes.com/2021/03/31/health/pfizer-biontech-vaccine-adolescents.html.

[27] Gray KJ, Bordt EA, Atyeo C, et al. Coronavirus disease 2019 vaccine response in pregnant and lactating women: a cohort study. Am J Obstet Gynecol. Published online March 26, 2021. doi:10.1016/j.ajog.2021.03.023.

[28] Joint CDC and FDA Statement on Johnson & Johnson COVID-19 Vaccine | FDA. Accessed July 11, 2021. https://www.fda.gov/news-events/press-announcements/joint-cdc-and-fda-statement-johnson-johnson-covid-19-vaccine.

[29] UK authorizes astrazenenca covid-19 vaccine. Accessed July 11, 2021. https://www.contagionlive.com/view/uk-approves-emergency-authorization-for-the-astrazeneca-and-oxford-covid-19-vaccine.

[30] COVID Data Tracker Weekly Review | CDC. https://www.cdc.gov/coronavirus/2019-ncov/covid-data/covidview/index.html. Accessed July 21, 2021.

[31] FDA and CDC Lift Recommended Pause on Johnson & Johnson (Janssen) COVID-19 Vaccine Use Following Thorough Safety Review. Accessed July 11, 2021. https://www.fda.gov/news-events/press-announcements/fda-and-cdc-lift-

recommended-pause-johnson-johnson-janssen-covid-19-vaccine-use-following-thorough.

[32] CDC Issues First Set of Guidelines on How Fully Vaccinated People Can Visit Safely with Others | CDC Online Newsroom | CDC. https://www.cdc.gov/media/releases/2021/p0308-vaccinated-guidelines.html. Accessed July 11, 2021.

[33] Thompson MG, Burgess JL, Naleway AL, et al. Interim Estimates of Vaccine Effectiveness of BNT162b2 and mRNA-1273 COVID-19 Vaccines in Preventing SARS-CoV-2 Infection Among Health Care Personnel, First Responders, and Other Essential and Frontline Workers - Eight U.S. Locations, December 2020-March 2021. MMWR Morb Mortal Wkly Rep. 2021;70(13):495-500. doi:10.15585/mmwr.mm7013e3.

[34] Ten threats to global health in 2019. https://www.who.int/news-room/spotlight/ten-threats-to-global-health-in-2019. Accessed March 31, 2021.

[35] Pullan S, Dey M. Vaccine hesitancy and anti-vaccination in the time of COVID-19: a google trends analysis. Vaccine March 2021. https://doi.org/10.1016/j.vaccine.2021.03.019.

[36] McAteer J, Yildirim I, Chahroudi A. The vaccines act: deciphering vaccine hesitancy in the time of COVID-19. Clin Infect Dis 2020;71(15):703–5. https://doi.org/10.1093/cid/ciaa433.

[37] Salmon DA, Dudley MZ, Brewer J, et al. COVID-19 vaccination attitudes, values and intentions among United States adults prior to emergency use authorization. Vaccine March 2021. https://doi.org/10.1016/j.vaccine.2021.03.034.

[38] Search engine market share. Accessed April 6, 2021. https://www.netmarketshare.com/search-engine-market-share.aspx.