

Title Page

Type: Original Investigation

Characterization of the Second Wave of the COVID-19 Pandemic in India: A Google Trends Analysis

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Ethics approval and consent to participate: This study was exempt from Rutgers’s Institutional Review Board approval.
Competing interests: The authors declare that they have no competing interests.
Funding: No funding provided for this study.

NOTE: This preprint reports new research that has not been certified by peer review and should not be used to guide clinical practice.
Abstract

Background: The second wave of the COVID-19 pandemic has led to considerable morbidity and mortality in India, in part due to lack of healthcare access, low health literacy, and poor disease surveillance. In this retrospective, descriptive ecological study, we utilized Google Trends (GT) to characterize the second COVID-19 wave and its association with official case counts based on search terms related to symptoms, testing, disease complications, medications, preventive behaviors, and healthcare utilization.

Methods: GT is a publicly available, online tracking system of Google searches. Searches are presented as relative search volumes (RSV) from 0 (least) to 100 (most number of searches). We performed pre-defined Web searches in India from 2/12/2021 to 5/09/2021. We characterized the peak RSV, RSV doubling rates, and Spearman rank correlation of selected search terms with official case counts. We also used date-adjusted linear regression to estimate the association between highly correlated search terms and official case counts. We then qualitatively classified public search queries into thematic groups to better understand public awareness and needs related to COVID-19.

Results: We observed that searches for symptoms (most searched terms in order: fever, cough, headache, fatigue, chest pain), disease states (infection, pneumonia), COVID-19-related medications (remdesivir, ivermectin, azithromycin, Fabiflu, dexamethasone), testing modalities (PCR, CT Scan, D-dimer, C-reactive protein, oxygen saturation), healthcare utilization (oxygen cylinders, hospital, physician), and preventive behaviors (lockdown, mask, pulse oximetry, hand sanitizer, quarantine) all demonstrated increases, in line with increases in official case counts. Symptoms, PCR testing, outpatient medications, and preventive behaviors peaked around April 24th, approximately two weeks prior to the peak RSV in official case counts. Contrarily, healthcare utilization factors, including searches for hospital, physicians, beds, disease states, and inpatient medications did not peak until the first week of May. There were highly significant correlations between ‘Coronavirus Disease 2019’ (r=0.959), ‘fever’ (r=0.935), ‘pulse oximetry’ (r=0.952), ‘oxygen saturation’ (r=0.944), ‘C-reactive protein’ (r=0.955), ‘D-Dimer’ (r=0.945), & ‘Fabiflu’ (r=0.943) and official case counts.

Conclusion: GT search terms related to symptoms, testing, and medications are highly correlated with official case counts in India, suggesting need for further studies examining GT’s potential use as a disease surveillance and public informant tool for public health officials.
Introduction

The COVID-19 pandemic has led to considerable morbidity, mortality, and near healthcare system collapse in India. This has been especially evident during the second wave of the COVID-19 pandemic, which has as of May 19th, 2021, resulted in a cumulative 25.5 million cases and over 283,000 reported deaths [1]. A novel B.1.617.2 Indian variant [2], mass gatherings, political rallies, slow governmental response, and considerable healthcare access issues have put India’s COVID-19 situation to the forefront of international media [3-7]. In addition, many experts, including the World Health Organization and Lancet Commission [3,4], have scrutinized data reporting in India due to its lack of comparability with crematorium accounts, ambiguity surrounding suspected case handling, and paradoxically low case fatality rates compared to other countries [5-7].

Real-world, data-driven approaches to understand public response and conduct disease surveillance are of paramount importance. One such tool, Google Trends™ (GT), has been successfully used to describe disease epidemics including Ebola, Influenza, and early COVID-19 responses in India [8]. In addition to nearly universal access to Google and real-time data collection, many individuals search Google before accessing healthcare [9], suggesting that we may be able to better capture disease burden, disease processes, and societal response via the GT tool, especially in countries with inadequate public health infrastructure.

The purpose of our retrospective, descriptive, ecological study of India’s second COVID-19 wave is to utilize GT to describe disease burden, symptomatology, and complications, and their associations with public interest in preventive measures, COVID-19 testing, and vaccination. We also determined the correlation of disease surveillance via GT with government-reported case and death rates. Lastly, we qualitatively describe themes of search queries to help clinicians and public officials better inform and address the general public’s questions.

Methods

Data source

We utilized GT, a publicly available, online tracking system of Google searches by search terms, topics, geographic region, and date. Rather than presenting absolute numbers of searches, GT displays the relative search volume (RSV) for pre-specified geographic, time, and search terms. The RSV for a time interval is determined as the search volume in that time interval divided by the largest search volume within the pre-specified criteria. It is then indexed from 0 to 100, where 100 is the reference, largest RSV and 0 is used when there is insufficient data. Further information about GT can be found at https://trends.google.com.

Search Strategy

As our primary interest was to describe the second wave of India’s COVID-19 pandemic, we conducted Google web searches in India, from February 12, 2021 to May 9th, 2021. The analysis was completed from May 11th to May 18th, 2021.

We initially compiled a list of 141 search terms within the following categories: General COVID-19 terms, Symptoms, Disease Process/Complications, Testing, Healthcare Utilization, Medication Use, Festivals/Holidays, Preventive Behaviors, and Control Searches (see Table 1).
Search terms were compiled with the help of physicians, researchers, and patients from India. Based on comparative searches within the GT platform, we narrowed down search terms to the top three to five searches within each category. We also utilized generalized ‘topic’ forms of each search term rather than the exact search term in order to capture variations in related searches such as non-English searches, abbreviations, and cultural and geographic colloquialisms. The final terms used are listed in Table 2.

Data Management

Once individual searches were completed, the corresponding CSV files were downloaded and combined in order to allow for further data analysis and visualization. This study was exempt from Rutgers IRB approval as all data was publicly available, only at the regional level, and de-identified. In order to compare results with official COVID-19 case and fatality data, we utilized raw data compiled by Johns Hopkins University Center for Systems Science and Engineering (JHU CCSE), available publicly at https://github.com/CSSEGISandData/COVID-19/. Our specific dataset is available upon reasonable request.

Statistical Analysis

This retrospective, ecological study was primarily meant to be a descriptive analysis of GT data. We determined relative proportional increases in RSV throughout the 90-day time period for all search terms using 2/12/21 as the reference, determined peaks in searches, and described common COVID-19 related questions related to the searches. We also determined initial and second doubling dates: initial or first doubling date was defined as the date during which the three-day average RSV doubled from the average RSV from 2/12/21 to 2/14/21. The second doubling date was the date where the three-day average RSV doubled from the initial doubling date.

We then determined the Spearman rank correlation between official COVID-19 case data and search terms in order to determine whether searches were comparable to official data. Where they were comparable, we subsequently estimated beta coefficients using time-adjusted linear regression to determine significant search covariates. We also performed multivariate linear regression to estimate future caseload; however, due to significant multicollinearity among search terms, this was not statistically sound and thus results are not presented. All analyses were done using SAS 9.4 with a significance level of 0.05.

Results

Clinically Relevant Search Terms

Out of 141 search queries, the top topics searched are presented in Table 2. In order from most to least common, searches for symptoms included fever, cough, headache, chest pain, and fatigue (Figure 1a). Whereas the peak RSVs for presenting symptoms (e.g. fever, cough) and associated symptoms (e.g. headache, fatigue) were generally in the last week of April, ‘chest pain’ peaked in the last week of the analysis (Table 3; first week of May). This was in line with official COVID-19 case counts, which also peaked from May 5th - May 7th within the time period of our analysis. Searches for ‘fever’ doubled by March 29th and doubled again 15 days later. This was nearly two weeks after official case counts doubled, whereas the peak RSV for ‘fever’ was two weeks earlier than official counts. The date by which ‘cough’ searches doubled
was delayed by approximately 2 weeks compared to ‘fever’ but also demonstrated a second doubling time of 11 days, identical to official case count doubling times (Table 3). Both ‘headache’ and ‘fatigue’ searches did not have a second doubling time due to a high baseline RSV.

Among disease complications, most individuals searched for pneumonia, infection, myocardial infarction, and stroke, in that order (Figure 1b). Searches for ‘pneumonia’ peaked on May 1st and had a first doubling date of April 1st and a second doubling date of April 18th. This is approximately 4 weeks after official case doubling times. However, the peak RSV for ‘pneumonia’ was five days prior to the peak in official cases (Table 3).

Among testing modalities, searches for ‘polymerase chain reaction’ (PCR) were of the highest RSV, followed by ‘computed tomography’ (CT Scan), ‘C-reactive Protein’, ‘D-dimer’, and ‘Oxygen Saturation’ (Figure 1c). The peak RSV was two weeks earlier for PCR searches than other testing modalities. Compared to official case counts, PCR searches peaked two weeks earlier and also had a first doubling date two weeks earlier (Table 3).

Among medication searches, the majority of searches were for ‘remdesivir’, followed by ‘ivermectin’, ‘azithromycin’, ‘fabiflu’, and ‘dexamethasone’ (Figure 1d). Ivermectin and Fabiflu, both medications used in the outpatient setting, peaked around April 23-25th, with an initial doubling date from March 15-20th. Largely inpatient medications, such as ‘remdesivir’ and ‘dexamethasone’ were more variable in their peak RSV and doubling times, with ‘remdesivir’ parameters two weeks earlier than ‘dexamethasone’ parameters (Table 3).

Socially-relevant Search Terms

General, healthcare utilization, preventive behavior, and festival/holiday searches also demonstrated similar peak RSVs and doubling times as clinically-relevant search terms (Table 3). General searches for the ‘Coronavirus Disease 2019’ topic peaked on May 1st, had a first doubling date of February 28th, approximately two weeks prior to official case count doubling, and a second doubling date of April 2nd, approximately two weeks after official case count doubling.

Among healthcare utilization searches, searches related to ‘oxygen’ were most prevalent, peaking on April 24th and having a second doubling time within one week of first doubling date. Searches for ‘physician’, ‘hospital’, and ‘bed’ peaked in the first week of May and did not show any doubling (Figure 2b, Table 3).

Among preventive behavior searches, we observed a general increase in searches for ‘lockdown’, as well as ‘mask’ and ‘pulse oximetry’ (Figure 1c). Nearly all preventive behavior searches peaked from April 18th to April 28th but had variable doubling dates (Table 3).

Among searches for festivals/mass gatherings, we see a tremendous increase in searches for Holi on March 29th and smaller, but significant, increases in other gatherings (Figure 2d). Peak searches of Eid-al-Fitr, Holi, Easter and Indian New Year occurred in the days leading up to the holiday. No searches under these general categories included queries regarding COVID-19. However, when searching for queries associated with Kumbh Mela, a Hindu festival that was held in Haridwar, Uttarakhand during April 2021 known to have been a “super-spreader” event, had increasing queries regarding the festival and “covid” or “covid cases” during this time frame.
When stratifying Indian New Year by regional festivities such as Ugadi, Gudi Padwa, Vaisakhi, and Vishu, there were no searches associated with “covid”.

Correlation Between Searches and Official Case Counts

We determined the Spearman rank correlation between search terms and official case counts (Table 4). The searches yielding the highest correlation included ‘Coronavirus Disease 2019’ (r=0.959), ‘fever’ (r=0.935), ‘pulse oximetry’ (r=0.952), ‘oxygen saturation’ (r=0.944), ‘C-reactive protein’ (r=0.955), ‘D-Dimer’ (r=0.945), and ‘fabiflu’ (r=0.943). This can also be seen visually in Figure 3. Using date-adjusted linear regression to estimate the association between search terms and official case counts, we found that every 1 unit increase in the RSV for ‘fever’ resulted in a mean increase of 4,854 cases (95% CI: 4,538 - 5,170; p<0.0001). Every 1 unit increase in ‘pulse oximetry’ yielded a mean increase of 3,141 (95% CI: 2,863 - 3,420; p<0.0001) cases. Every 1 unit increase in ‘fabiflu’ resulted in a mean increase of 2,318 (95% CI: 1,821 - 2,815; p<0.0001) cases. When looking at the correlation between official case counts and control search terms, we found that ‘film’ and ‘election’ had no correlation, but other control terms including ‘cricket’, ‘bank’, and ‘animal’ were significantly negatively correlated (Table 4). When we determined the correlation of search terms with official case counts stratified by time period (first 21 days, middle period, and last 21 days), we observed that correlations were of lesser significance in the first and last 21 days (data not shown).

We also determined the correlation between search terms and official death counts, which yielded similar but lower magnitude correlations (Table 5).

Qualitative Theme Analysis

In order to understand the underlying questions for specific search topics, we grouped related search queries into observed themes, namely administrative (testing, registration, location, costs), symptom expectations (disease progression, symptom management), and health literacy (meaning of terms, etiology, normal levels). Many individuals seemingly are unsure of testing locations, vaccine registration protocol, location of available hospitals, and costs of various tests, medications and healthcare utilization factors. Individuals are also unsure of whether presenting symptoms are related to COVID-19 and have questions about expected length of fever, definition of fever, normal values for common laboratory tests, and over-the-counter treatment options for common symptoms like fever and cough (Table 6).

Discussion

In this retrospective, descriptive, ecological study of GT search terms related to the second wave of the COVID-19 pandemic in India, we observed that searches for symptoms (e.g. fever, cough), disease states (e.g. infection, pneumonia), COVID-19-related medications (e.g. remdesivir, ivermectin), testing modalities (e.g. PCR, CT Scan), healthcare utilization (e.g. oxygen cylinders, hospital), and preventive behaviors (e.g. pulse oximetry, lockdown) all demonstrated an increase over our time period from 2/12/21 - 5/9/2021, in line with increases in official case counts. While peak RSVs and doubling rates varied across search categories, we generally observed that symptoms, PCR testing, outpatient medications, and preventive behaviors peaked around April 24th, approximately two weeks prior to the peak RSV in official case counts, but exhibited a doubling date one-two weeks later than official case counts.
Contrarily, healthcare utilization factors, including searches for hospital, physicians, beds, disease states, and inpatient medications did not peak until the first week of May. There was a highly significant correlation between ‘Coronavirus Disease 2019’, ‘Fever’, ‘Pulse oximetry’, ‘Oxygen saturation’, ‘C-reactive protein’, ‘D-Dimer’, & ‘Fabiflu’ and official case counts.

GT has been used to understand various aspects of the first wave of the COVID-19 pandemic worldwide, including its use as a digital surveillance tool [10-14], its use as a psychosocial behavior informant [15], and its use as a method to characterize novel symptoms such as ageusia and agnosia [16]. GT has many advantages, including real-time, real-world analysis, large sample size, and non-healthcare-related searches that may be missed in studies looking only at patients seeking healthcare.

We found that fever, cough, headache, fatigue, and chest pain were the most prevalent symptom-related searches during our time period, suggesting that these may be the most common presenting symptoms during the current COVID-19 wave. Searches for gastrointestinal symptoms, agnosia/ageusia, body/muscle aches, and other commonly reported symptoms from the first wave were not nearly as prevalent nor did they demonstrate a significant rise during our time period. These results are in line with current literature describing prevalence of symptoms [17]. Additionally, fever and cough demonstrated the strongest correlation with official case counts, whereas headache and fatigue showed significant, but lower, correlation and did not display a second doubling. This may suggest that either headache and fatigue are specific to certain patients, that there was already a baseline high level of RSV possibly due to ‘long-haul’ Covid [18], or that the pattern of symptom searching is biased away from headache and fatigue, which can be easily overlooked. The increase in searches for chest pain is likely the result of pleuritic chest pain from COVID-19 pneumonia rather than chest pain due to cardiovascular disease; however, Ciofani et al. showed in the U.S. population that hospital admissions for myocardial infarction decreased, while searches for chest pain increased in line with COVID-19 cases. This may suggest that patients may be self-triaging themselves or avoiding seeking care for true cardiovascular chest pain [19]. Interestingly, searches for fever and cough peaked nearly two weeks earlier than case counts, suggesting that symptomatic individuals may search symptoms prior to getting tested and being included in official case counts. If this is in fact true, GT may provide a useful tool to target populations with increases in searches for symptoms, by for example, providing testing facilities earlier in disease course.

These results demonstrate that GT may be useful in not only characterizing the symptoms of a novel population-wide disease but also in understanding the relative prevalence of certain symptoms among all individuals including those who otherwise have mild infection but may still search about fever or cough.

As severe COVID-19 infection is known to cause a pro-inflammatory state with elevated inflammatory markers and susceptibility to clot formation, we explored searches related to laboratory testing and disease complications including myocardial infarction, stroke, and pulmonary embolism. While searches for C-reactive protein and D-dimer were amongst the most highly correlated searches with official case counts - likely because PCR tests for disease are done in coordination with other laboratory tests and CT scans in suspected cases - we did not see a significant rise in myocardial infarction, stroke, or pulmonary embolism, suggesting that individuals with severe complications may not search before seeking care. Future studies should include terms for signs/symptoms of complications rather than the disease complication itself.
Our search term topics included commonly-used related terms (e.g. heart attack), but may not have been comprehensive enough to capture all related searches.

In addition to clinically-relevant searches, we also explored preventive behaviors and healthcare utilization. Searches for ‘oxygen saturation’, ‘pulse oximetry’, and ‘oxygen’ (cylinders) were highly prevalent and also significantly associated with official case counts. This is in agreement with the well-publicized issue of oxygen shortages in India and difficulties of finding hospital beds [20]. Despite the increase in searches for ‘hospitals’, we did not see a concomitant increase in searches for ‘ambulance’, making it unclear whether ambulance shortages were lower than hospital shortages, whether families were more likely to transport patients, or whether searches for hospitals were the result of media publicization rather than the primary cause.

In addition to GT’s use as a potential method to characterize disease, of equal importance is its role to better understand public questions concerning COVID-19 [21]. We found that related search queries could be grouped into three main themes, administrative, symptom expectations, and symptom management. This is in line with GT analyses by Hu et al. and Springer et al. that remarked that there is a need for increased disease awareness, with respect to treatment options and disease course [22,23]. This is especially evident and necessary in India, where health literacy remains low and many search queries were concerned with symptom management. There is also a need for India to address administrative questions including cost, location, and availability of testing, vaccine, and hospital facilities. Inability to access healthcare due to administrative issues is a primary source of disease burden and disproportionately affects those of lower socioeconomic status.

The results should be interpreted with caution due to many limitations. Firstly, our ecological study design does not allow us to make inferences at the individual patient level, nor does it provide information on the direction of correlation. Increases in searches may, at least partially, be due to increased presence of related topics in the media rather than individual situations. For example, Remdesivir exports were prohibited by Indian government officials on April 11th in anticipation of the predicted spike in demand for the drug. This may have contributed to the rise in interest for this term earlier than other medications.

Furthermore, searches for symptoms may not be solely due to COVID-19. However, given the high prevalence of COVID-19 in India and the significant correlation with confirmed COVID-19 cases, it is reasonable to infer that rises in related search terms are due to COVID-19. Additionally, search terms may not capture all non-English languages and regional colloquialisms. Although we tried to choose terms that would capture the largest percentage of related terms, this may have decreased specificity of searches. For example, the search topic “mask” rather than “face mask” or “covid mask” may encompass all of the intended searches with a high sensitivity; although the decision to choose the more general search term decreases specificity when including searches intended to find other masks, such as those for skincare or fashion purposes. Despite these limitations, GT’s large sample size, real-world and real-time benefits, and ability to capture populations that may otherwise be excluded from traditional research studies provide a useful tool to understand COVID-19. In particular, our major strength is there has been no comprehensive study on various clinical and social aspects of the second wave of the COVID-19 pandemic in India.
Future Directions

Future studies should attempt to reconcile the predictive power of GT search terms, including highly correlated symptoms, testing, and healthcare utilization factors, in India, within specific regions in India, and other countries. Studies should also attempt to understand the impact of mass gatherings on GT searches to allow for prediction after upcoming events such as Eid. Future studies may also focus on understanding the association between search terms and official death counts in India, including prediction of underreporting of data based on GT models developed in other countries.

Furthermore, examination of other Internet activity besides Google Web Search (such as Youtube, Facebook, and Whatsapp) may provide a more accurate depiction of Internet-based health searches. In particular, Whatsapp is one of the largest modes of learning and spreading health-related information in South Asia [24]. Popular “chain-messages” or posts may be studied for keywords and interest based on time-course to check for correlation with COVID-19 case data and risk prediction capability.

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| General Terms | Symptom Terms | Disease Course | Mass Gathering Terms | Testing Terms | Healthcare Utilization Terms | Preventive Behaviors | Medication Use Terms | Control Group Terms |
|---------------|--------------|----------------|---------------------|--------------|-------------------------------|---------------------|---------------------|---------------------|
| COVID-19      | Fever        | Pneumonia      | Holi                | RT-PCR       | Bed                           | Quarantine          | Remdesivir          | Bollywood           |
| Corona        | Cough        | ARDS           | Easter              | CT Score     | Oxygen                        | Isolation           | Ivermectin          | Cricket             |
| Coronavirus    | Shortness of Breath | Myocardial Infarction | Eid | CT Scan | Hospital | Lockdown | Dexamethasone | Animals |
| COVID-19 Testing | Trouble breathing | Stroke | Indian New Year | X-ray | Blood | Hand sanitizer | Azithromycin | Modi |
| COVID-19 Vaccine | Fatigue | Pulmonary Embolism | New Year | D-dimer | Physician | Face mask | Doxycycline | Election |
| Virus         | Loss of Taste | Cardiac arrest | Hindu New Year | C-reactive protein | Ambulance | N95 mask | Fabiflu | Film |
| Pandemic      | Loss of Smell | Oxygen desaturatio n | Kumbh Mela | CBC | ICU | Social distancing | Paracetamol | Bank |
| Cremation    | Chest Pain | Low oxygen | Political Rally | Ferritin | Oxygen concentrator | Hand washing | Aspirin |
| Funeral       | Muscle Ache | Pain | Farmer Protests | Interleukin-6 | Blood plasma | Hygiene | Inhaler |
| Double mutant | Body Ache | DVT | Weddings | Swab test | Pharmacy | Public health | Hydroxychloroquine |
| Triple mutant | Diarrhea | Myocarditis | Cricket matches | Blood pressure | Nurse | Research | Vitamin D |
| Nausea        | Heart Failure | Blood glucose | Telehealth | Event cancellatio n | Steroids |
| Vomiting      | Kidney injury | Oxygen saturation | Bed | Vaccine | Itolizumab |
| Headache      | Kidney failure | Electrolyte | Cylinder | Donations | Oxygen therapy |
| Chills         | Chronic fatigue | Antibody test | Ayurvedic medicine | Gloves | Ventilator |
| Congestion    | Liver failure | Troponin | Helpline | PPE | Tocilizumab |
| Sore throat   | New Diabetes | Creatinine | Covid tent | Healthy diet | Plasma therapy |
| Runny nose    | Organ failure | ECG | Vaccine registration | Exercise | Favipiravir |
| Weakness      | Multisystem Inflammatory Disease | Calcium | Transportatio n | Smoking cessation | |
| Category       | Top Searched Topics                                                                 |
|---------------|-------------------------------------------------------------------------------------|
| General       | Coronavirus Disease 2019, Coronavirus, COVID-19 Testing, COVID-19 Vaccine             |
| Symptoms      | Fever, Cough, Headache, Fatigue, Chest Pain                                         |
| Disease Process| Infection, Pneumonia, Myocardial Infarction, Stroke, Pulmonary Embolism             |
| Testing       | Polymerase Chain Reaction, Computed tomography, D-dimer, C-reactive protein, Oxygen Saturation |
| Healthcare Utilization | Oxygen Cylinder, Physician, Hospital, Pharmacy, Bed                   |
| Medication Use| Remdesivir, Ivermectin, Azithromycin, Ivermectin, Dexamethasone                    |
| Festivals     | Holi, Eid, Indian New Year, Kumbh Mela                                              |
| Preventive Behaviors | Lockdown, Quarantine, Mask, Pulse Oximetry, Hand Sanitizer                        |
| Control Groups| Cricket, Bollywood, Animals, Bank, Election                                         |
| Search Term                  | Peak RSV | Peak 3-day RSV | Initial Doubling Date | 2nd Doubling Date | Case Lag Time |
|-----------------------------|----------|---------------|-----------------------|------------------|--------------|
| Official COVID-19 Cases     | 5/6/2021 | 5/5 - 5/7     | 3/10/2021             | 3/21/2021        |              |
| General Terms               |          |               |                       |                  |              |
| Coronavirus Disease 2019    | 5/1/2021 | 4/29 - 5/1    | 2/28/2021             | 4/2/2021         | 5            |
| Coronavirus                 | 4/26/2021| 4/26 - 4/28   | 3/17/2021             | 4/5/2021         | 10           |
| COVID-19 Testing            | 4/27/2021| 4/27 - 4/29   | 3/17/2021             | 3/30/2021        | 9            |
| COVID-19 Vaccine            | 5/1/2021 | 4/29 - 5/1    | 2/28/2021             | 4/22/2021        | 5            |
| Symptoms                    |          |               |                       |                  |              |
| Fever                       | 4/24/2021| 4/24 - 4/26   | 3/29/2021             | 4/13/2021        | 12           |
| Headache                    | 4/26/2021| 4/29 - 5/1    | 4/23/2021             | N/A%             | 10           |
| Fatigue                     | 4/21/2021| 4/19 - 4/21   | 4/18/2021             | N/A              | 15           |
| Cough                       | 4/28/2021| 4/21 - 4/23   | 4/10/2021             | 4/21/2021        | 8            |
| Chest pain                  | 5/5/2021 | 5/5 - 5/7     | 4/8/2021              | 5/2/2021         | 1            |
| Disease Process/Complications|          |               |                       |                  |              |
| Stroke                      | 5/7/2021 | 3/8 - 3/10    | N/A                   | N/A              | -1           |
| Pneumonia                   | 5/1/2021 | 5/1 - 5/3     | 4/1/2021              | 4/18/2021        | 5            |
| Myocardial Infarction       | 4/30/2021| 4/29 - 5/1    | 4/28/2021             | N/A              | 6            |
| Infection                   | 5/5/2021 | 5/5 - 5/7     | 4/15/2021             | N/A              | 1            |
| Healthcare Utilization      |          |               |                       |                  |              |
| Pharmacy                    | 4/24/2021| 4/22 - 4/24   | N/A                   | N/A              | 12           |
| Physician                   | 5/8/2021 | 5/4 - 5/6     | N/A                   | N/A              | -2           |
| Oxygen                      | 4/24/2021| 4/24 - 4/26   | 4/6/2021              | 4/13/2021        | 12           |
| Hospital                    | 5/1/2021 | 5/7 - 5/9     | 4/17/2021             | N/A              | 5            |
| Bed                         | 5/5/2021 | 5/5 - 5/7     | N/A                   | N/A              | 1            |
| Preventive Behaviors        |          |               |                       |                  |              |
| Quarantine                  | 4/19/2021| 4/19 - 4/21   | 4/3/2021              | N/A              | 17           |
| Pulse Oximetry              | 4/24/2021| 4/23 - 4/25   | 3/16/2021             | 3/30/2021        | 12           |
| Mask                        | 4/26/2021| 4/26 - 4/28   | 4/14/2021             | N/A              | 10           |
| Lockdown                    | 4/19/2021| 4/18 - 4/20   | 2/15/2021             | 2/18/2021        | 17           |
| Hand Sanitizer              | 4/27/2021| 5/6 - 5/8     | 4/1/2021              | 4/14/2021        | 9            |
| Testing                     |          |               |                       |                  |              |
| Oxygen Saturation           | 5/5/2021 | 5/4 - 5/6     | 3/20/2021             | 3/30/2021        | 1            |
| Computed Tomography         | 5/3/2021 | 5/2 - 5/4     | 3/29/2021             | 4/14/2021        | 3            |
| Polymerase Chain Reaction   | 4/19/2021| 4/22 - 4/24   | 2/23/2021             | 3/24/2021        | 17           |
| C-reactive Protein          | 5/8/2021 | 5/6 - 5/8     | 3/18/2021             | 4/2/2021         | -2           |
| D-Dimer                     | 5/6/2021 | 5/6 - 5/8     | 3/11/2021             | 3/29/2021        | 0            |
| Medication Use              |          |               |                       |                  |              |
| Dexamethasone               | 5/1/2021 | 5/2 - 5/3     | 4/8/2021              | 4/18/2021        | 5            |
| Drug       | Date       | Relative Search Volume |
|------------|------------|------------------------|
| Azithromycin | 5/3/2021  | 5/3 - 5/5               |
|            | 3/25/2021  | 4/7/2021               |
| Ivermectin | 4/25/2021  | 4/23 - 4/25            |
|            | 3/20/2021  | 4/3/2021               |
| Fabiflu    | 4/23/2021  | 4/23 - 4/25            |
|            | 3/15/2021  | 3/22/2021              |
| Remdesivir | 4/18/2021  | 4/18 - 4/20            |
|            | 3/20/2021  | 3/31/2021              |

Format of dates: Month/Day/Year; RSV = Relative Search Volume. All searches conducted from 2/12/21 to 5/9/21

*Peak RSV refers to the date at which a specific search query hits 100 (its highest point in our time period)
*Initial doubling date is defined as the date at which the three-day average RSV exceeds 2 times that of the RSV from 2/12 – 2/14/21. The second doubling date is defined as the date at which the three-day average RSV exceeds 2 times that of the RSV from the initial doubling date.
*Case lag time is defined as the number of days between the peak RSV of the official case count and the peak RSV of the search term of interest.
*N/A means that the search query did not double further or reach the doubling date.
Table 4. Correlation Between Search Terms and Official Case Count

| Search Term                        | Spearman Rank Correlation | P-value   | Time-adjusted β coefficient (95% CI) | P-value |
|------------------------------------|---------------------------|-----------|-------------------------------------|---------|
| **General Terms**                  |                           |           |                                     |         |
| Coronavirus Disease 2019           | 0.959                     | <0.0001   | 5924 (5542 - 6305)                  | <0.0001 |
| Coronavirus                        | 0.921                     | <0.0001   | 6339 (5653 - 7024)                  | <0.0001 |
| COVID-19 Testing                   | 0.928                     | <0.0001   | 5987 (5120 - 6853)                  | <0.0001 |
| COVID-19 Vaccine                   | 0.849                     | <0.0001   | 7778 (6062 - 9494)                  | <0.0001 |
| **Symptoms**                       |                           |           |                                     |         |
| Fever                              | 0.935                     | <0.0001   | 4854 (4538 - 5170)                  | <0.0001 |
| Headache                           | 0.809                     | <0.0001   | 4275 (3178 - 5372)                  | <0.0001 |
| Fatigue                            | 0.778                     | <0.0001   | 2037 (708 - 3366)                   | 0.0038  |
| Cough                              | 0.905                     | <0.0001   | 4033 (3678 - 4388)                  | <0.0001 |
| Chest pain                         | 0.757                     | <0.0001   | 3553 (2853 - 4252)                  | <0.0001 |
| **Disease Process/Complications**  |                           |           |                                     |         |
| Stroke                             | -0.089                    | 0.41      | -865 (-2011 - 280)                  | 0.13    |
| Pneumonia                          | 0.886                     | <0.0001   | 3670 (3149 - 4192)                  | <0.0001 |
| Myocardial Infarction              | 0.414                     | <0.0001   | 2348 (1406 - 3288)                  | <0.0001 |
| Infection                          | 0.857                     | <0.0001   | 5048 (4342 - 5752)                  | <0.0001 |
| **Healthcare Utilization**         |                           |           |                                     |         |
| Pharmacy                           | 0.495                     | <0.0001   | 3982 (3313 - 4651)                  | <0.0001 |
| Ambulance                          | 0.746                     | <0.0001   | 2714 (2246 - 3183)                  | <0.0001 |
| Physician                          | 0.494                     | <0.0001   | -951 (-1128 - 3031)                 | 0.37    |
| Oxygen                             | 0.885                     | <0.0001   | 2706 (2323 - 3090)                  | <0.0001 |
| Hospital                           | 0.884                     | <0.0001   | 5333 (4415 - 6250)                  | <0.0001 |
| Bed                                | 0.612                     | <0.0001   | 4187 (2933 - 5440)                  | <0.0001 |
| **Preventive Behaviors**           |                           |           |                                     |         |
| Quarantine                         | 0.875                     | <0.0001   | 2507 (1385 - 3629)                  | <0.0001 |
| Pulse Oximetry                     | 0.952                     | <0.0001   | 3141 (2863 - 3420)                  | <0.0001 |
| Mask                               | 0.885                     | <0.0001   | 3689 (3075 - 4303)                  | <0.0001 |
| Lockdown                           | 0.891                     | <0.0001   | 1363 (212 - 2514)                   | 0.021   |
| Hand Sanitizer                     | 0.88                      | <0.0001   | 3885 (3514 - 4257)                  | <0.0001 |
| **Testing**                        |                           |           |                                     |         |
| Oxygen Saturation                  | 0.944                     | <0.0001   | 3356 (3118 - 3594)                  | <0.0001 |
| Computed Tomography                | 0.913                     | <0.0001   | 4094 (3483 - 4706)                  | <0.0001 |
| Polymerase Chain Reaction          | 0.915                     | <0.0001   | 2410 (1570 - 3250)                  | <0.0001 |
| C-reactive protein                 | 0.955                     | <0.0001   | 4553 (4014 - 5093)                  | <0.0001 |
| D-Dimer                            | 0.945                     | <0.0001   | 3521 (3155 - 3888)                  | <0.0001 |
| **Medication Use**                 |                           |           |                                     |         |
| Inhaler                            | 0.677                     | <0.0001   | 3344 (2969 - 3719)                  | <0.0001 |
| Drug               | β Coefficient | p-value | Mean (95% CI)     | p-value |
|--------------------|---------------|---------|------------------|---------|
| Paracetamol        | 0.911         | <0.0001 | 4158 (3259 - 5057) | <0.0001 |
| Doxycycline        | 0.876         | <0.0001 | 3510 (3174 - 3845) | <0.0001 |
| Dexamethasone      | 0.765         | <0.0001 | 3268 (2734 - 3803)* | <0.0001 |
| Azithromycin       | 0.933         | <0.0001 | 3223 (2862 - 3584) | <0.0001 |
| Ivermectin         | 0.927         | <0.0001 | 3000 (2694 - 3306)* | <0.0001 |
| Fabiflu            | 0.943         | <0.0001 | 2318 (1821 - 2815) | <0.0001 |
| Remdesivir         | 0.902         | <0.0001 | 1522 (961 - 2083)* | <0.0001 |

### Control Search Terms

| Search Term | β Coefficient | p-value | Mean (95% CI)     | p-value |
|-------------|---------------|---------|------------------|---------|
| Film        | 0.076         | 0.49    | -426 (-2059 - 1205) | 0.61    |
| Election    | 0.0092        | 0.93    | -400 (-788 - 1589)* | 0.51    |
| Cricket     | -0.735        | <0.0001 | -180 (-764 - 402)* | 0.54    |
| Bank        | -0.389        | 0.0002  | 1683 (-2529 - 836) | 0.0002  |
| Animal      | -0.44         | <0.0001 | 641 (-2438 - 1155) | 0.48    |

Time-adjusted β regression coefficient is estimated using a multivariate linear regression model with the search term and number of days as covariates.

*Search terms may not comply with normality assumptions as residual plots were not random. However, we still present regression coefficients for completeness and due to sufficient sample size.
| Search Term                        | Spearman Rank Correlation | P-value |
|-----------------------------------|---------------------------|---------|
| **General Terms**                 |                           |         |
| Coronavirus Disease 2019          | 0.945                     | <0.0001 |
| Coronavirus                       | 0.918                     | <0.0001 |
| COVID-19 Testing                  | 0.916                     | <0.0001 |
| COVID-19 Vaccine                  | 0.816                     | <0.0001 |
| **Symptoms**                      |                           |         |
| Fever                             | 0.921                     | <0.0001 |
| Headache                          | 0.808                     | <0.0001 |
| Fatigue                           | 0.764                     | <0.0001 |
| Cough                             | 0.908                     | <0.0001 |
| Chest pain                        | 0.75                      | <0.0001 |
| **Disease Process/Complications** |                           |         |
| Stroke                            | -0.131                    | 0.23    |
| Pneumonia                         | 0.89                      | <0.0001 |
| Myocardial Infarction             | 0.417                     | <0.0001 |
| Infection                         | 0.853                     | <0.0001 |
| **Healthcare Utilization**        |                           |         |
| Pharmacy                          | 0.513                     | <0.0001 |
| Ambulance                         | 0.741                     | <0.0001 |
| Physician                         | 0.508                     | <0.0001 |
| Oxygen                            | 0.878                     | <0.0001 |
| Hospital                          | 0.863                     | <0.0001 |
| Bed                               | 0.585                     | <0.0001 |
| **Preventive Behaviors**          |                           |         |
| Quarantine                        | 0.869                     | <0.0001 |
| Pulse Oximetry                    | 0.954                     | <0.0001 |
| Mask                              | 0.883                     | <0.0001 |
| Lockdown                          | 0.897                     | <0.0001 |
| Hand Sanitizer                    | 0.897                     | <0.0001 |
| **Testing**                       |                           |         |
| Oxygen Saturation                 | 0.941                     | <0.0001 |
| Computed Tomography               | 0.908                     | <0.0001 |
| Polymerase Chain Reaction         | 0.918                     | <0.0001 |
| C-Reactive Protein                | 0.952                     | <0.0001 |
| D-Dimer                           | 0.938                     | <0.0001 |
| **Medication Use**                |                           |         |
| Drug          | Correlation Coefficient | P-value |
|---------------|--------------------------|---------|
| Inhaler       | 0.709                    | <0.0001 |
| Paracetamol   | 0.89                     | <0.0001 |
| Doxycycline   | 0.864                    | <0.0001 |
| Dexamethasone | 0.785                    | <0.0001 |
| Azithromycin  | 0.929                    | <0.0001 |
| Ivermectin    | 0.927                    | <0.0001 |
| Fabiflu       | 0.927                    | <0.0001 |
| Remdesivir    | 0.891                    | <0.0001 |

**Control Search Terms**

| Term   | Correlation Coefficient | P-value |
|--------|--------------------------|---------|
| Film   | 0.072                    | 0.51    |
| Election | -0.012               | 0.91    |
| Cricket | -0.729                 | <0.0001 |
| Bank   | -0.37                    | 0.0004  |
| Animal | -0.448                  | <0.0001 |
Table 6: Thematic Analysis of Common Search Term-related Queries

| Search Category | Search Terms | Related Queries                                                                 | Associated Themes          |
|-----------------|-------------|----------------------------------------------------------------------------------|---------------------------|
| General         | Coronavirus | coronavirus vaccine registration, coronavirus testing, coronavirus third wave;    | Testing                   |
|                 |             |                                                                                  |                           |
|                 | COVID-19    | covid test near me;                                                              | Testing                   |
| Testing         |             |                                                                                  |                           |
|                 | COVID-19    | covid vaccine registration, covid-19 vaccine registration online, covid-19 vaccine near me | Vaccine                   |
| Vaccine         |             |                                                                                  |                           |
| Symptoms        | Fever       | fever after covaxin, continuous fever in covid, 99.9 fever                       | Vaccine, Symptoms          |
|                 |             |                                                                                  |                           |
|                 | Cough       | how long does covid cough last, lupituss cough syrup, wet cough in corona         | Treatment Options, Symptom Expectations |
|                 |             |                                                                                  |                           |
|                 | Headache    | headache after covid, headache after covishield, covid headache                  | Vaccine, Symptom Management |
|                 |             |                                                                                  |                           |
|                 | Chest pain  | chest pain covid, chest pain in covid, chest pain in corona                       | Symptom Management        |
|                 |             |                                                                                  |                           |
|                 | Fatigue     | bio bubble fatigue, symptoms of corona, covid symptoms                            | Symptom Expectations      |
| Disease Process | Symptom Management/Expectations | Covid Specific/Symptom | Treatment Options/Disease Progression | Meaning of term |
|-----------------|--------------------------------|------------------------|---------------------------------------|-----------------|
| Loss of Taste   | loss of smell but not taste, loss of taste and smell covid, loss of taste and smell in covid | Symptom Management |  |  |
| Loss of Smell   | loss of smell but not taste, loss of smell covid which day, corona symptoms, loss of smell reasons, loss of smell in covid | Symptom Management, Symptom Expectations |  |  |
| Diarrhea        | covid diarrhea, covid symptoms, is diarrhea a symptom of covid | Symptom Expectation |  |  |
| Vomiting        | vomiting during covid, vomiting sensation reasons, vomiting in covid | Covid Specific, Symptom |  |  |
| Pneumonia       | remdesivir, stages of covid pneumonia, progressive pneumonia, atypical viral pneumonia, covid pneumonia recovery time | Treatment Options, Disease Progression |  |  |
| ARDS            | ards full form in medical | Meaning of term |  |  |
| Infection       | vaccination after covid infection, covid lung infection recovery time, fungal infection after covid, covid infection timeline, lungs infection medication, lung infection symptoms | Covid Specific, Complications, Etiology, Disease Progression |  |  |
| Heart Attack         | symptoms of corona, how to prevent heart attack, reasons for heart attack, first aid for heart attack, heart attack symptoms in hindi | Etiology, Treatment Options, Meaning of term |
|---------------------|---------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|
| Heart Failure       | heart failure symptoms                                                                                                          | Symptoms Expectation                        |
| Stroke              | heat stroke, stroke symptoms                                                                                                     | Symptoms Expectation                        |
| **Testing**         | D-dimer                                                                                                                          | Normal levels, Testing                      |
|                     | d dimer covid, d dimer in covid, crp d dimer, crp, crp test, high d dimer                                                        |                                             |
| CT Scan             | CT scan for covid, covid chest CT scan, CT severity score, chest CT scan, CT scan price, ct scan is harmful, ct scan side effects | Normal levels, Cost, Side Effects, Testing  |
| RT-PCR              | rt pcr test near me, rt pcr report, rt pcr test report, rt-pcr test, pcr, rt pcr test government centers near me                   | Locations, Testing                          |
| C Reactive Protein  | c reactive protein covid, c reactive protein in covid, c reactive protein and covid, d dimer test, high c reactive protein, c reactive protein increased, c reactive protein meaning in hindi | Normal levels, Meaning of Term, Testing     |
| IL-6                | il-6 test                                                                                                                        | Testing                                    |
| Ferritin       | ferritin levels in covid, serum ferritin means, ferritin test in hindi, ferritin test, ferritin in covid | Normal levels, Meaning of Term, Testing |
|---------------|--------------------------------------------------------------------------------------------------|----------------------------------------|
| Oxygen Saturation | normal saturation level of oxygen, normal pulse rate, oxygen concentrator, saturation meaning, oxygen saturation level | Normal levels, |
| Blood Pressure | oximeter price, blood pressure measuring instrument, pulse oximeter, diastolic blood pressure range, yoga for high blood pressure | Normal levels, Treatment options, Cost |
| Blood glucose | blood glucose normal, blood glucose level, blood glucose level normal, glucose level in blood, normal glucose level in blood | Normal levels, |
| Healthcare Utilization | Hospital | hospital near me, apollo, apollo hospital, best hospital, eye hospital, covid hospital near me | Location |
| ICU | neonatal intensive care unit, icu full form | Meaning of Term |
| Ambulance | supro ambulance, drdo bike ambulance, ambulance with ventilator, ambulance service, ambulance number. | Location, Contact information |
| Cylinder | oxygen concentrator price, oxygen cylinder refill near me, oxygen cylinder in lucknow, oxygen cylinder, oxygen | Cost, Location |
|----------|--------------------------------------------------------------------------------------------------------|---------------|
| Doctor   | doctor tamil movie cast, esanjeevani doctor login, doctor video, doctor near me, dr, doctor stranger k drama | Location      |
| Medication Use | Remdesivir | Remdisivir online, remdesivir injection online, buy remdesivir injection, remdesivir injection buy online, remdesivir availability | Purchase options |
| Paracetamol | can we take paracetamol after covid vaccine, bagged packaged goods, how many paracetamol 650 in a day, parcip 650 | Medication intake, Vaccine |
| Doxycycline | ivermectin use, azithromycin 500, ivermectin 12 mg, doxycycline 100 mg uses in hindi, doxycycline and lactic acid bacillus cap uses | Medication intake, Meaning of term, Medication usage |
| Azithromycin | ivermectin use, doxycycline 100 mg, is azithromycin an antibiotic, azithromycin, azithromycin oral suspension ip uses in hindi | Medication usage, Meaning of term |
| Drug                          | Uses                                                                 | Information                        |
|-------------------------------|----------------------------------------------------------------------|------------------------------------|
| Ivermectin                    | doxycycline covid, doxy 100 uses, ivermectin 12 mg uses, tab        | Meaning of Term, Cost, Medication Usage |
|                               | ivermectin 12 mg hindi, ivermectin 12 mg price                     |                                    |
| Dexamethasone                 | remdesivir injection, dexamethasone 6 mg, dexamethasone vs remdesivir, dexamethasone brand name, dexamethasone tablet uses in tamil | Medication usage, Meaning of term |
| Vitamin D                     | when to take vitamin d, vitamin d3 60k, vitamin d 60000 iu, vitamin c tablets, depura vitamin d3 | Medication Intake                  |

| Category                      | Information                                                                 |
|-------------------------------|-----------------------------------------------------------------------------|
| Preventative Behaviors        | **Lockdown** lockdown in telangana 2021, lockdown extended in delhi, raipur lockdown news, bihar lockdown guidelines, weekend lockdown in up |
| Quarantine                    | quarantine hotels in mumbai, quarantine meaning in marathi, quarantine meaning in bengali, home quarantine schedule, bhoomi quarantine watch |
| Face Masks                    | facemask, full face mask for men, face shield, best face mask, face mask price |
| Category       | Description                                                                                      | Section                                    |
|----------------|-----------------------------------------------------------------------------------------------|--------------------------------------------|
| Pulse Oximeters| oximeter online india, which oximeter is best, gilma oximeter, what is pr bpm in oximeter, oximeter price bangalore | Purchase options, Cost, Meaning of Term    |
| Handwashing    | Handwashing steps, handwashing machine, second hand washing machine, step of hand washing, handwash refill | Guideline                                  |
| Sanitizer      | Hand sanitizer, spray sanitizer, sanitizer price, sanitizer machine                            | Purchase options, Cost                     |
Figure 1. Clinically Relevant COVID-19 Search Terms

COVID-19 Testing Modalities

- D-dimer
- Reactive protein
- Polymerase chain reaction
- Computed tomography
- Oxygen saturation

Most Prevalent Symptoms

- Chest pain
- Headache
- Fever
- Cough
- Fatigue

Common Medications

- Dexamethasone
- Fabiflu
- Remdesivir
- Ivermectin
- Azithromycin

Disease Process/Complications

- Pulmonary embolism
- Stroke
- Infection
- Pneumonia
- Myocardial infarction
Figure 2. Socially Relevant COVID-19 Search Terms

General COVID-19 Terms

A

Healthcare Utilization

B

Preventive Behaviors

C

Festivals/Mass Gatherings

D
Figure 3. Correlation Between COVID-19 Cases and Search Terms

General Terms and Symptoms

Medication Use and Disease Complications

Oxygen-related Search Terms

Laboratory Testing