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ORIGINAL RESEARCH

Loss of smell and taste: a new marker of COVID-19? Tracking reduced sense of smell during the coronavirus pandemic using search trends

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ABSTRACT

Objectives: It has been demonstrated that reduction in smell and/or taste is the most predictive symptom in SARS-CoV-2/Covid-19 infection. We used Google Trends to analyze regional searches relating to loss of smell and taste across Italy, Spain, France, Brazil, and the United States of America and determined the association with reported Covid-19 cases.

Methods: In order to retrieve the data, we built a Python software program that provides access to Google Trends data via an application program interface. Daily COVID-19 case data for subregions of the five countries selected were retrieved from respective national health authorities. We sought to assess the association between raw search interest data and COVID-19 new daily cases per million for all regions individually.

Results: In total, we yielded 2188 sets of Google Trends data which included 548 time series of 4 anosmia and ageusia search concepts over the study period for 137 regions. These data indicated that differences in search interest for terms relating to anosmia and ageusia, between regions, is associated with geographical trends in new Covid-19 cases.

Conclusions: We feel that Google search trends relating to loss of smell can be utilized to identify potential Covid-19 outbreaks on a national and regional basis.

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1. Introduction

The loss or reduction of the sense of smell has been widely reported as a key symptom of SARS-CoV-2/Covid-19 infection and, in a significant proportion of cases, it has been demonstrated to be the only complaint [1–3]. The positive predictive value for olfactory dysfunction (OD), or loss of smell, for Covid-19 positivity has been demonstrated to be over 60%; higher than any other associated symptoms [4]. The World Health Organization (WHO) integrated loss of smell and/or taste to their official list of associated symptoms and Public Health England have recently updated their recommendations for self-isolation to include olfactory dysfunction.

Self-isolation and social distancing are seen as key public health strategies in controlling the Covid-19 outbreak [5]. Internationally, governments are now looking to reduce restrictions on their populations to prevent economic damage. As prohibitive measures are reduced, it is likely that there will be further outbreaks of Covid-19 [6]. Moving forward, accurate tracking of Covid-19 cases and early quarantining of infected people or populations will be vital in reducing transmission and preventing secondary outbreak [6]. Effective strategies will need to be adopted by leaders and public health bodies internationally to reflect this. With a worldwide need for Polymerase Chain Reaction (PCR) tests and a significant associated economic cost, particularly in low-to-middle income countries, it is paramount to develop alternative strategies to track outbreaks aside from PCR testing and tracing [6,7].

Walker *et al.* have demonstrated the utility of search term analysis, using Google trends, in determining significant associations between reported Covid-19 cases on a countrywide level [8]. Using search interest data to infer population-wide behavior in developed countries has recently become possible. This is due to an increase in mobile internet usage from 17% to 78%, in the United Kingdom between 2008 and 2018 and through the adoption of unified browser Uniform Resource Locator (URL) and search bars after 2010 [9]. The two major mobile platforms use Google which drives almost all mobile search traffic through this search engine. This has reinforced a new behavior whereby people quickly and easily search for anything, wherever they are, almost exclusively with Google.

We used Google Trends to analyze regional searches relating to loss of smell and taste across Italy, Spain, France, Brazil, and the United States of America (USA) and determined the association with reported Covid-19 cases using a self-developed software programme (Python). Moving forward, regional and sub-regional tracking of outbreaks using this or a similar method could help a targeted local public health strategies and testing. This has the potential to reduce the demand on costly PCR tests and

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allow areas that are not affected by new infections to avoid restrictive measures and open up their local economies and healthcare system.

2. Methods

2.1. Data selection

We chose the five countries worst affected by COVID-19 according to Johns Hopkins global COVID-19 data; USA, UK, Spain, Italy, and France [10]. However, Google Trends subdivides the UK into the home nations only (England, Scotland, Wales, and Northern Ireland) making further regional analysis impossible. Therefore, Brazil was used in place of the UK.

2.2. Google trends data

Google Trends is an open access platform providing data on the amount of search requests performed using Google. For a chosen search term, date range and geographical region Google Trends data contains the relative changes in volume of search requests over time and between regions. Of particular usefulness, the geographical boundaries use ISO-3166 standard national subregions which typically match COVID-19 reporting from the parent countries.

Google Trends data is normalized over the time period and geography in question against all other searches that took place. A value of 100 indicates the highest popularity for that term and 0 the lowest popularity. Similarly, for geographical comparisons, a score of 100 for a region indicates the highest relative popularity and 0 the lowest – for that country or region within a country [11].

We defined four concepts that individuals may perform a Google search for when experiencing anosmia or ageusia:

- Loss of sense of smell
- Sense of smell
- Loss of sense of taste
- Sense of taste

These four concepts were manually translated using the Google Trends Related Queries tool in order to find the appropriate semantic translation and grammar – as opposed to a literal translation. Table 1 shows the results of this.

National subregions were defined by their ISO-3166 codes – with the exception of France as Google Trends uses the pre-2016 regional boundaries [12]. The time period of interest for Google Trends data started when each country began recording subregional COVID-19 data and ended on 17 May 2020. The USA was an exception as the previous method exceeded Google Trends 90-day window for daily data aggregations, therefore the date any US state passed 10 cases of COVID-19 was taken as the start date. Search interest data were aggregated on a daily basis within the period of interest.

Table 1. Results of manual semantic translation of search terms relating to anosmia and ageusia.

Country	Loss of sense of smell	Sense of smell	Loss of sense of taste	Sense of taste
USA	Loss of smell	Sense of smell	Loss of taste	Sense of taste
Italy	Perdita olfatto	Olfatto	Perdita gusto	Gusto
Spain	Perdida olfato	Olfato	Perdida gusto	Gusto
France	Perte odorat	Odorat	Perte gout	Gout
Brazil	Perda olfato	Olfato	Perda paladar	Paladar

In order to retrieve the data, we built a Python software program, which includes the pytrends open source library that provides access to Google Trends data via an application program interface (API) [13]. Using the pytrends request methods we collected search interest data over time for each translated term per subregion of each country. A second set of search interest data was collected for individual days within the time period per search term and country which provided relative values for search interest between subregions.

2.3. Regional COVID-19 cases and population data collection

Daily COVID-19 case data for subregions of the five countries selected were retrieved from respective national health authorities [14–18]. Regional population data were supplied with COVID-19 data from Brazil and the USA. Census population data were retrieved separately for Italy, Spain, and France [19–21].

French COVID-19 and population data were reorganized from department level grouping into the pre-2016 regional structure in order to match the search interest geographies used by Google Trends.

2.4. Analysis

Further data processing was performed using our self-developed software program. Unadjusted search interest data could be used for within region analyses over time. To conduct between region analyses, search interest over time per region was combined with national search interest data providing relative weightings between regions producing a figure for daily weighted search interest.

COVID-19 data were normalized against the population of each region producing a value for new cases per million. Normalizing COVID-19 case data were required to adjust for population differences in order to make between region comparisons between regions within a country.

Raw search interest data, weighted search interest data, and COVID-19 new daily cases per million data were smoothed using a 7-day moving-mean to reduce the noise introduced by recording errors and low data volumes.

We then sought to assess the association between smoothed raw search interest data and smoothed COVID-19 new daily cases per million for all regions individually. Following this we looked broadly at the number of regions with significant associations and the strength of any association.

A second analysis pooled the smoothed, weighted search interest data for all regions within a country and the smoothed COVID-19 new daily cases per million. This second analysis was an attempt to understand whether search interest data could provide insights into geographical as well as temporal changes in anosmia and ageusia secondary to Covid-19.

3. Results

In total 137 regions were included in the study; Italy (20), USA (51), Spain (17), France (22) and Brazil (27). Running until the 17 May 2020, the following start dates and number of days are shown for each country:

- Italy: 24 February 2020–83 days
- USA: 21 February 2020–86 days
- Spain: 20 February 2020–87 days
- France: 24 February 2020–83 days
- Brazil: 26 February 2020–81 days

In total this yielded 2188 sets of Google Trends data which included 548 time series of the 4 anosmia and ageusia search concepts over the study period for all 137 regions, aggregated per day. The remaining 1640 sets of Google Trends data consisted of the regional comparison data per country and search concept on each date within the study period.

3.1. Within region analyses

The search interest data with 7-day moving-mean, although continuous, would still have been bound at an upper and lower limit. In addition, Kolmogorov-Smirnov testing demonstrated the data was nonparametric. Therefore, Spearman's rank correlation test was used in all regions and for all 4 translated search concepts. Daily search interest data (7-day moving-mean) were tested against daily new Covid-19 cases per million (7-day moving-mean) over time within each region.

For seven sets of results Google Trends returned an insufficient data response. This affected Molise, Basilicata, and Valle d'Aosta in Italy and North Dakota and Wyoming in the USA. Therefore, in all other combinations of regions and search concepts 541 Spearman's rank correlation tests were performed – Table 2 shows a summary of the results.

A strong (r_s > 0.65) or moderate (r_s 0.3 to 0.65) positive correlation between new daily Covid-19 cases and search interest for 'loss of sense of smell' was observed in 110 regions (82%), for 'loss of sense of taste' 113 regions (84%), 'sense of smell' 107 regions (78%) and for 'sense of taste' 83 regions (61%). Of this total of 413 strong to moderate test results, 381 had a significance value of less than 0.001. Our data shows 121 regions (88%) as having a moderate or strong correlation between either 'loss of sense of smell' or 'loss of sense of taste' and new daily Covid-19 cases.

Weakly positive or negative correlations (r_s 0.3 – −0.3) were observed in 10 regions for 'loss of smell' (7.5%), 7 regions for 'loss of sense of taste' (5.1%), 12 regions for 'sense of smell' (8.8%) and 10 regions for 'sense of taste' (7.4%).

Moderate negative correlations (r_s −0.3–0.65) were not observed in any regions for 'loss of sense of smell', 2 regions for 'loss of sense of taste' (1.5%), 3 regions for 'sense of smell' (2,2%) and 5 regions for 'sense of taste' (3.7%). No strongly negative correlations were observed.

Brazil had the highest number of strong or moderate correlations at 97 out of 108 (90%), then France with 78 out of 88 (89%), Spain had 56 out of 68 (82%), Italy 52 out of 75 (69%) and then the USA with 130 out of 202 (64%). The USA had a tendency toward more regions with moderate than strong correlations, whereas for regions from other countries the reverse is true. Italy had the highest proportion of weak correlations with 8 (11%) and the USA the highest amount of moderate negative correlations (3.5%).

Our data indicate that in general for any individual region there is a temporal relationship between Google search volume for terms relating to anosmia and ageusia and new cases of Covid-19. This phenomenon appears strongest for search terms specifically mentioning loss of either smell or taste.

3.2. Between region analyses

Weighted search interest scores were produced by applying daily regional weighting data to the original time series data. Kolmogorov-Smirnov testing indicated the weighted search

Table 2. Summary of Spearman's rank correlation test outcomes for search interest in terms relating to anosmia and ageusia and new daily Covid-19 cases per million (both data as 7-day moving-mean) the table shows counts of regions within each country and result group. r_s : Spearman's rank correlation coefficient. * Significance level of $p < 0.05$.

Search concept	Country	Strong positive r_s >0.65 *	Moderate positive r_s 0.65 to 0.3 *	Weak positive r_s 0.3 to 0 *	Weak negative r_s 0 to −0.3 *	Moderate negative r_s −0.3 to −0.65 *	Non- significant r_s > 0 *	Non- significant r_s < 0 *
Loss of sense of smell	Brazil	15	7	2	0	0	0	3
	Spain	8	8	1	0	0	0	0
	France	12	9	0	0	0	1	0
	Italy	8	5	2	0	0	1	1
	USA	6	32	4	1	0	5	3
Loss of sense of taste	Brazil	17	6	0	0	0	2	2
	Spain	9	7	1	0	0	0	0
	France	17	5	0	0	0	0	0
	Italy	9	7	1	0	0	0	1
	USA	7	29	5	0	2	5	3
Sense of smell	Brazil	16	9	1	0	1	0	0
	Spain	11	5	0	0	0	1	0
	France	16	2	2	0	0	2	0
	Italy	11	5	2	0	0	2	0
	USA	5	27	5	2	2	5	5
Sense of taste	Brazil	19	8	0	0	0	0	0
	Spain	3	5	1	1	0	5	2
	France	6	11	2	0	0	3	0
	Italy	3	4	1	2	2	2	6
	USA	3	21	3	0	3	12	7

interest data pooled by country was not normally distributed. Spearman's rank correlation analysis was used to assess the relationship between weighted search interest (7-day moving mean) and daily new Covid-19 cases per million (7-day moving mean) over time and regions within each country. The results are shown in Table 3.

All four search concepts demonstrated a significant ($p < 0.05$), positive correlation with new daily Covid-19 cases. However, 'loss of sense of smell' and 'loss of sense of taste' had a higher range for r_s when compared to 'sense of smell' and 'sense of taste'. This finding conforms to our previous observation that interest in terms including loss of either smell or taste more closely follow population changes in Covid-19 cases.

The most obvious differences between countries are that Italy has a slightly lower range for the test statistic (r_s 0.141 to 0.510) and Brazil a higher range (r_s 0.601 to 0.637). These differences appear reduced with search interest for 'loss of sense of smell' and 'loss of sense of taste'.

The data suggest for any given point in time within a single country that regions with higher Covid-19 cases will also have higher search interest for terms relating to anosmia and ageusia.

Within region analysis reveals that when considering a single region, higher numbers of Covid-19 cases typically correspond with higher search interest for terms relating to anosmia and ageusia. Between region analysis demonstrates an association between the relative increase in Covid-19 cases and relative increase in search interest for anosmia and ageusia that shows consistency across all regions within a country. Taken together this data is evidence of a widespread association between Covid-19 cases and search interest for anosmia and ageusia that is observed in regional geographies inside the studied countries.

4. Discussion

As often stated, a global pandemic is a series of smaller national epidemics which themselves consist of a series of smaller outbreaks. Walker, et al.'s findings demonstrate an association between search interest in loss of smell and new Covid-19 cases at a national level and we have now found evidence of this at a regional level reflecting smaller disease outbreaks [8]. When analyzing whether the relative size of search interest changes reflected numbers of Covid-19 cases between regions we were also able to demonstrate positive correlations.

Observed regional and national variations in the strength of the association we describe may be attributed to factors we could not account for. Such factors would include differences in internet usage behaviors, the level public awareness of Covid-19 symptoms and internet availability.

As we now know the significance of the reduction of sense of smell in Covid-19 positivity, finding ways of tracking the reporting of this symptom is important. Mobile application-based reporting tools, such as the one produced by Menni et al., could be one method of tracking cases based on symptomatology [22]. However, allowing access to geo-locations on a population wide level is controversial due to impacts on the right to privacy and as such may prove unpopular. Tracking search terms does not identify an individual and does not interfere with this human right.

Tracking symptomatology through Google is a newly developed technique and has transferability to other areas of medicine and future pandemics depending on the disease phenotype. Due to the recent increase in widespread usage of mobile internet and the use of Google on the biggest platforms as the primary search engine, this data has become more reliable when compared to previous years. Comparison with previous pandemics, due to this behavioral change in internet interaction, was not undertaken in this study for that reason.

Covid-19 has affected numerous nations with significantly disparate Gross Domestic Products (GDPs) and public health budgets. Sudan, for example, spends £25 per capita on health compared with £2989 in the UK [23,24]. Countries, which are not able to invest in PCR testing or future antibody assays, will look for more cost-effective means to track their outbreaks and reduce transmission. The use of mobile internet, in general, is high in these low-to-middle income countries and; 75% of the population of Sudan have access [25].

Excess mortality is now being adopted as the most accurate measure of Covid-19-related mortality due to differences in testing between nations and the relatively low sensitivity of the standard PCR test [26,27]. Loss of smell search terms have the potential to identify active cases on an international basis as long as access to the internet and subsequent search term data is freely available. This is something that is more easily accessible and available in less developed countries with healthcare infrastructure that is not well resourced. We do not yet know if similar trends will continue in countries who have already been impacted by a large number of Covid-19 cases but this can be assessed prospectively going forwards and modeling can be subsequently adapted.

5. Conclusion

We have demonstrated that there is clear association between Google Trends search terms relating to loss of smell and taste and Covid-19 cases both on a regional, national, and international basis. We feel that Google search trends relating to loss of smell can

Table 3. Spearman's rank correlation test outcomes for weighted search interest in terms relating to anosmia and ageusia and new daily Covid-19 cases per million (both data as 7-day moving-mean) or time and regional geography. r_s = Spearman's rank correlation coefficient.

Search concept	Country	r_s	p-Value
Loss of sense of smell	Italy	0.510	<0.001
	USA	0.485	<0.001
	Spain	0.494	<0.001
	France	0.480	<0.001
	Brazil	0.624	<0.001
Loss of sense of taste	Italy	0.443	<0.001
	USA	0.460	<0.001
	Spain	0.562	<0.001
	France	0.557	<0.001
	Brazil	0.637	<0.001
Sense of smell	Italy	0.385	<0.001
	USA	0.386	<0.001
	Spain	0.489	<0.001
	France	0.509	<0.001
	Brazil	0.601	<0.001
Sense of taste	Italy	0.141	<0.001
	USA	0.378	<0.001
	Spain	0.062	0.021
	France	0.159	<0.001
	Brazil	0.610	<0.001

be utilized to identify potential Covid-19 outbreaks on a regional basis within countries. This could help the implementation of targeted public health measures in these areas; which will be of particular benefit in low-to-middle income countries where testing is not widely available. If regional outbreaks are identified, spread throughout a country could be prevented whilst allowing other areas to continue with reduced restrictions therefore diminishing negative impact on economic growth and non-Covid-19-related healthcare activity which is of significant concern in itself.

Github repository

https://github.com/GeorgeCherry/anosmia_search_interest_covid-19

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Declaration of interest

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Author contributions

GC contributed to study design, developed the software which retrieved the data, analyzed the data and drafted the Methods and Results section of the manuscript. JR contributed to the study design and drafted the Introduction, Discussion, and Conclusion sections of the manuscript. MC, JL, ML, VL, and BNK revised the manuscript and approved the final version for publication.

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