# Special Report

## Clinical Predictors of SARS-CoV-2 Testing Pressure on Clinical Laboratories: A Multinational Study Analyzing Google Trends and Over 100 Million Diagnostic Tests

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### ABSTRACT

**Objective:** Evidence has shown that Google searches for clinical symptom keywords correlates with the number of new weekly patients with COVID-19. This multinational study assessed whether demand for SARS-CoV-2 tests could also be predicted by Google searches for key COVID-19 symptoms.

**Methods:** The weekly number of SARS-CoV-2 tests performed in Italy and the United States was retrieved from official sources. A concomitant electronic search was performed in Google Trends, using terms for key COVID-19 symptoms.

**Results:** The model that provided the highest coefficient of determination for the United States ($R^2$ = 82.8%) included a

combination of searching for cough (with a time lag of 2 weeks), fever (with a time lag of 2 weeks), and headache (with a time lag of 3 weeks; the time lag refers to the amount of time between when a search was conducted and when a test was administered). In Italy, headache provided the model with the highest adjusted $R^2$ (86.8%), with time lags of both 1 and 2 weeks.

**Conclusion:** Weekly monitoring of Google Trends scores for nonspecific COVID-19 symptoms is a reliable approach for anticipating SARS-CoV-2 testing demands ~2 weeks in the future.

**Keywords:** laboratory medicine, SARS-CoV-2, diagnostic testing, infodemiology, laboratory management, COVID-19

The ongoing COVID-19 pandemic has placed unprecedented strain on clinical laboratories.[1] Despite significant efforts, the high demand for SARS-CoV-2 diagnostic tests, compounded by increased patient loads, shortages of reagents, and limited qualified personnel to perform the tests, has encumbered effective responses by laboratories to the pandemic.[1,2] A recent survey by the American Association of Clinical Chemistry concluded that the vast majority of worldwide laboratories are encountering serious challenges in obtaining reagents

**Abbreviation:**

USA, United States of America.

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and test kits for routine SARS-CoV-2 diagnostics, along with shortages in qualified personnel to run the molecular assays.[3] Given that diagnostic testing with identification and isolation of patients who test positive is the most effective policy for preventing or containing local outbreaks[4] and that laboratory shortages are expected to continue well into 2021, the identification of predictors that could anticipate testing pressure on laboratories days or even weeks in advance would be helpful in preparing laboratories for a surge in demand and informing public health decision-making.

As previously shown, tracking the number of weekly Google searches for clinical symptom keywords, in particular the loss of taste and the loss of smell, correlated strongly with the number of weekly cases of patients diagnosed with COVID-19 2 weeks later.[5] However, the demand for laboratory tests may be impacted by many factors other than the number of actual patients with SARS-CoV-2, such as the circulation of common cold viruses, influenza, or

even seasonal allergies, all of which can mimic COVID-19 symptoms. As such, in this retrospective, multinational study, we aimed to assess whether the demand for SARS-CoV-2 tests could be accurately predicted by Google searches for key COVID-19 symptoms.

## Materials and Methods

The weekly number of SARS-CoV-2 tests performed in Italy and the United States (USA) was retrieved by searching the official website of the Italian National Institute of Health (IstituSuperiore di Sanità) and the Centers for Disease Control and Prevention. Data was retrieved from both websites for a period between March 1 (ie, the beginning of the outbreak in the 2 countries) and December 20, 2020. A concomitant electronic search was carried out in Google Trends (Google Inc., Mountain View, CA), using the Italian and English terms for the most common symptoms described by COVID-19 patients: *febbre* (fever), *tosse* (cough), *dispnea* (dyspnea), *perdita olfatto* (olfactory loss), *perdita gusto* (taste loss), and *mal di testa* (headache). A weekly Google Trends score was obtained for each keyword, reflecting the cumulative number of Google searches during the previous 7 days. Data from Google Trends were retrieved for each country and keyword independently.

Cross-correlation analysis was conducted to identify time lags that provided the highest possible correlations between the Google Trends searches and SARS-CoV-2 testing (ie, the amount of time between when a search was conducted and when a test was administered). Time-series linear regression was performed for each search term to evaluate its predictive value in estimating the weekly number of SARS-CoV-2 tests. To adjust for the varying accessibility and number of available diagnostic tests over the course of local outbreaks, a numeric variable representing the epidemiologic month was included in each model. Further variable selection was based on the previous cross-correlation analysis. Model performance was assessed using adjusted $R^2$ and graphical analysis. All statistical analysis was performed using R software (The R Project for Statistical Computing, Vienna, Austria).

The study was conducted in accordance with the Declaration of Helsinki, under the terms of relevant local legislation. This analysis was based on electronic searches in unrestricted, publicly available repositories, so that no informed consent or ethical committee approvals were needed.

## Results

A total of 114,936,353 SARS-CoV-2 diagnostic tests, 25,366,124 tests from Italy and 89,570,229 from the USA, were analyzed over the study period. The results of the cross-correlation analysis are presented in **Table 1**. In the data from Italy, fever, cough, and dyspnea provided the highest correlations with no time lag, headache and smell loss hit their peak cross-correlation coefficient when there was a time lag of 2 weeks, and taste loss had its highest correlation when there was a time lag of 3 weeks. In the USA, fever, cough, taste loss, and dyspnea provided the highest correlation with the number of SARS-CoV-2 tests when the Google Trends search had a time lag of 1 week. The term *headache* reached its peak correlation when there was a 4-week time lag, and smell loss had its highest correlation when there was no time lag.

Time-series linear regression analysis (**Table 2**) showed that the effects of the Google Trends search series for fever (a lag of 2 weeks), headache (a lag of 3 weeks), cough (a lag of 2 weeks), and dyspnea (lags of both 1 and 2 weeks) were each significant when adjusted for the monthly trend of an increase in tests in the USA, and all provided adjusted $R^2$ values of >77%. Neither smell nor taste loss showed significant effects in the number of weekly tests. The model that provided the highest coefficient of determination for this data, $R^2 = 82.8\%$, included a combination of cough (a lag of 2 weeks), fever (a lag of 2 weeks), and headache (a lag of 3 weeks) in addition to the monthly trend.

Similar results were found using the Italian data: Both fever and cough, when there was a 2-week time lag, had significant effects on the number of weekly SARS-CoV-2 tests and provided adjusted $R^2$ values of 76.4% and 76.9%, respectively, when adjusted for the monthly trend. The same was observed for smell loss, when there was a 2-week time lag, producing an adjusted $R^2$ of 80.7%. Taste loss also had significant effects on the number of weekly tests, at both 1- and 3-week time lags, with an adjusted $R^2$ of 84.3%. The term *headache* provided the model with the highest adjusted $R^2$ (86.8%), when there was a time lag of both 1 and 2 weeks. The Google Trends search series for

## Table 1. Cross-Correlation Analysis Between Weekly Number of SARS-CoV-2 tests in the USA and Italy with Google Trends Scores for Suggestive Symptoms

**USA**

| Search Term | Optimal Time Lag | Cross-Correlation Coefficient | P Value |
|---|---|---|---|
| Fever | −1 | −0.643 | <.001 |
| Cough | −1 | −0.632 | <.001 |
| Headache | −4 | −0.538 | <.001 |
| Smell loss | 0 | 0.345 | .027 |
| Taste loss | −1 | 0.386 | .013 |
| Dyspnea | −1 | −0.494 | .002 |

**Italy**

| | | | |
|---|---|---|---|
| Fever | 0 | −0.118 | .4499 |
| Cough | 0 | −0.091 | .5601 |
| Headache | −2 | 0.426 | .006 |
| Smell loss | −2 | 0.306 | .050 |
| Taste loss | −3 | 0.408 | .009 |
| Dyspnea | 0 | −0.396 | .011 |

## Table 2. Time-Series Linear Regression Analysis for Weekly Number of SARS-CoV-2 Tests in the USA and Italy with Google Trends Scores for Suggestive Symptoms

| USA | | | | Italy | | | |
|---|---|---|---|---|---|---|---|
| Variable | Coefficient | SE | P Value | Variable | Coefficient | SE | P Value |
| Month | 371514.413 | 37173.475 | <.001 | Month | 124197.56 | 10271.921 | <.001 |
| Taste loss (lag: 2 weeks) | −4604.735 | 4542.435 | .317 | Taste loss (lag: 1 week) | 3264.247 | 1174.573 | .009 |
| $R^2 = 0.744$ | | | | Taste loss (lag: 3 weeks) | 4430.998 | 1172.683 | .001 |
| | | | | $R^2 = 0.843$ | | | |
| Month | 368141.424 | 34967.842 | <.001 | Month | 130744.074 | 11033.681 | <.001 |
| Smell loss (lag: 2 weeks) | −6205.882 | 4995.789 | .222 | Smell loss (lag: 2 weeks) | 6025.338 | 1289.034 | <.001 |
| $R^2 = 0.736$ | | | | $R^2 = 0.807$ | | | |
| Month | 286427.622 | 38786.036 | <.001 | Month | 139022.829 | 12484.744 | <.001 |
| Fever (lag: 2 weeks) | −18475.442 | 6310.324 | .006 | Fever (lag: 2 weeks) | 6359.982 | 1887.627 | .002 |
| $R^2 = 0.787$ | | | | $R^2 = 0.764$ | | | |
| Month | 284906.054 | 34068.422 | <.001 | Month | 140929.918 | 12454.365 | <.001 |
| Cough (lag: 2 weeks) | −18397.907 | 4754.003 | <.001 | Cough (lag: 2 weeks) | 5794.213 | 1645.429 | .001 |
| $R^2 = 0.814$ | | | | $R^2 = 0.769$ | | | |
| Month | 292549.787 | 35925.514 | <.001 | Month | 125283.07 | 9150.488 | <.001 |
| Headache (lag: 3 weeks) | −29846.516 | 10117.8591 | .006 | Headache (lag: 3 weeks) | 7519.16 | 2735.181 | .009 |
| $R^2 = 0.773$ | | | | Headache (lag: 2 weeks) | 8828.424 | 2753.355 | .003 |
| | | | | $R^2 = 0.868$ | | | |
| Month | 305947.217 | 31327.072 | <.001 | Month | 142714.572 | 16100.452 | <.001 |
| Dyspnea (lag: 1 week) | −15789.835 | 7301.935 | .038 | Dyspnea (lag: 2 weeks) | 3697.781 | 2514.167 | .150 |
| Dyspnea (lag: 2 weeks) | −17374.205 | 7050.279 | .01878 | $R^2 = 0.707$ | | | |
| $R^2 = 0.814$ | | | | | | | |
| Month | 305214.726 | 38859.025 | <.001 | … | … | … | … |
| Cough (lag: 2 weeks) | −52445.943 | 18270.325 | .007 | … | … | … | … |
| Fever (lag: 2 weeks) | 50882.5341 | 23382.953 | .037 | … | … | … | … |
| Headache (lag: 3 weeks) | −25093.088 | 10181.607 | .019 | … | … | … | … |
| $R^2 = 0.828$ | | | | … | | | |

*SE, standard error.*
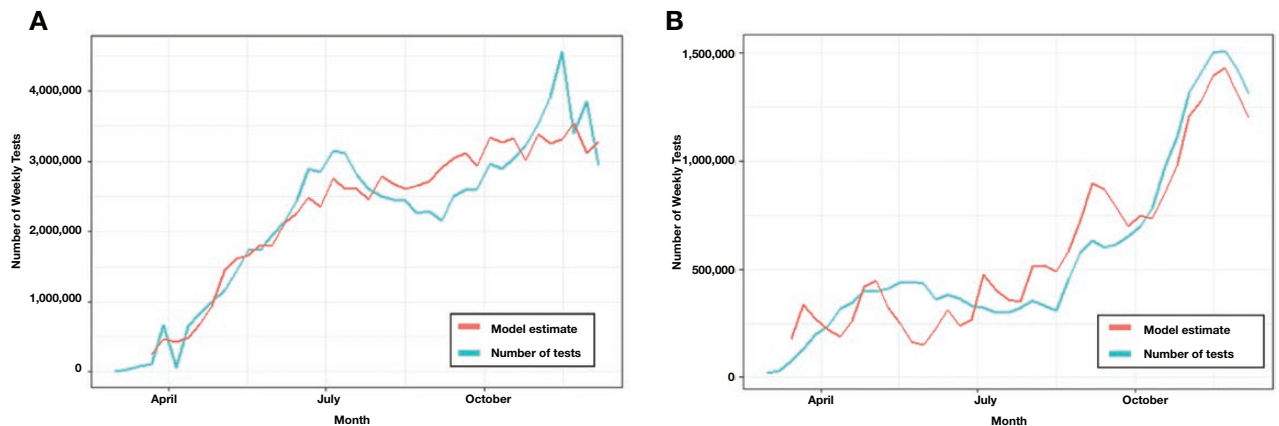
**Figure 1**

Highest adjusted $R^2$ time-series linear regression results for the number of weekly SARS-CoV-2 tests in the USA **(A)** and Italy **(B).**

the term *dyspnea* had no significant effect on the weekly test numbers. The 2 models with the highest adjusted $R^2$ for each country are represented in **Figure 1**.

## Discussion

The results of our analysis show that Google Trends data can anticipate the demand for SARS-CoV-2 diagnostic tests. Overall, the results were relatively consistent between both countries. Interestingly, we observed that nonspecific symptoms (fever, headache, and cough) were the best predictors for the number of weekly diagnostic tests 2 to 3 weeks after the search was conducted. This result contrasts with data previously observed for predicting the number of patients diagnosed weekly with COVID-19 using the same symptom keywords, in which specific symptoms, ie, taste loss and smell loss, were the best predictors.[5] We suspect that this contrast is because nonspecific COVID-19 symptoms can result from numerous other conditions, which may also have seasonal variability, such as the common cold or allergies, all of which are likely to lead individuals to seek SARS-CoV-2 testing.

Our study was limited by its retrospective design and the fact that access to COVID-19 testing, availability of test kits, number of tests performed, and public health testing programs may have all changed over the course of the pandemic. We controlled for this by using the month as a variable in the linear regression.

## Conclusion

Based on the results of our analysis, we recommend that clinical laboratories and public health officials monitor weekly Google Trends scores for nonspecific symptom searches, which can obtained freely and easily in seconds and on a more localized, regional level. A 2- to 3-week lag for the keywords *fever, headache,* and *cough* to anticipate testing demands would enable clinical laboratories to stock up on reagents and plan staffing accordingly and to inform public health officials to set up pop-up testing sites and allocate additional resources to upcoming hot spots, as appropriate. **LM**

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