Factors Associated With Access to and Timing of Coronavirus Testing Among US Adults After Onset of Febrile Illness

Mark J. Pletcher, MD, MPH; Jeffrey E. Olgin, MD; Noah D. Peyser, PhD; Madelaine Faulkner Modrow, MPH; Feng Lin, MS; Jeffrey Martin, MD, MPH; Thomas Carton, PhD; Alexis L. Beatty, MD, MAS; Eric Vittinghoff, PhD; Gregory M. Marcus, MD, MAS

Abstract

IMPORTANCE Active SARS-CoV-2 (coronavirus) transmission continues in the US. It is unclear whether better access to coronavirus testing and more consistent use of testing could substantially reduce transmission.

OBJECTIVE To describe coronavirus testing in persons with new onset of febrile illness and analyze whether there are changes over time and differences by race and ethnicity.

DESIGN, SETTING, AND PARTICIPANTS This cohort study used data from the COVID-19 Citizen Science Study, launched in March 2020, which recruited participants via press release, word-of-mouth, and partner organizations. Participants completed daily surveys about COVID-19 symptoms and weekly surveys about coronavirus testing. All adults (aged at least 18 years) with a smartphone were eligible to join. For this analysis, US participants with new onset of febrile illness from April 2020 to October 2020 were included. Data analysis was performed from November 2020 to March 2021.

MAIN OUTCOMES AND MEASURES Receipt of a coronavirus test result within 7 days of febrile illness onset.

RESULTS Of the 2679 participants included in this analysis, the mean (SD) age was 46.3 (13.4) years, 1983 were female (74%), 2017 were college educated (75%), and a total of 3865 distinct new febrile illness episodes were reported (300 episodes [7.8%] from Hispanic participants, 71 episodes [1.8%] from Black participants, and 3494 episodes [90.4%] from not Black, not Hispanic participants) between April 2 and October 23, 2020. In weekly surveys delivered during the 14 days after fever onset, 12% overall (753 participants) indicated receipt of a test result. Using serial survey responses and parametric time-to-event modeling, it was estimated that by 7 days after onset of febrile illness, a total of 20.5% (95% CI, 19.1%-22.0%) had received a test result. This proportion increased from 9.8% (95% CI, 7.5%-12.0%) early in the epidemic to 24.1% (95% CI, 21.5%-26.7%) at the end of July, but testing rates did not substantially improve since then, increasing to 25.9% (95% CI; 21.6%-30.3%) in late October at the start of the winter surge. Black participants reported receiving a test result about half as often as others (7% [7 of 103] of survey responses vs 12% [53 of 461] for Hispanic vs 13% [693 of 5516] for not Black, not Hispanic; P = .03). This association was not statistically significant in adjusted time-to-event models (hazard ratio = 0.59 vs not Black, not Hispanic participants; 95% CI, 0.26-1.34).

CONCLUSIONS AND RELEVANCE Systematic underuse of coronavirus testing was observed in this cohort study through late October 2020, at the beginning of the winter COVID-19 surge, which may have contributed to preventable coronavirus transmission.

Key Points

Question How often do persons with new febrile illness access coronavirus testing and receive a test result within 7 days of illness onset?

Findings In this cohort study, generally low rates of coronavirus testing were observed in 2679 participants reporting new onset of febrile illness. Although testing rates improved somewhat during the study period, timely coronavirus test results were sought and received by only 25.9% of newly febrile persons at the end of the study analysis period in late October 2020.

Meaning Our results suggest systematic underuse of coronavirus testing in patients with febrile illness that may contribute to community transmission.

Author affiliations and article information are listed at the end of this article.
Introduction
The US has had a disproportionate share of morbidity and mortality from the COVID-19 pandemic. One potential explanation for this failure is the slow dissemination of testing capacity, but increases in testing rates through Fall 2020 did not seem to blunt the large COVID-19 surge that occurred the following winter.

The effectiveness of coronavirus testing depends not only on the number of tests performed but also on who is getting tested. Testing may be administered for a variety of reasons: to diagnose COVID-19 in symptomatic patients, to detect asymptomatic infection in persons exposed to infection or at high risk of transmitting infection to others (eg, essential workers), to detect outbreaks in schools or other venues where in-person gatherings are now being allowed, or for other reasons that may be more or less useful for prevention of coronavirus transmission. Without knowing who is getting tested, it is unclear how effective coronavirus testing programs are in the US and, in particular, how available testing is to persons at highest risk for infection.

Persons with new onset of febrile illness are at relatively high risk of being infected with SARS-CoV-2 and infecting others. Fever is a cardinal sign of coronavirus infection, and appears relatively early in the course of disease. Therefore, it is of presumably high value to detect infection in newly febrile persons so they can isolate themselves, and so their contacts can get tested and quarantine themselves to avoid infecting others. It is not clear how effective current testing programs are at providing timely access to coronavirus testing in persons with new onset of febrile illness, and whether disparities in access to testing may be contributing to higher rates of COVID-19 illness and death in Black and Hispanic persons.

The COVID-19 Citizen Science Study, launched in late March 2020, collects survey data daily on symptoms of COVID-19 and weekly on coronavirus testing. We used these responses to estimate time to receipt of test results among participants with new onset of febrile illness, and analyzed time trends in timely coronavirus testing over the course of the pandemic and disparities by race/ethnicity.

Methods
Study Design and Participants
The COVID-19 Citizen Science Study is a dynamic cohort study hosted on the National Institutes of Health-funded Eureka Research Platform, and delivered entirely via smartphone app. All adults with a smartphone who confirmed their phone number by text message were eligible and provided informed consent electronically before participating. There are no monetary incentives or other payments provided to participants. The study launched in late March 2020, and recruited primarily via press release, word-of-mouth, and partner organizations. For this analysis, we included only US adults who reported new onset of a febrile illness during follow-up through October 23, 2020. The study was approved by the University of California San Francisco Institutional Review Board.

New Onset of Febrile Illness
We defined new onset of febrile illness as a report of either (1) fever or chills or (2) a temperature greater than 100.4 °F or 38.0 °C on a daily survey for participants enrolled for at least 5 days and having no prior report of fever in the prior 5 days. Participants with prior positive coronavirus test results were excluded. All episodes meeting entrance criteria, sometimes more than 1 per participant, were analyzed.

Obtaining a Test and Receiving Results
All participants receive a weekly survey that included questions about coronavirus testing in the past week (without specifying a date). Survey questions were designed to distinguish tests for active infection (virus) or past infection (antibody); we assumed it was a test for active infection if
participants were unsure. Focusing on tests for active infection, we coded each survey response as not tested, tested but awaiting results, tested with inconclusive results, or test results received (either positive or negative). Sequential survey responses (up to 3 received within 14 days) were used to specify the bounds of the interval during which a test was (or was not) received.

Race, Ethnicity, and Other Participant Characteristics
Participants register with their date of birth, provide informed consent, and then complete a series of baseline surveys, including self-report of race (multiple categories allowed) and ethnicity. We categorized participants as “Hispanic, any race,” “Black, not Hispanic,” or “Not Hispanic, not Black,” according to their survey responses, given higher rates of COVID-19 illness and death in Black and Hispanic persons.6,7 Participants also reported subjective social status (MacArthur 10-point scale9) and education; use of cigarettes, e-cigarettes, and alcohol; and a variety of medical conditions. Current use was defined as any use in the last 30 days for cigarettes or e-cigarettes, and in the last week for alcohol.

Statistical Analysis
We compared baseline characteristics across the 3 race/ethnicity categories for participants with at least 1 new febrile illness. For statistical testing across these 3 categories, we used χ² or Fisher exact tests (when expected values were less than 5), and analysis of variance or Kruskal-Wallis tests (when outcomes were not normally distributed) for continuous variables. All tests were 2-sided, and the significance threshold was \( P < .05 \).

We then described weekly survey results about coronavirus testing, overall and stratified by race/ethnicity, subjective social status, days after illness onset that the weekly survey was delivered, and calendar month. Across these strata we compared response proportions, and then survey responses among respondents, using χ² tests.

Because the exact date of testing was unknown and could be interval- or right-censored, we used a parametric Weibull model for estimating time to receipt of a test result. To define the interval during which a test result was received, we used up to 3 weekly survey results reported on the day of or up to 14 days after onset of febrile illness. Survey results received after illness day 7 were ignored if the participant did not respond to a previous survey delivered on or before day 7 (making subsequent surveys about the last 7 days difficult to interpret). Fitted cumulative incidence of testing was plotted along with survey responses by days after onset of illness. All models accounted for clustering and nonindependence due to multiple episodes per person.

To analyze changes in testing availability during different phases of the pandemic, we flexibly modeled calendar time using a cubic spline with 3 knots, and present tests for time trend overall and for nonlinearity. We then tested the contribution of our 3-level race/ethnicity variable to that model by including a main effect (with 3 levels) and interactions with each of the time trend spline variables. The main effect was also estimated in models adjusting for age, sex, medical conditions, cigarette/e-cigarette use and alcohol use, and then additionally for subjective social status and education.

We conducted sensitivity analyses to explore how our results might change with different assumptions about missing survey responses. In the first, we assumed that a test result was received 1 day after a participant reported that they were awaiting a test result, unless we know from a subsequent survey response that such a result was definitely not received. In more extreme sensitivity analyses, we assumed that any person who did not respond to a survey about coronavirus testing had actually not received coronavirus testing (one extreme), or had actually received a test result on day 3 after onset of febrile illness if their first survey response was missing or 1 day after their last completed response (the other extreme). We also conducted 3 analyses, under base case assumptions, exploring results in 3 subsets of episodes: (1) the first episode for each person; (2) episodes where fever was reported on both the first and the second day; and (3) episodes where a high temperature (>100.4 °F or 38.0 °C) was reported (rather than just subjective “fever or chills”).
We used Stata statistical software version 16.1 (StataCorp) for all analyses. Parametric interval-censored survival-time regression was accomplished using Stata's stintreg command. Data analyses were performed from November 2020 to March 2021.

Results

Between March 26 and October 23, 2020, 37,436 people enrolled in the COVID-19 Citizen Science Study; 2% self-identified as Black and 7% as Hispanic. After enrollment, 3001 participants reported at least one episode of fever or chills or a high temperature and met our criteria for new onset of a febrile illness. We excluded 95 with incomplete data on race or ethnicity, and 227 who live outside the US. The 2679 participants included in our analysis contributed a total of 3865 episodes overall, including 300 episodes (7.8%) from 183 Hispanic participants, 71 episodes (1.8%) from 41 Black participants, and 3494 episodes (90.4%) from 2455 participants who were neither Black nor Hispanic.

Among the 2679 participants included in our analysis with at least 1 febrile episode, age varied widely with a mean (SD) of 46.3 (13.4) years, most were female (n = 1983; 74%) and college-educated (n = 2017; 75%), and few reported comorbid illness (eg, 656 participants with hypertension [24%] and 176 participants with diabetes [6.6%]) (Table 1). Few participants reported current cigarette use (n = 164 [6.1%]), but more than half reported current alcohol use (n = 1399 [52%]).

Even with small numbers of Black and Hispanic participants, some systematic differences were noted across the 3 groups, including lower levels of education and subjective social status in Black and Hispanic participants, and higher prevalence of some medical conditions in Black participants. Black and Hispanic participants contributed more febrile episodes each than participants who were neither Black nor Hispanic (Table 1).

A total of 8006 weekly surveys about coronavirus testing were delivered up to 14 days after fever onset (1-3 surveys/episode), with a 76% response rate (n = 6080 total responses). Across all survey responses, 5051 participants (83%) reported they had not been tested, and only 753 participants (12%) noted receiving a test result; an additional 276 participants (5%) noted that they had taken a test but not yet received a test result (Table 2). For surveys completed on day 0 (the same day that a fever was first reported), 7% (92 participants) reported already having received test results; this proportion increased steadily over the course of illness to a peak of 20% (76 participants) on day 5 after onset (Table 2, Figure 1, P < .001).

Accounting for all survey responses submitted during the course of illness, we estimate that 20.5% (95% CI, 19.1%-22.0%) of patients received a coronavirus test result within 7 days of febrile illness onset (Figure 1). Substantial changes were apparent over the course of the pandemic (Figure 2, P < .001 for time trend); coronavirus test results at 7 days after febrile illness increased from 9.8% (95% CI, 7.5%-12.0%) at the beginning of April to 24.1% (95% CI, 21.5%-26.7%) by the end of July. Progress slowed at that point (P = .004 for nonlinearity); by late October, coronavirus testing within 7 days had increased only slightly more, to 25.9% (95% CI, 21.6%-30.3%) (Figure 2).

Black participants reported receiving a test result only about half as often as other participants (7% of responses in Black participants [7/103] vs 12% of responses in Hispanic participants [53/461] vs 13% of responses in participants who were not Black and not Hispanic [693/5516]; P = .03) (Table 2). This association was also apparent in statistical models but was not statistically significant in adjusted models (Table 3).

In a sensitivity analysis, we assumed that a test result was received 1 day after a participant reported that they were awaiting a test result (unless we know otherwise from a subsequent survey response), and found a slightly higher proportion receiving timely test results (26.8%; 95% CI, 22.4%-31.1%). In another, we assumed nonrespondents actually received a coronavirus test on day 3 of illness (or 1 day after their last completed response). Under these extreme assumptions, timely testing rates were higher (43.9%; 95% CI, 39.3%-48.5%) but remained substantially below 50%.
With assumptions set at the other extreme (nonresponse means no test performed), timely testing rates were lower (22.4%; 95% CI, 18.6%-26.2%). We also analyzed results, with base case assumptions, in several subsets of febrile episodes: Timely testing rates were 30.0% (23.0%-35.6%) when limiting to first episodes per participant, 34.2% (95% CI, 24.7%-43.7%) in the subset where

Table 1. Characteristics of COVID-19 Citizen Science Participants Developing at Least One New Febrile Illness

| Baseline characteristics               | Hispanic, any race | Black, not Hispanic | Not Hispanic, not Black | P value* |
|----------------------------------------|-------------------|---------------------|-------------------------|---------|
| Participants, No.                      | 183               | 41                  | 2455                    | NA      |
| Episodes, No.                          | 300               | 71                  | 3494                    | NA      |
| Age, y                                 |                   |                     |                         |         |
| 18-29                                  | 30 (16)           | 7 (17)              | 208 (8)                 |         |
| 30-39                                  | 45 (25)           | 9 (22)              | 657 (27)                | .01     |
| 40-49                                  | 45 (24)           | 5 (12)              | 588 (24)                |         |
| 50-59                                  | 41 (22)           | 12 (29)             | 561 (23)                |         |
| ≥60                                    | 22 (12)           | 8 (20)              | 441 (18)                |         |
| Sex                                    |                   |                     |                         |         |
| Female                                 | 135 (74)          | 31 (76)             | 1817 (74)               | .33     |
| Male                                   | 48 (26)           | 9 (22)              | 630 (26)                |         |
| Prefer not to disclose                 | 0                 | 1 (2)               | 8 (0.3)                 |         |
| Self-reported race                     |                   |                     |                         |         |
| American Indian or Alaskan Native      | 4 (2)             | 2 (5)               | 25 (1)                  | .03     |
| Asian                                  | 8 (4)             | 2 (5)               | 131 (5)                 | .93     |
| Black                                  | 7 (4)             | 41 (100)            | 0                       | <.001   |
| Native Hawaiian or Pacific Islander    | 3 (2)             | 0                   | 6 (0.2)                 | .04     |
| White                                  | 143 (78)          | 11 (27)             | 2339 (95)               | <.001   |
| Don’t know                             | 2 (1)             | 0                   | 5 (0.2)                 | .11     |
| Subjective socioeconomic statusb       |                   |                     |                         |         |
| Mean (SD)                              | 6.1 (1.8)         | 5.9 (1.8)           | 6.6 (1.7)               | <.001   |
| <6                                     | 68 (37)           | 12 (29)             | 600 (24)                | .001    |
| 6-8                                    | 101 (55)          | 29 (71)             | 1601 (65)               |         |
| 9-10                                   | 14 (8)            | 0                   | 254 (10)                |         |
| Education                              |                   |                     |                         |         |
| High school degree or less             | 6 (3)             | 3 (7)               | 92 (4)                  |         |
| Some college                           | 64 (35)           | 9 (22)              | 452 (18)                |         |
| College graduate                       | 55 (30)           | 13 (32)             | 841 (34)                | <.001   |
| Post-graduate                          | 57 (31)           | 15 (37)             | 1036 (42)               |         |
| Other or missing                       | 1 (0.6)           | 1 (2)               | 34 (1)                  |         |
| Current cigarette usec                 | 13 (7)            | 4 (10)              | 147 (6)                 | .40     |
| Current e-cigarette usec               | 7 (4)             | 0                   | 90 (4)                  | .61     |
| Current alcohol usec                   | 79 (63)           | 17 (63)             | 1303 (67)               | .52     |
| High blood pressure or hypertensiond   | 46 (25)           | 14 (34)             | 596 (24)                | .34     |
| Diabetesc                              | 15 (8)            | 0                   | 161 (7)                 | .14     |
| Heart diseasec                         | 20 (11)           | 10 (24)             | 165 (7)                 | <.001   |
| Strokec                                | 3 (2)             | 3 (7)               | 54 (2)                  | .10     |
| COPDc                                  | 11 (6)            | 4 (10)              | 69 (3)                  | .004    |
| Cancer undergoing active treatmentc    | 8 (4)             | 3 (7)               | 104 (4)                 | .49     |
| Immunodeficiencyc                      | 9 (5)             | 5 (14)              | 99 (4)                  | .03     |
| Pregnanc                              | 3 (2)             | 0                   | 13 (0.5)                | .15     |
| Total No. of febrile episodes during follow-up | | | | |
| Median (IQR)                           | 1 (1-2)           | 1 (1-2)             | 1 (1-1)                 | .001    |
| Mean (SD)                              | 1.6 (1.2)         | 1.7 (1.0)           | 1.4 (1.0)               | .005    |

Abbreviations: COPD, chronic obstructive pulmonary disease; IQR, interquartile range; NA, not applicable.

* P values calculated using a χ² test, Fisher exact test, one-way analysis of variance or Kruskal-Wallis tests (see Methods section). For education, we used a χ² test excluding the other/missing category.

† Subjective social status was self-reported using the MacArthur 10-point scale, with 10 being the highest.

‡ Some participants were measuring missingness, refused to answer, or answered “don’t know” for cigarette use (n = 26), e-cigarette use (n = 20), alcohol (n = 588), high blood pressure (n = 13), diabetes (n = 12), heart disease (n = 5), stroke (n = 22), COPD (n = 24), cancer (n = 10), immunodeficiency (n = 61), pregnant (n = 18).
fever was reported also on the second day of illness, and 34.7% (95% CI, 22.5%-47.0%) in the subset where a high temperature greater than 100.4 °F or 38.0 °C was reported.

**Discussion**

In this analysis of the COVID-19 Citizen Science Study, we found low rates of coronavirus testing after new onset of a febrile illness. We estimate that in late October 2020, when this analysis was

**Table 2. Response to Weekly Survey Questions About Testing up to 14 Days After a Febrile Illness**

| Characteristic                   | Episodes, No. | Weekly surveys delivered in first 2 weeks after new onset of febrile illness reported | Survey response, No. (% of responses) | Tested | Received a test result (positive or negative) |
|---------------------------------|---------------|---------------------------------------------------------------------------------------|----------------------------------------|--------|---------------------------------------------|
|                                 |               |Responded, No. (% of delivered)                                                        | Not tested                             |        |                                             |
|                                 |               |                                                                                       |                                        |        |                                             |
|                                 |               |Delivered, No.                                                                          |                                        |        |                                             |
| Total                           | 3865          | 8006                                                                                   | 6080 (76)                              | 83     | 5                                           |
|                                 |               |                                                                                        |                                        |        |                                             |
| Race/ethnicity                  |               |                                                                                        |                                        |        |                                             |
| Hispanic, any race              | 300           | 644                                                                                   | 461 (72)                               | 82     | 7                                           |
| Black, not Hispanic             | 71            | 149                                                                                   | 103 (69)                               | 90     | 3                                           |
| Not Hispanic, not Black         | 3494          | 7213                                                                                   | 5516 (76)                              | 83     | 4                                           |
| P value                         | NA            | NA                                                                                     | .003<sup>b</sup>                       | NA     | NA                                          |
| Subjective social status        |               |                                                                                        |                                        |        |                                             |
| <6                              | 1107          | 2325                                                                                   | 1696 (73)                              | 84     | 5                                           |
| 6-8                             | 2417          | 4979                                                                                   | 3837 (77)                              | 83     | 5                                           |
| 9-10                            | 341           | 702                                                                                   | 547 (78)                               | 82     | 4                                           |
| P value                         | NA            | NA                                                                                     | <.001<sup>b</sup>                      | NA     | NA                                          |
| Days after illness onset        |               |                                                                                        |                                        |        |                                             |
| 0                               | NA            | 1371                                                                                   | 1257 (92)                              | 85     | 7                                           |
| 1                               | NA            | 378                                                                                   | 348 (92)                               | 81     | 9                                           |
| 2                               | NA            | 460                                                                                   | 357 (78)                               | 77     | 7                                           |
| 3                               | NA            | 478                                                                                   | 363 (76)                               | 78     | 6                                           |
| 4                               | NA            | 473                                                                                   | 369 (78)                               | 79     | 6                                           |
| 5                               | NA            | 518                                                                                   | 382 (74)                               | 78     | 2                                           |
| 6                               | NA            | 483                                                                                   | 361 (75)                               | 81     | 4                                           |
| 7                               | NA            | 671                                                                                   | 519 (77)                               | 79     | 2                                           |
| 8                               | NA            | 559                                                                                   | 311 (56)                               | 79     | 2                                           |
| 9                               | NA            | 408                                                                                   | 283 (69)                               | 83     | 4                                           |
| 10                              | NA            | 398                                                                                   | 270 (68)                               | 86     | 3                                           |
| 11                              | NA            | 416                                                                                   | 294 (71)                               | 86     | 2                                           |
| 12                              | NA            | 409                                                                                   | 281 (69)                               | 92     | 1                                           |
| 13                              | NA            | 401                                                                                   | 275 (69)                               | 92     | 2                                           |
| 14                              | NA            | 583                                                                                   | 410 (70)                               | 89     | 3                                           |
| P value                         | NA            | NA                                                                                     | <.001<sup>b</sup>                      | NA     | NA                                          |
| Month                           |               |                                                                                        |                                        |        |                                             |
| April                           | 588           | 1278                                                                                   | 978 (77)                               | 91     | 3                                           |
| May                             | 592           | 1279                                                                                   | 949 (74)                               | 87     | 4                                           |
| June                            | 448           | 948                                                                                   | 675 (71)                               | 81     | 5                                           |
| July                            | 494           | 1043                                                                                   | 771 (74)                               | 78     | 7                                           |
| August                          | 519           | 1098                                                                                   | 840 (77)                               | 82     | 4                                           |
| September                       | 694           | 1467                                                                                   | 1160 (79)                              | 82     | 4                                           |
| October                         | 530           | 893                                                                                   | 707 (79)                               | 77     | 6                                           |
| P value                         | NA            | NA                                                                                     | <.001<sup>b</sup>                      | NA     | NA                                          |

Abbreviation: NA, not applicable.

<sup>a</sup> Includes 7 inconclusive test results.

<sup>b</sup> P values are from a χ² test comparing response (responded or not) across categories.

<sup>c</sup> P values are from a χ² test comparing the 3-level survey response variable across categories, among respondents.
completed, only 25.9% of persons with new febrile illness were receiving a test result within 7 days. We found that Black participants were about half as likely to report receiving test results than other participants; but with only limited numbers of such participants in our study, we could not make conclusions about this with statistical certainty. Improvements in testing rates after onset of febrile illness were apparent early in the pandemic, but very little improvement occurred after testing ramped up in Summer 2020.

Figure 1. Self-reported Coronavirus Test Result Status as Reported by Participants With New Febrile Illness by Days Since Onset

Figure 2. Proportion With a Coronavirus Test Result at 7 Days After Febrile Illness Onset, Over Calendar Time, by Race/Ethnicity

Table 3. Relative Likelihood of Receiving a Coronavirus Test Result

| Race/ethnicity | Receipt of coronavirus test results in the US, hazard ratio (95% CI) |
|----------------|---------------------------------------------------------------|
|                | Unadjusted | Adjusted for age, sex, medical conditions, cigarette/e-cigarette and alcohol use | Additionally adjusted for subjective social status and education |
| Hispanic, any race | 1.01 (0.73-1.40) | 0.99 (0.73-1.37) | 1.02 (0.74-1.40) |
| Black, not Hispanic | 0.55 (0.24-1.23) | 0.60 (0.27-1.34) | 0.59 (0.26-1.34) |
| Not Hispanic, not Black | 1 [Reference] | 1 [Reference] | 1 [Reference] |

* All results include calendar time, modeled as a cubic spline.

\( P \) value in the table is 0.34, 0.46, and 0.45 for Hispanic, any race; Black, not Hispanic; and Not Hispanic, not Black, respectively.

**P** value represents a test of the 3-category race/ethnicity variable, main effect only.
Testing capacity in the US is known to have been limited early in the pandemic. Our models indicate that only 9.8% of persons with new onset of febrile illness at the beginning of April 2020 received a test result within a week. With the Food and Drug Administration’s issuance of Emergency Use Authorizations for medical devices related to coronavirus testing, the National Institute of Health’s Rapid Acceleration of Diagnostics (RADx) Program and other federal efforts to support expansion of testing capacity, testing volume rapidly expanded through the end of July to nearly 1 million tests per day. This increase is mirrored in our data, which show testing by 7 days after febrile illness onset to have increased from 9.8% to about 24.1% in late July. National data from August through October show continuing (although slower) increases in testing volume in the US to approximately 1.2 million tests per day in late October. Despite this increase in testing volume, we saw very little continued increase in the likelihood of getting tested after a febrile illness, which we estimate at 25.9% at the time of our analysis in late October, such that nearly three-fourths of persons with febrile illness remain untested for coronavirus a week after onset of their illness. We are not aware of other data available for estimating testing rates in symptomatic persons or others for whom testing might be particularly important for disease control.

We sought to determine whether coronavirus testing disparities might be contributing to disparities in coronavirus outcomes, which are well documented. We found lower rates of testing in Black participants, but these differences were not statistically significant due to the small numbers of Black participants in our sample. Prior evidence on this point is mixed. Analyses have demonstrated lower testing rates in New York City neighborhoods with a lower proportion of White residents, and fewer testing sites and longer travel times to testing sites in areas with higher proportions of minority residents. Analyses of individual patients using medical records have demonstrated lower testing rates in non-English speakers in Washington state, but higher testing rates in Black patients than in either Hispanic or non-Hispanic White patients among patients receiving care at the US Department of Veterans Affairs and among active patients in 53 health systems across 21 states analyzed by the Kaiser Family Foundation. Unlike total testing volume and positivity rates, the race and ethnicity of patients tested for coronavirus are not widely available so population-level testing rates by race and ethnicity cannot be calculated using publicly reported data.

Limitations
Our sample and analysis are subject to a number of limitations. Because of the small number of Black and Hispanic participants in our sample, we were underpowered to detect disparities in timely coronavirus testing after onset of febrile illness, so our lack of statistically significant differences by race and ethnicity should not be interpreted as absence of a disparity in testing in the population. Our sample also skews toward higher education and social status than the general population, as is typical for internet-based volunteer samples. However, this stratum of the US population generally has better access to health care and resources than others, so if testing rates are low in our participants, they are likely even lower in more vulnerable subsets of the population. Participants in our study are prompted to report symptoms on a daily basis, but they do not necessarily submit a response every day; we are likely to miss some febrile illnesses completely, and to catch some illnesses 1 or more days after onset. Evidence of this phenomenon can be seen in Table 2, which shows that substantially more survey responses are received on day 0 of febrile illness than would be expected, possibly due to the SMS (text) message participants receive with the weekly survey. The result of reporting a fever late (days after it truly started) would be to artificially inflate the proportion receiving a test result by 7 days after onset, so actual testing rates at 7 days are likely to be even lower than estimates from our analysis. We are missing some responses in our weekly testing surveys; but even extreme sensitivity analyses imputing test results when survey responses are missing yield estimates of testing at 7 days after onset of febrile illness that remain quite low compared with what might be optimal or expected. Finally, we are unable to determine why patients did not receive a coronavirus test.
Conclusions

This cohort study’s results suggest systematic underuse of coronavirus testing in patients with febrile illness. Whether this is because of lack of testing availability, knowledge about how to get a test, understanding about the importance of testing, or active avoidance (e.g., to avoid economic hardships associated with isolation and quarantine of contacts if one tests positive) is unclear. We cannot know for certain what the impact of more effective targeting of coronavirus testing would be on disease transmission in the US, how it might have blunted the 3rd wave that recently swept through the US, or how it might be used to reduce transmission of new coronavirus variants. However, it is clear that countries such as China and South Korea have a much more aggressive targeted approach to testing and appear to have substantially lower community transmission rates. Clear guidelines with well-resourced public health service announcements targeted to both clinicians and the public, ensuring adequate test capacity and convenience, and provision of resources to mitigate the hardships of isolation and quarantine that come with a positive test are all likely to reduce barriers to coronavirus testing and increase the likelihood of identifying new infections in the community and reducing transmission in the US.

ARTICLE INFORMATION

Accepted for Publication: March 11, 2021.
Published: May 3, 2021. doi:10.1001/jamanetworkopen.2021.8500
Open Access: This is an open access article distributed under the terms of the CC-BY License. © 2021 Pletcher MJ et al. JAMA Network Open.

Corresponding Author: Mark J. Pletcher, MD, MPH, Department of Epidemiology and Biostatistics, University of California, San Francisco, 550 16th St, Mission Hall, 2nd Fl, San Francisco, CA 94143-0560 (mark.letcher@ucsf.edu).

Author Affiliations: Department of Epidemiology and Biostatistics, University of California, San Francisco, San Francisco (Pletcher, Modrow, Lin, Martin, Beatty, Vittinghoff); Division of General Internal Medicine, Department of Medicine, University of California, San Francisco, San Francisco (Pletcher); Division of Cardiology, Department of Medicine, University of California, San Francisco, San Francisco (Olgin, Peyser, Beatty, Marcus); Louisiana Public Health Institute, New Orleans (Carton).

Author Contributions: Dr Pletcher had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Concept and design: Pletcher, Olgin, Peyser, Martin, Carton, Marcus.

Acquisition, analysis, or interpretation of data: Pletcher, Olgin, Peyser, Modrow, Lin, Beatty, Vittinghoff, Marcus.

Drafting of the manuscript: Pletcher.

Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Pletcher, Lin, Vittinghoff.

Obtained funding: Pletcher, Olgin, Modrow, Martin, Carton, Marcus.

Administrative, technical, or material support: Olgin, Peyser, Modrow, Martin, Carton, Marcus.

Supervision: Olgin.

Conflict of Interest Disclosures: Dr Beatty reported Apple Inc stock ownership and employment from 2018 to 2019 outside the submitted work. No other disclosures were reported.

Funding/Support: This study has received support from the Patient-Centered Outcomes Research Institute (PCORI, contract COVID-2020C2-10761), the Bill and Melinda Gates Foundation (INV-017206), and the National Institutes of Health (3U2CEB021881-05S1).

Role of the Funder/Sponsor: The funders had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Additional Contributions: The authors would like to thank the Citizen Scientists participating in the COVID-19 Citizen Science Study. They were not compensated.
REFERENCES
1. Johns Hopkins University & Medicine. Coronavirus resources center. Accessed November 2, 2020. https://coronavirus.jhu.edu/
2. Boburg S, O’Harrow RJ, Satija N, Goldstein A. Inside the coronavirus testing failure: alarm and dismay among the scientists who sought to help. Washington Post. Published April 3, 2020. Accessed October 30, 2020. https://www.washingtonpost.com/investigations/2020/04/03/coronavirus-cdc-test-kits-public-health-labs/?arc404=true
3. The New York Times. Track coronavirus cases in places important to you. Accessed March 9, 2021. https://www.nytimes.com/interactive/2020/us/covid-cases-deaths-tracker.html
4. Wiersinga WJ, Rhodes A, Cheng AC, Peacock SJ, Prescott HC. Pathophysiology, transmission, diagnosis, and treatment of coronavirus disease 2019 (COVID-19): a review. JAMA. 2020;324(8):782-793. doi:10.1001/jama.2020.12839
5. Larsen JR, Martin MR, Martin JD, Kuhn P, Hicks JB. Modeling the onset of symptoms of COVID-19. Front Public Health. 2020;8:473. doi:10.3389/fpubh.2020.00473
6. Gold JAW, Rossen LM, Ahmad FB, et al. Race, ethnicity, and age trends in persons who died from COVID-19 in United States, May-August 2020. MMWR Morb Mortal Wkly Rep. 2020;69(42):1517-1521. doi:10.15585/mmwr.mm6942e1
7. Kullar R, Marcellin JR, Swartz TH, et al. Racial disparity of coronavirus disease 2019 in African American communities. J Infect Dis. 2020;222(6):890-893. doi:10.1093/infdis/jiaa372
8. University of California San Francisco. COVID-19 Citizen Science. Accessed May 4, 2020. https://covid19.eurekaplatform.org
9. The John D. and Katherine T. MacArthur Foundation. The MacArthur Scale of Subjective Social Status. Accessed November 13, 2020. https://www.macses.ucsf.edu/research/psychosocial/subjective.php#measurement
10. American Society of Microbiology. ASM expresses concern about coronavirus test reagent shortages. Published March 10, 2020. Accessed March 23, 2021. https://asm.org/Articles/Policy/2020/March/ASM-Expresses-Concern-about-Test-Reagent-Shortages
11. FEMA. Federal support to expand national testing capabilities. Published May 5, 2020. Accessed Oct 30, 2020. https://www.fema.gov/fact-sheet/federal-support-expand-national-testing-capabilities
12. Owen WF Jr, Carmona R, Pomeroy C. Failing another national stress test on health disparities. JAMA. 2020;323(19):1905-1906. doi:10.1001/jama.2020.6547
13. Bibbins-Domingo K. This time must be different: disparities during the COVID-19 pandemic. Ann Intern Med. 2020;173(3):233-234. doi:10.7326/M20-2247
14. Lieberman-Cribbin W, Tuminello S, Flores RM, Taïoli E. Disparities in COVID-19 testing and positivity in New York City. Am J Prev Med. 2020;59(3):326-332. doi:10.1016/j.amepre.2020.06.005
15. Kim HN, Lan KF, Nyekyery E, et al. Assessment of disparities in COVID-19 testing and infection across language groups in Seattle, Washington. JAMA Netw Open. 2020;3(9):e2021213. doi:10.1001/jamanetworkopen.2020.21213
16. McNinn S, Carl森 A, Jaspers B, Talbot R, Adeline S. In large Texas cities, access to coronavirus testing may depend on where you live. NPR. May 27, 2020. Accessed March 23, 2021. https://www.npr.org/sections/health-shots/2020/05/27/862215848/across-texas-black-and-hispanic-neighborhoods-have-fewer-coronavirus-testing-sites
17. Kim HN, Lan KF, Nyekyery E, et al. Assessment of disparities in COVID-19 testing and infection across language groups in Seattle, Washington. JAMA Netw Open. 2020;3(9):e2021213. doi:10.1001/jamanetworkopen.2020.21213
18. McNinn S, Carl森 A, Jaspers B, Talbot R, Adeline S. In large Texas cities, access to coronavirus testing may depend on where you live. NPR. May 27, 2020. Accessed March 23, 2021. https://www.npr.org/sections/health-shots/2020/05/27/862215848/across-texas-black-and-hispanic-neighborhoods-have-fewer-coronavirus-testing-sites
19. Rentsch CT, Kidwai-Khan F, Tate JP, et al. Patterns of COVID-19 testing and mortality by race and ethnicity among United States veterans: a nationwide cohort study. PLoS Med. 2020;17(9):e1003379. doi:10.1371/journal.pmed.1003379
22. Kaiser Family Foundation. COVID-19 racial disparities in testing, infection, hospitalization, and death: analysis of Epic patient data. Published September 16, 2020. Accessed October 30, 2020. https://www.kff.org/report-section/covid-19-racial-disparities-in-testing-infection-hospitalization-and-death-analysis-of-epic-patient-data-methods/

23. Servick K. ‘Huge hole’ in testing data blurs racial, ethnic disparities. Science. 2020;369(6501):237-238. doi: 10.1126/science.369.6501.237

24. Guo X, Vittinghoff E, Olgin JE, Marcus GM, Pletcher MJ. Volunteer participation in the Health eHeart Study: a comparison with the US Population. Sci Rep. 2017;7(1):1956. doi: 10.1038/s41598-017-02232-y

25. Wilson C. The third wave of COVID-19 in the U.S. is officially worse than the first two. Time. Published October 25, 2020. Accessed March 25, 2021. https://time.com/5903673/record-daily-coronavirus-cases/

26. Galloway SE, Paul P, MacCannell DR, et al. Emergence of SARS-CoV-2 B.1.1.7 Lineage - United States, December 29, 2020-January 12, 2021. MMWR Morb Mortal Wkly Rep. 2021;70(3):95-99. doi: 10.15585/mmwr.mm7003e2

27. Gan N. China is testing millions of people in Xinjiang for Covid-19 after one asymptomatic case found. CNN. Published October 26, 2020. Accessed March 25, 2021. https://www.cnn.com/2020/10/26/asia/xinjiang-kashgar-coronavirus-intl-hnk/index.html

28. Lee D, Lee J. Testing on the move: South Korea’s rapid response to the COVID-19 pandemic. Transp Res Interdiscip Perspect. 2020;5:100111. doi: 10.1016/j.trip.2020.100111

29. Kim SR, Kung T, Abdelmalek M. Trust, testing and tracing: How South Korea succeeded where the US stumbled in coronavirus response. ABC News. May 1, 2020. Accessed March 25, 2021. https://abcnews.go.com/Health/trust-testing-tracing-south-korea-succeeded-us-stumbled/story?id=70433504