Original article

Predictors of COVID-19 perceived susceptibility: insights from population-based self-reported survey during lockdown in the United States

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ABSTRACT

Background: The COVID-19 pandemic during lockdown has highlighted the importance of identifying individuals most at risk of infection with SARS-CoV-2, underscoring the need to assess factors contributing to susceptibility to disease. With the rapidly evolving nature of the pandemic and its new variants, there is an inadequate understanding on whether there are certain factors such as a specific symptom or collection of symptoms that combined with life-style behaviors may be useful to predict susceptibility. The study aims to explore such factors from pre-vaccination data to guide public health response to potential new waves.
Methods: An anonymous electronic survey was distributed through social media during the lockdown period in the United States from April to June 2020. Respondents were questioned regarding COVID testing, presenting symptoms, demographic information, comorbidities, and confirmation of COVID-19 test results. Stepwise logistic regression was used to identify predictors for COVID-19 perceived susceptibility. Selected classifiers were assessed for prediction performance using area under receiver operating characteristic (AUROC) curve analysis.
Results: A total of 130 participants deemed as susceptible because they self-reported their perception of having COVID-19 (but without the evidence of positive test) were compared with 130 individuals with documented negative test results. Participants had a mean age of 45 years, and 165 (63%) were female. Final multivariable model showed significant associations with perceived susceptibility for the following variables: fever (OR:33.5; 95%CI: 3.9,85.9), body ache (OR:3.0; 95%CI:1.1,6.4), contact history (OR:2.7; 95%CI:1.1,6.4), age > 50 (OR:2.7; 95%CI:1.1, 6.6) and smoking (OR:3.3; 95%CI: 1.2,9.1) after adjusting for other symptoms and presence of comorbid conditions. The AUROC ranged from poor to fair (0.65–0.76) for cluster of symptoms but improved to a good model (AUROC = 0.803) after inclusion of sociodemographic and lifestyle behaviors e.g., age and smoking tobacco.
Conclusions: Fever and body aches suggest association with perceived COVID-19 susceptibility in the presence of demographic and lifestyle behaviors. Using other constitutional and respiratory symptoms with fever and body aches, the parsimonious classifier correctly predicts 80.3% of COVID-19 perceived susceptibility. A larger cohort of respondents will be needed to study and refine classifier performance in future lockdowns and with expected surge of new variants of COVID-19 pandemic.

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Introduction

Coronavirus 2019 (COVID-19) is a disease involving several body systems e.g., respiratory, neurological, gastrointestinal, cardiovascular and immune systems [1]. Ever since 41 cases were initially reported by the World Health Organization (WHO) in January 2020, COVID-19 has spread on an unprecedented scale. To date, it has

infected over 170 million people worldwide, and resulted in more than 3 million deaths [2]. Wide variations in mortality rates are reported worldwide that ranges from as low as 0.04 to as high as 300 per 100,000 population [3]. Several leading causes of death such respiratory and cardiac failure along with multiorgan failure, and septicemia are exacerbated by existing comorbid conditions [4–8]. The ongoing waves of the COVID-19 pandemic has amplified the importance of identifying individuals who are most at risk of infection; hence, the need for further investigation to assess patterns of susceptibility.

Known symptoms of COVID-19 include fever or chills, cough, shortness of breath, body aches, headache, loss of taste or smell, sore throat, runny nose, nausea or vomiting, and diarrhea and these may appear 2–14 days after initial exposure [8]. Persistence or severity of these symptoms have also been observed with the fast-growing infection rate during new waves [9]. Rapid and accurate testing for COVID-19 is therefore critical for tracing, tracking and decelerating the spread of the virus to prevent future outbreaks. In order for public to remain open, individuals need to get tested and follow mask wearing and social distancing [8, 10, 11]. Hence this way public can know the status of their being positive and isolate themselves when there is an upsurge, especially when there are issues of vaccine hesitancy. Testing for COVID-19 can have an effect on percent positivity which has been used to understand dynamics of communal transmission [12] and also to inform the public regarding their susceptibility to COVID-19.

The initial phases of the pandemic brought unprecedented challenges to clinical laboratories worldwide [13,14]. In the U.S., these labs struggled to provide good quality and accurate test results. The uncertainty and lack of supplies were a significant hurdle thereby limiting everyday laboratory operations and hence the inability to increase and expand testing capacity [15]. The limited availability and capacity for testing resulted in the establishment of stringent testing criteria requiring individuals to have known contact with someone infected with COVID-19, a recent travel history, or be exhibiting symptoms [16,17]. The result was that many individuals undoubtedly remained susceptible because they were unable to get tested. Also, during the early phases of pandemic, there was an indication of inequitable access to COVID-19 testing that appeared as an area of high concern for health authorities [15]. Considering this scenario, studies were conducted to understand perceived ability to access COVID-19 testing and socio-economic indicators [15], as well as perceived immunity to COVID-19 and adherence to protective measures [18]. Perceived susceptibility or believing that one has COVID-19 in the presence of testing and diagnostic obstacles during earlier lockdown thus remains an important area to be visited, especially for insights on clinical and lifestyle behavioral attributes.

In the U.S., incidence, and mortality rates as well as hospitalization due to COVID-19 continue to remain high in underserved communities and high-risk populations [19,20]. Convenient accessibility to good quality and fast testing is important to make certain that new cases are duly identified and tracked, as well as treated in a timely manner [13]. Accessibility to testing is also critical in communities where vaccine hesitancy is an issue [21,22]. If these gaps in test accessibility and uptake continue, there will be likely an exacerbation to the spread of the virus. This will indeed make the outcomes worse and continue with existing disparities, with the situation becoming further complicated from the evolution of the virus in the form of variants [23–25]. Hence, some assessment to predict COVID-19 susceptibility is paramount to controlling the spread and may help to provide insights regarding infection in underserved communities and other resource limited settings.

One of the more puzzling aspects of the causative agent of COVID-19 i.e., SARS-CoV-2, is that susceptibility to infection appears to vary widely. Few studies that have presented prediction models

for COVID-19 positivity appear to have mainly focused on prognostic factors for survival [26]. Some of these prediction models for diagnosis have also been reported using chest computed tomography and other laboratory diagnosis as predictors [27]. One COVID-19 diagnostic model evaluated smell and taste change with other respiratory symptoms [16]. Other studies have hypothesized that differences in COVID-19 susceptibility may be related to age [28], genetics [29], and sex-dependent immune responses [30]. If such hypotheses are confirmed, it would suggest important differences in immune response to the virus among some population subgroups relative to others. One opportunity to dynamically monitor continually evolving pandemic is through self-reported data from cross-sectional surveys that also allow for real-time estimation of individual risk of COVID-19 [26,31]. Moreover, these kinds of surveys also allow for data collection on information about known exposures as well as offer insights that COVID-19 epidemiological studies might not have accounted for in association-analyses [32]. Given the above, the current population-based study sought to present a risk model to predict perceived susceptibility to COVID-19. Identifying a parsimonious set of predictors of perceived susceptibility can provide context to help improve decision making on COVID-19 test resource allocation in regions where testing still may be a challenge.

Methods

Data source and participants

A baseline survey during mandatory lock-down was carried out across different states and municipalities in US from April 13 to June 8, 2020. The study analysis is part of an ongoing longitudinal study of psychological, social and health behavior impacts of COVID-19 [33–35]. With the objective of obtaining a large number of responses in a short period of time during lock-down period, the survey was publicized through several social media outlets targeting participant-volunteers who were ≥ 18 years of age, residing in US, and fluent in English or Spanish. To ensure a more representative sample of participants in terms of gender and ethnic composition, targeted online advertising via Facebook sponsored posts and an online crowdsourcing platform Soapbox sample (https://www.soapbox-sample.com/) was pursued in 50 US states. The survey was available online in both languages on the Qualtrics survey platform (Provo, UT) [36].

Measurement of variables

Outcome measures

The development of the survey questions in multiple domains is described in our published protocol along with an in-depth assessment on self-reported adherence to stay-at-home orders, social distancing, and personal protective behaviors [33]. Since the diagnosis of COVID-19 requires laboratory confirmation of SARS-CoV-2 infection and widespread antigen testing was not available at the time of data collection, we relied on self-reported responses to infection with COVID-19. Confirmed susceptibility to COVID-19 was captured by two main binary questions (Yes/No): (1) "Have you ever been tested for COVID-19?", (2) "Did you test positive for COVID-19?" and additionally we also asked a third question if the participants required hospitalization. However, to measure *'perceived'* susceptibility to COVID-19, we asked the participants if they thought they had COVID-19 but did not get tested for any reason. Response options were "Yes" and "No" that we analyzed as outcome variable; and if former response, then participants were also additionally asked to elaborate reasons on believing that they have the disease e.g., having flu-like symptoms, contact with someone with flu-like symptoms or contact with known cases, travel from part of the world where initial surge of pandemic was reported such as China,

Italy, and Korea. These text responses were cross-checked with the dichotomous responses on symptoms in the section on clinical factors (see individual level factors next).

Individual level factors

Sociodemographic

We asked individuals about their age, gender, race/ethnicity, marital status, education level, household income, and their zip code and cross-street addresses. We also asked the participants to elaborate if their work status changed as a result of pandemic and also probed into their current living situation if they lived in the area that is stay-, safer- at home, or under shelter-at-home order.

Contact-exposure history and life-style factors

Participants were asked if in the last three weeks, they had direct contact with a (1) person with flu-like symptoms; (2) person with confirmed-diagnosis of COVID-19; or (3) no contact. Regarding alcohol use, individuals were first asked if they drink alcohol (yes/no), and if so, whether their alcohol consumption had "increased", "decreased", or "stayed the same" since the pandemic. For tobacco smoking, items were taken from the Global Adult Tobacco Survey [35,37]. Individuals were first asked if they currently smoke tobacco "on a daily basis", "less than daily", or "not at all".

Clinical factors

The survey asked participants if they experienced any symptoms such as fever, cough, headache, body aches, fatigue/tiredness, shortness of breath, runny nose, sore throat, loss of smell or taste. These symptoms were divided into 'constitutional' and 'respiratory symptoms' for analysis and coded as yes/no. For comorbid conditions, we asked, "Do you currently have a chronic/serious health condition (yes/no)?" If individuals responded affirmatively, we also asked them to specify the condition. Comorbidity such as cancer, heart disease, chronic lung disease, diabetes, any autoimmune disease, and intestinal diseases were captured as single binary question (yes/no).

Statistical analysis

Statistical analysis was performed using Statistical Package for the Social Sciences version 27 (SPSS; IBM Corp., Armonk, NY). The outcome variable was COVID-19 perceived susceptibility. Self-reported demographic, lifestyle information and symptoms were reported using descriptive statistics. Univariate analysis was used to evaluate the association of variables with perceived susceptibility, including demographics (age, gender, education, race/ethnicity, and income) and lifestyle (smoking and alcohol drinking), contact history as well as comorbid conditions (cancer, heart disease, chronic lung disease, diabetes, autoimmune disease, and intestinal disorders). Presence of constitutional and respiratory cluster of symptoms (constitutional: fever, headache, body aches; and respiratory: cough, shortness of breath, rhinorrhea, sore throat, and loss of smell/taste) were assessed as well.

To determine the best predictors of COVID-19 perceived susceptibility a stepwise, forward selection, logistic regression was performed with perceived susceptibility as the dependent variable and presence of each of the independent variables within symptoms, demographics, and lifestyle behaviors. Correlations between independent variables were also assessed before making decision on the selection of the most parsimonious model. In the multivariable model, both the outcome and predictor variables were dichotomized into 'Yes' or 'No' responses, along with age that was categorized as ≤ 50 or > 50. The stepwise regression analysis incorporated thresholds of p = 0.05 for entry and 0.10 for removal with maximum iterations that were set at 20 and included classifier cutoff at 0.5

[16]. To assess for potential effects of all symptoms and confounders, all variables were also entered in a full logistic regression model.

After selecting relevant symptom classifiers based on the stepwise regression model, receiver operating characteristic (ROC) curves were generated to appraise predictor performance. Area under the ROC curve (AUROC) analysis was carried out to assess the ability of symptom classifiers to discriminate COVID-19–perceived susceptible subjects from those who believed that they did not have the disease. AUROC between 0.7 and 0.8 was considered as fair model i.e., 70–80% chance that model will be able to distinguish susceptible cases perceived as positives and negatives. AUROC of more than 0.8 was considered as a good model with more than 80% discrimination capacity between perceived- susceptible and negative groups.

Results

A total of 2435 individuals consented to participate in an online survey anonymously with overall survey completion rate of 91%. A total of 371 participants responded to a question of whether they had been tested for COVID-19. About 54% of these participants reported that they believed that they had COVID-19 but were not tested during the lock-down period, and 170 participants self-reported as negative for the disease (46%). The number of participants who could confirm their COVID-19 positivity through the available laboratory testing at the time was only 30. Finally, 130 participants who self-reported their belief of being positive were analyzed as 'perceived COVID-19 susceptible' with one-to-one ratio of 130 participants who replied in the negative after removing individuals of both groups with missing data. Table 1a, b shows distribution of demographic information, contact history and lifestyle factors along with clinical and comorbid conditions in the two groups. Overall a higher proportion of females are observed in COVID-negative group (76.9%) and included higher proportion of Caucasians in both groups. Most of the participants were college educated in both groups (62.3% in perceived susceptible group versus 70.8% in negative group). Table 1a also summarizes univariate analysis with unadjusted odds ratios of potential associations. Those that were positively associated with COVID-19 perceived susceptibility were males, African Americans and Hispanics, with a contact history and were smokers. Also, fever and being diabetic were associated with perceived susceptibility (Table 1b).

Stepwise, forward selection, logistic regression analysis was performed to determine the predictor variables associated with COVID-19 perceived susceptibility. We first analyzed the symptom clusters only (Figs. 1a and b) and then additionally analyzed them in the multivariable models with demographic and lifestyle behavior (Table 2).

The predictive value of the combination of symptoms was fair (Fig. 1a and b) for constitutional (AUROC: 0.756 for fever, headache, body aches, fatigue, and cough) and respiratory symptoms (AUROC: 0.702 for fever, loss of smell/taste, shortness of breath, sore throat, and rhinorrhea). However, when using discrimination ability of symptom classifiers with contact history, age, and smoking history, a particularly good classifier performance of more than 0.800 was obtained (Table 2). This is demonstrated in the final most parsimonious Model III, the proportion that were correctly classified as COVID-perceived as susceptible was 80.3% (AUROC = 0.803).

Multivariable analysis in Table 2 with Model III shows that contact history with someone with flu-like symptoms and/or with someone with confirmed diagnosis (odds ratio [OR], 2.7; 95% confidence interval [CI], 1.1, 6.4) and smokers (OR, 3.3; 95%CI, 1.2, 9.1) were more likely to be perceived as susceptible to COVID-19. Also, the odds of having fever among the perceived-susceptible group is 33.5 times the odds among individuals who were not perceived-

Table 1a
Univariate analysis of demographics, contact history and lifestyle factors[a].

	COVID-19 Negative (n = 130)	COVID-19 Perceived as Susceptible (n = 130)	OR (95% CI)[b]
	n (%)	n (%)	
DEMOGRAPHICS			
Age	22 (16.9)	26 (20.0)	Ref
18–30	54 (41.5)	64 (49.2)	1.0 (0.5, 2.0)
31–50	49 (37.7)	29 (22.3)	0.5 (0.2, 1.0)
51–70	5 (3.8)	11 (8.5)	1.9 (0.6, 6.2)
>70			
Gender	100 (76.9)	65 (50.4)	Ref
Female	28 (21.5)	61 (47.3)	3.4 (1.9, 5.8)
Male			
Education level	92 (70.8)	81 (62.3)	Ref
College educated	38 (29.2)	49 (37.7)	1.5 (0.9, 2.5)
Not college educated			
Race/ethnicity	98 (79.0)	64 (50.0)	Ref
Caucasian	4 (3.2)	29 (22.7)	11.1 (3.7, 33.1)
African American	8 (6.5)	21 (16.4)	4.0 (1.7, 9.6)
Hispanics	14 (11.3)	14 (10.9)	1.5 (0.7, 3.4)
Others			
Annual Income		18 (14.3)	Ref
> 150,000	27 (22.1)	27 (21.4)	2.7 (1.1, 6.4)
100,000–149,999		22 (17.5)	2.1 (0.9, 5.0)
75,000–99,999	15 (12.3)	40 (31.7)	1.4 (0.7, 2.9)
25,000–74,999		19 (15.1)	1.4 (0.6, 3.2)
< 25,000	16 (13.1)		
	43 (35.2)		
	21.(17.2)		
CONTACT HISTORY & LIFESTYLE FACTORS			
Contact History	112 (86.8)	91 (70.5)	Ref
No contact history	10 (7.8)	27 (20.9)	3.3 (1.5, 7.2)
With person showing flu like symptoms	7 (5.4)	11 (8.5)	1.9 (0.7, 5.2)
With person of confirmed diagnosis			
Alcohol drinking	48 (52.7)	54 (49.1)	Ref
No	43 (47.3)	56 (50.9)	1.3 (0.7, 2.3)
Yes			
Tobacco smoking	72 (79.1)	64 (58.2)	Ref
Not at all	14 (15.4)	32 (29.1)	2.6 (1.3, 5.2)
Daily	5 (5.5)	14 (12.7)	3.2 (1.1, 9.2)
Less than daily			

[a] Column percentages are from total of yes and no answers.
[b] CI:Confidence Interval.

susceptible. Body aches was also associated with COVID-19 perceived susceptibility (OR, 3.0; 95%CI, 1.1, 8.0).

Discussion

The growing intensity of COVID-19 and its more fatal variants [38] has highlighted the importance of identifying individuals who are or can be susceptible to infection. The results of this study underscore the need to assess susceptibility in extreme situations such as lockdowns. After adjusting for several common symptoms and presence of comorbidity, the final logistic regression model shows that fever, body aches, contact history, age ≥ 50, and smoking is associated with increased risk of SARS-CoV-2 infection among those who believed that they had COVID-19 disease. We also found that while AUROC for COVID-19 perceived susceptibility for combination of constitutional and respiratory symptoms ranged from poor to fair (Fig. 1a and b), but when the models included history of contact, age, smoking, and presence of comorbidity, the AUROC ranged from fair to good (Table 2).

In this study even though, those who believed themselves to be susceptible reported less frequency of some of the symptoms; fever and body aches, however, were significantly associated with the COVID-19 perceived susceptibility albeit wide confidence intervals. The fewer number of people with symptoms in perceived susceptible group also indicate the asymptomatic nature of this infection and can be considered as perceived-susceptible-at risk. The lack of testing for this group may also imply the preference of testing

Table 1b
Univariate analysis of clinical symptoms and comorbid conditions[a].

	COVID-19 Negative (n = 130)	COVID-19 Perceived as Susceptible (n = 130)	OR (95% CI)[b]
	n (%)	n (%)	
Constitutional symptoms			
Fever	4 (16.1)	21(28.0)	23.7 (3.1, 82.3)
Headache	16 (25.8)	21 (28.0)	1.1 (0.5, 2.4)
Body aches	21 (33.9)	16 (21.3)	0.5 (0.2, 1.1)
Fatigue/tiredness	8 (12.9)	5 (6.7)	0.5 (1.5, 1.6)
Respiratory symptoms			
Cough	18 (29.0)	54 (72.0)	1.9 (0.9, 3.9)
Shortness of breath	24 (38.7)	33 (44.0)	0.9 (0.5, 1.9)
Runny nose	14 (22.6)	28 (37.3)	1.4 (0.7, 3.1)
Sore throat	19 (30.6)	19 (25.3)	0.8 (0.4, 1.6)
Loss of smell or taste	15 (24.2)	14 (18.7)	0.7 (0.3, 1.6)
Comorbidity			
Cancer	18 (13.8)	25 (19.2)	1.5 (0.8, 2.9)
Heart disease	3 (2.8)	6 (5.6)	2.1 (0.5, 8. 5)
Chronic lung disease	15 (13.4)	16 (14.7)	1.1 (0.5, 2.4)
Diabetes	4 (13.7)	19 (16.8)	5.3 (1.7, 16.0)
Autoimmune diseases	11 (9.9)	13 (11.7)	1.2 (0.5, 2.8)
Intestinal diseases	6 (5.5)	12 911.1)	2.2 (0.8, 6.0)

[a] Column percentages are from total of yes and no answers
[b] CI:Confidence Interval.

a.   Fever + Headache   (0.658)
        Fever + Headache + Body aches   (0.722)
        Fever + Headache + Body aches + Fatigue   (0.750)
        Fever + Headache + Body aches + Fatigue + cough   (0.756)
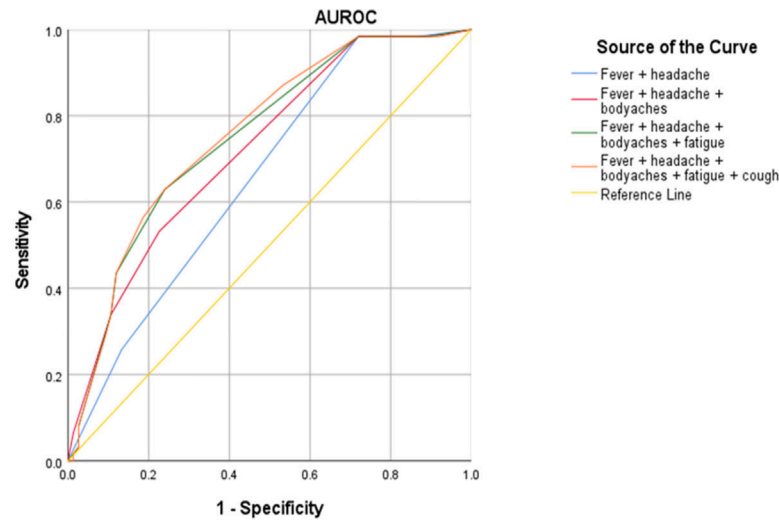
b.   Fever + loss of taste/smell   (0.672)
        Fever + Loss of taste/smell +shortness of breath (so**b**)   (0.692)
        Fever + Loss of taste/smell +shortness of breath (so**b**) + sore thro**at** (0.700)
        Fever + Loss of taste/smell +shortness of breath (so**b**) + sore thro**at** + rhinorrhea (0.702)
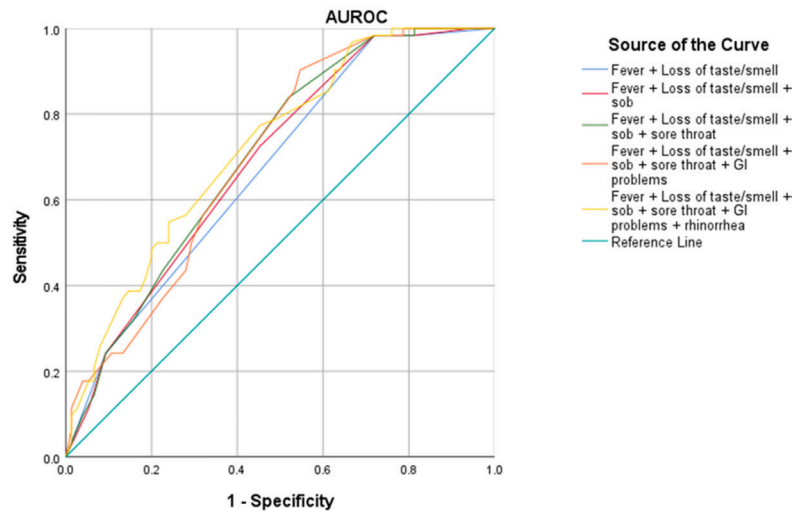
Fig. 1. (a and b) AUROC for COVID-19 Perceived Susceptibility using combination of different (a) constitutional symptoms and (b) respiratory symptoms. AUROC values are presented in parenthesis.

individuals who show flu-like symptoms more than asymptomatic individuals, even though absence of symptoms did not mean absence of SARS-CoV-2 infection at the time. This observation is consistent with longitudinal study on COVID-19 that built predictive models of COVID-19 test results on symptoms and has shown that users of tests who experienced fever, cough, or loss of taste/smell among other symptoms had higher odds of being tested compared to users who did not report symptoms [39]. The results from our study also give credence to the observation that those who might have received testing could have been those who reported more symptoms which could have been used as screening criteria for determining who receives a test. This could have potentially missed

large number of individuals who were asymptomatic even though when they were in touch with positive contact, had comorbidity, and were of older age with risky life-style behavior.

In other studies, regarding symptoms such as loss of smell/taste and fever along with other symptoms, strong associations have been shown with positive COVID-19 test with a fair AUROC of 0.700 [40]. Most studies carried out on test positive COVID patients indicate an important association of both olfactory and gustatory dysfunctions, but with slightly different results for cough, sore throat, and gastrointestinal symptoms in these patients [16, 41, 42]. In our study, loss of sense/taste, rhinorrhea, headache, cough and sore throat did not show an association with susceptibility which suggests that

Table 2

Predictive models for COVID-19 Perceived susceptibility adjusted for symptoms, demographics, and lifestyle behavior.

	Model I		Model II		Model III	
	OR (95%CI)	p	OR (95%CI)	p	OR (95%CI)	p
Fever	32.7 (4.1, 89.2)	0.001	34.8 (4.1, 85.1)	0.001	33.5 (3.9, 85.9)	0.001
Body aches	3.1 (1.2, 7.6)	0.016	2.9 (1.1, 7.6)	0.019	3.0 (1.1, 8.0)	0.026
Contact history	2.6 (1.1, 5.7)	0.016	2.7 (1.2, 6.5)	0.019	2.7 (1.1, 6.4)	0.027
Age > 50 years			3.0 (1.1,8.6)	0.037	2.5 (0.9, 6.8)	0.072
Smokers					3.3 (1.2, 9.1)	0.022
AUROC		0.752		0.788		0.803

Models adjusted for other symptoms: headache, cough shortness of breath, rhinorrhea, and sore throat and comorbid conditions.

commonly used symptoms may not be sufficient criteria for evaluating perceived susceptibility in the same way as for COVID-19 positive individuals. It has also been previously reported that many people infected with SARS-CoV-2 are asymptomatic, mildly symptomatic or in pre-symptomatic phase of their presentation, and therefore unaware that they are infected [39,43].

In an exceptionally short period of time, the literature on COVID-19 has reported several clinical and genetic risk factors that may contribute to susceptibility [39]. While genetics is also considered an important predictor of susceptibility in some studies, this cannot be assessed through our self-reported survey. However, our study did indeed allow for near approximation to real-time assessment of individual-level COVID-19 perceived susceptibility risk with some demographic, lifestyle behaviors, comorbid conditions, and clinical symptoms. The results point out that differences in known exposures can explain for some of the associations for a perceived susceptible outcome. And our analysis also yielded evidence that some of the clinical features, contact history, age ≥ 50, smoking is associated with perceived susceptibility. Studies have suggested that COVID-19 susceptibility differences are mostly related to age whereas age, smoking and additionally underlying chronic health conditions are related to COVID-19 severity [44–46]. While we did not assess severity, our study showed that age ≥ 50 and smoking after adjustment for symptoms and presence of comorbid condition were independently associated with susceptibility as well. While there has been some debate whether smoking increases the infectivity or that it may lead to more severity of disease, a cell culture study reported that exposure to smoking in human airway cells from previously healthy patients who were not chronic smokers can lead to increased level of infection with SARS-CoV-2 [47].

We did not tailor our analyses to advance any hypothesis(s), to substantiate that prior viral infections by SARS-CoV-2 or different strains of coronaviruses or even exposure to other respiratory viruses may predispose to more severe forms of COVID 19. This hypothesis will be interesting to explore further with robust invivo studies as suggested in an Italian report [48]. Furthermore, our study may suffer from misclassification bias since the results are based on self-reported survey data, especially those who self-reported on smoking and drinking behavior. Moreover, during lockdown, a relatively small percentage of US population was prioritized for PCR testing, so the analysis of test results that came out to be positive was small and could not give any meaningful interpretation of the data. In order to understand the reasons on why and where the COVID-19 continues to spread even with restrictive mitigation strategies, there was a need for individual level data on symptoms, behavior, and demographics among those who remain susceptible. The understanding from this study could allow medical professionals and public health practitioners to shed more light on the clinical features of the infection that can help tailor intervention measures among those who apparently show no symptoms. This can help address efficient allocation of test resources and even address disparities in test accessibility in different regions and communities.

Ethics approval and consent to participate

The study was approved by the Institutional Review Board of Baylor College of Medicine; H-47505. (BCM Protocol H-47505 – 'The COVID-19 Pandemic: Psychosocial and Health Behavior Impacts'). Online bilingual advertisements consisted of a short description of the survey with a hyperlink directing participants to the survey information. The information described the purpose of the research, eligibility, and risks/benefits. In the end, individuals were allowed to voluntarily check a box to consent.

Competing interests

None declared.

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