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Imperfect messengers? An analysis of vaccine confidence among primary care physicians

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ABSTRACT

Background: Growing narratives emphasize using primary care physicians as leaders in efforts to promote COVID-19 vaccination among the vaccine hesitant. Critically however, little is known about vaccine confidence among primary care physicians themselves. The objective of this study was to assess both physician confidence that in general, vaccines are safe, effective, and important, as well as physician confidence in each COVID-19 vaccine in the United States.

Methods: We rely on data from a national survey of primary care physicians conducted from May 14-May 25, 2021. We assess the influence of demographic, social, and political factors on physician beliefs that in general, vaccines are safe, effective, and important, as well as physician confidence in the safety of the Moderna, Pfizer, and Johnson & Johnson COVID-19 vaccines.

Results: 10.1% of primary care physicians do not agree that, in general, vaccines are safe, 9.3% do not agree they are effective, and 8.3% do not agree they are important. While 68.7% of physicians were 'very confident' in the safety of the Moderna vaccine and 72.7% were 'very confident' in the safety of the Pfizer vaccine, only 32.1% of physicians were 'very confident' in the safety of the Johnson & Johnson COVID-19 vaccine.

Conclusion: A troubling proportion of primary care physicians lack high levels of vaccine confidence. These physicians may not be well positioned to actively promote COVID-19 vaccination even as political and media narratives push physicians to lead this effort. Interventions aimed at improving vaccine confidence among some physicians may be needed so that all physicians can fulfill needed roles as trusted vaccine communicators.

1. Introduction

The COVID-19 pandemic has had a profound impact on lives around the globe, affecting health care systems, the global economy, and health outcomes [1–3]. The development of multiple effective vaccines against the SARS-CoV-2 virus initially provided hope that the spread of the virus could swiftly be curbed, and widespread vaccination was quickly regarded as the best path forward for ending the pandemic [4]. Unfortunately, however, in the United States, a significant portion of the American public has thus far elected to forego vaccination. As of March 1st, 2022, only 76.4% of Americans had received at least one dose of the COVID-19 vaccine and only 64.9% of Americans were fully vaccinated [5]. More problematically, in 20 states, fewer than 70% of state residents had received at least one dose of the COVID-19 vaccine [5]. These low rates of vaccine uptake place a substantial share of the American public at elevated risk of COVID-19 infection, hospitalization, and death [6].

Considerable research has been conducted to understand the reasons for COVID-19 vaccine hesitancy in the American public [7,8]. Vaccine hesitancy refers to delay in acceptance or refusal to vaccinate despite the availability of vaccination services [9,10]. Past work points to disparities in COVID-19 vaccine uptake based on race, gender, socioeconomic status, religiosity, trust in medical and scientific experts, and general dispositions towards vaccines

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[8,11]. Scholars have additionally pointed to public concern about the speed of vaccine development, vaccine safety, the efforts of anti-vaccine advocacy groups, the spread of conspiracy theories, the politicization of COVID-19, and rare adverse side effects in affecting COVID-19 vaccine hesitancy [8,12–14].

Given high levels of COVID-19 vaccine hesitancy across the country, public health officials, scholars, and the media have devoted significant attention to identifying and promoting strategies that could improve vaccine confidence, thereby reducing vaccine hesitancy and increasing COVID-19 vaccination uptake [15]. While scholarly and media accounts have suggested that efforts to reduce the presence and endorsement of conspiracy theories on social media, public health promotion campaigns, and depoliticizing COVID-19 vaccination could be effective in increasing COVID-19 vaccine confidence, perhaps the most prominent strategy in public discourse focuses on encouraging pro-vaccination messages from 'trusted' messengers [11,7,16]. These messengers – which include community leaders, religious leaders, and critically for our purposes, primary care physicians – can build upon the trust that they have established with individuals in their communities to encourage vaccination in a manner more likely to be heard, respected, and adopted.

Prior work provides considerable reason to believe that physician recommendations to vaccinate are amongst the most effective strategies for increasing vaccine uptake [11,17,18]. Notably, studies exploring the effect of physician recommendations on HPV vaccination suggest that these recommendations are particularly important for increasing uptake of new vaccines [19,20]. Furthermore, research suggests that the vast majority of primary care physicians and pediatricians have been highly supportive of recommending that patients vaccinate against HPV and other infectious diseases, with some differences based on vaccine type, patient characteristics, and whether the physician is an alternative or integrative medicine physician [21–25].

Although prior research suggests that physician recommendations could prove critical to reducing hesitancy, additional evidence problematically suggests that to this point, COVID-19 vaccine confidence among some health care workers is low [25,26]. Vaccine confidence as defined by the CDC reflects the trust that individuals (or providers) have in recommended vaccines and the belief that the processes and policies that lead to new vaccines will create vaccines that are safe and effective [27]. Even though they were prioritized for early vaccination, only 52% of frontline health care workers had received at least one COVID-19 vaccine dose by March 2021 [28]. By the end of May 2021, roughly a quarter of hospital workers with direct patient contact had yet to vaccinate, resulting in conflict within some health systems between health care administrators requiring vaccination as a condition for employment, and vaccine hesitant health care workers pushing back with protests and lawsuits [29].

This lack of vaccine confidence among some health care workers could portend a troubling question for strategic efforts to emphasize the use of trusted messengers like physicians to encourage vaccine uptake. Can we trust physicians to serve as vaccine champions given the low COVID-19 vaccine confidence that exists among some health care workers? While narratives to this point have focused on health care workers in general, how much confidence physicians in particular have in vaccines remains an open question. This study is designed to begin to answer that important question by relying on an original survey of U.S. primary care physicians to investigate primary care physician vaccine confidence.

2. Methods

To understand vaccine confidence among primary care physicians, we developed and administered an original national survey to 737 physicians in the United States. The web-based survey was fielded from May 14 to May 25, 2021, using the survey research firm Dynata – a widely respected survey research firm regularly used in social science research [30–33]. Dynata invited primary care physicians (identified via responses to an initial inventory survey) to participate in our survey from their large, online, opt-in sampling frame of potential survey participants. Of the 737 respondents identified as PCPs by Dynata who began the survey, 625 of also satisfied additional screeners that we imposed as a precondition for qualification in our study; i.e., by self-identifying as a PCP working in family medicine, internal medicine, or general practice. These 625 physicians serve as the sample for our analysis.

We provide a comparison of our sample with primary care physician population benchmarks in the appendix which demonstrates that our sample closely approximates the demographic characteristics of primary care physicians nationwide. Primary care physician population benchmarks from the Association of American Medical Colleges and Medscape suggest that our sample closely resembles the proportion of primary care physicians who are Hispanic or Asian and produces similar salary estimates. Small deviations are seen between our sample and population benchmarks for gender and race, with our sample slightly underrepresenting women and Black physicians. Critically however, these differences are small in magnitude. Limitations aside, our study provides the only national sample to date capable of analyzing primary care physician vaccine confidence.

2.1. Outcome measures

In our study, we measured vaccine confidence in three different ways. First, we captured physician vaccine confidence through the proportion of primary care physicians who have been vaccinated against COVID-19. This measure was developed from a survey question asking whether physicians had been fully vaccinated, partially vaccinated, or not been vaccinated against COVID-19. Next, we offer a second operationalization of physician vaccine confidence via a series of measures that have been validated and used previously in the existing literature designed to reveal general dispositions towards vaccination [34,35]. These measures come from survey questions that offer 5-point Likert scales (ranging from strongly agree to strongly disagree) asking whether physicians believe that in general, vaccines are safe, effective, and important. Finally, our analysis measured physician vaccine confidence in the safety of COVID-19 vaccines by asking respondents to report their confidence that the Moderna, Pfizer, and Johnson & Johnson vaccines are safe on four-point scales (ranging from very confident to not at all confident).

Our analysis begins by presenting a descriptive look at physician vaccine confidence, exploring the proportion of physicians unvaccinated at the time of our survey, the proportion of physicians who do and do not agree that vaccines are safe, effective, and important, and the proportion of physicians who do and do not have confidence in the safety of the COVID-19 vaccines available in the United States. Notably, we contextualize general physician dispositions towards vaccines (our second set of dependent variable questions) by comparing PCP responses to each question vs. responses to an identical set of questions asked in a nationally representative sample of US adults, drawn from the Wellcome Global Monitor (in partnership with Gallup) [36]. Wellcome data for the American public was taken from a probability sample of mobile and landline phones from July 12 - August 23, 2018. All quantities for the American public from the Wellcome data were weighted to account for any potential deviations between the general public sample and the US adult population.

2.2. Explanatory measures

In addition to offering a descriptive look at physician vaccine confidence, we also assess several potential correlates (in multivariate regression models) of general physician vaccine confidence and physician confidence in each COVID-19 vaccine. Based on previous research tying vaccine attitudes and behaviors to political ideology, we included a standard measure from political science to control for physician political ideology; a 7-point measure ranging from extremely liberal to extremely conservative [11,37,38] We also included a dichotomous measure for whether each physician had contracted COVID-19 to account for the possibility that previously infected physicians might view the virus as more serious (making them eager to protect themselves and others through vaccination), or alternatively view vaccination as less important (because they believe they have obtained some degree of immunity without vaccinating). While one might suspect personal experiences with contracting COVID to influence COVID-19 vaccination attitudes more strongly than general vaccine dispositions, we include it in general confidence models as well to account for the possibility that contracting COVID-19 could lead physicians to see greater (or less) value in vaccinating in general based on their own experiences with the virus.

Our models also include standard demographic characteristics that have been found to influence vaccine hesitancy in the general public in the existing literature [8,14]. These include measures to account for physician gender – a dichotomous measure with female coded as 1, age (continuous), indicators for Asian, Black, and Hispanic racial/ethnic status, income (based on a 10-point scale), and religiosity based on a 5-point scale from very inactive to very active involvement in religion. We also considered measures accounting for physician work environment (hospital, large group practice, small practice), patient panel size, patient pool demographic characteristics, region, and state Trump 2020 vote share. Measures for work environment, panel size, region, and Trump vote share are excluded due to their lack of statistical significance. Models including patient demographics are available in Appendix A. Furthermore, Appendix A includes models replicating Tables 2 and 4 using both Holm-Bonferroni corrected and Bonferroni corrected p-values. Survey question wordings are available in Appendix B. All analyses were performed using Stata version 15 (StataCorp, College Station, TX).

Table 1
Comparison of Vaccination Attitudes between Primary Care Physicians and the General Public.

	Physician Survey N = 625	US Adult Population N = 983
Vaccines are Safe		
Strongly Agree	67.4% [63.7, 71.1]	47.7% [43.7, 51.6]
Somewhat Agree	21.4% [18.2, 24.7]	24.4% [21.0, 27.9]
Neither Agree nor Disagree	3.4% [1.9, 4.8]	15.7% [12.6, 19.0]
Somewhat Disagree	1.9% [0.8, 3.0]	6.2% [4.2, 8.2]
Strongly Disagree	4.8% [3.1, 6.5]	4.9% [3.2, 6.7]
Don't Know/Refused	1.1% [0.3, 2.0]	1.1% [0.0, 1.8]
Vaccines are Effective		
Strongly Agree	75.5% [72.1, 78.9]	60.0% [55.7, 63.7]
Somewhat Agree	14.4% [11.6, 17.2]	24.4% [20.9, 27.8]
Neither Agree nor Disagree	2.1% [1.0, 3.2]	8.9% [6.5, 11.3]
Somewhat Disagree	0.5% [0.0, 1.0]	3.7% [2.1, 5.3]
Strongly Disagree	6.7% [4.8, 8.7]	2.1% [0.8, 3.3]
Don't Know/Refused	0.8% [0.1, 1.5]	1.2% [0.0, 2.2]
Vaccines are Important		
Strongly Agree	76.3% [73.0, 79.7]	73.9% [70.2, 77.6]
Somewhat Agree	13.4% [10.8, 16.1]	13.0% [10.0, 15.9]
Neither Agree nor Disagree	2.1% [1.0, 3.2]	7.5% [4.4, 8.7]
Somewhat Disagree	0.5% [0.0, 1.0]	3.8% [2.1, 5.6]
Strongly Disagree	5.8% [3.9, 7.6]	2.3% [1.0, 2.36]
Don't Know/Refused	1.9% [0.8, 3.0]	0.5% [0.0, 1.2]

Notes: Comparison estimates for the US adult population were drawn from the Wellcome Global Monitor; national sample data were drawn from individuals recruited to participate via a probability sample of mobile and landline phones from July 12 – August 23, 2018. The Wellcome results are nationally representative of the US adult population. Quantities in brackets indicate 95% confidence intervals.

3. Results

We began our analysis by investigating the proportion of primary care physicians that have been vaccinated against COVID-19. Our analysis finds that only 5.2% (95% CI: 3.4, 6.9) of our sample of primary care physicians was unvaccinated as of May 2021, far lower than vaccine refusal rates for other types of health care workers, and the American public more generally [31]. Widespread vaccination among physicians provides initial support for the idea that most primary care physicians have at least some level of confidence in the COVID-19 vaccines and can serve as credible COVID-19 vaccine promoters.

Of course, it is critical to recognize that the decision by physicians to vaccinate themselves may be impacted by factors beyond vaccine confidence including their high-risk work environments or the expectations of employers. For that reason, it is also important to analyze general physician confidence in vaccination and confidence in the safety of each COVID-19 vaccine as well. We begin to present that analysis in Table 1, where we assessed physician beliefs that, in general, vaccines are safe, effective, and important and compare those results to a US adult population sample from the Wellcome Global Monitor that asked identical questions.

Two noteworthy patterns emerge from Table 1. First, as expected, primary care physicians are significantly more likely to agree that vaccines are safe and effective than the general public (significance denoted by the non-overlapping confidence intervals presented in the table, which indicate statistically significant differences between groups at the $p < 0.05$ level, two-tailed). Second and more importantly, however, there is heterogeneity in physician attitudes towards vaccination that the existing literature and physician-driven vaccination promotion narratives do not account for. 10.1% of physicians do not agree (strongly or somewhat) that vaccines are safe, 9.3% do not agree that they are effective, and 8.3% do not agree that they are important. In addition, to the extent that we might expect more vaccine advocacy amongst physicians who strongly agree that vaccines are safe, effective, and important, it is also valuable to explore the proportion of physicians most likely to believe in vaccines. Our results show that only 67.4% of primary care physicians strongly agree that vaccines are safe, and roughly 75% strongly agree that they are effective (75.5%) and important (76.3%).

While it is helpful, albeit troubling, to realize that a non-trivial proportion of primary care physicians lack confidence in vaccines like the general public, investigating what factors predict beliefs in vaccine safety, effectiveness, and importance can help us better understand why many physicians lack vaccine confidence. We explored that question in Table 2, relying on a series of ordered logistic regression models given the ordinal nature of our dependent variables [39,40].

In Model 1, which focuses on confidence in safety, we find that elevated levels of political conservatism are negatively and significantly associated with agreeing that vaccines are safe. We also find that these effects are substantively large. Holding all other covariates in Model 1 at their sample means, we find that while the predicted probability that extreme liberals strongly agree that vaccines are safe is 78%, the likelihood that extreme conservative PCPs feel the same way is just 59% - a 19% difference across the full range of the ideological spectrum.

Furthermore, we find that wealthier PCPs are significantly more likely to believe that vaccines are safe while PCPs who had COVID-19 were significantly less likely to believe that vaccines were safe. Specifically, holding all other covariates at their sample means, we find that while the predicted probability of strongly agreeing that vaccines are safe is 70% among PCPs who had not had COVID-19, it was only 54% among those who had.

A similar pattern holds in Model 2, exploring physician beliefs that vaccines are effective. There, we found that holding all other variables at their means, extreme liberals were predicted to be 18% more likely than extreme conservatives to strongly agree that vaccines are effective. In addition, while the predicted probability that PCPs who had not had COVID-19 would strongly agree that vaccines are effective was 77%, it was only 64% for those who had.

Model 3, focuses on the perceived importance of vaccines. Again, we find that PCPs who contracted COVID-19 are significantly less likely to believe in vaccine importance, but the measure for political ideology is no longer significant.

Next, we assessed physicians' confidence in the safety of each of the COVID-19 vaccines approved for use in the U.S. We explore that question in Table 3, which descriptively presents the levels of confidence primary care physicians hold in the safety of each COVID-19 vaccine. Our analysis in Table 3 revealed that primary care physicians were significantly more confident in the safety of the mRNA vaccines of Moderna and Pfizer than in the Johnson & Johnson COVID-19 vaccine. Specifically, we found that while 68.7% and 72.7% of primary care physicians were very confident in the safety of the Moderna and Pfizer vaccines respectively, only 32.1% of physicians were very confident in the safety of the Johnson & Johnson vaccine as of May 2021. When we include those who were in the 'confident' category as well, we found that over 90% of physicians were either 'very confident' or 'confident' in the mRNA vaccines but only 68.0% of physicians fell into those two categories for the Johnson & Johnson vaccine.

We sought to better understand what factors were associated with physicians' comparatively higher confidence in the mRNA vaccines over the Johnson & Johnson vaccine, developing outcome measures equal to one if a physician was more confident in an mRNA vaccine than the Johnson & Johnson vaccine, and zero in all other cases. Relying on logistic regression due the dichotomous nature of our dependent variables, Model 4 in Table 4 presents evidence which suggests that physicians who believe that vaccines are effective are significantly more likely to prefer the Moderna vaccine over the Johnson and Johnson vaccine [39,40]. Substantively, we find that the predicted probability that PCPs prefer the Moderna to the J&J vaccine is 55% for those who strongly agree that vaccines are safe (in general). In contrast, that same quantity for those who strongly disagree that vaccines are effective feel the same way is just 26%. We caveat, however, the p-value for the parameter estimate used to calculate these predictions is p = 0.051, just below the threshold for statistical significance. Finally, in Model 5, which compares preferences for the Pfizer vaccine as compared to the J&J vaccine, we find that physicians who had COVID-19 were significantly less likely to prefer the Pfizer vaccine over the J&J vaccine.

Table 2
Predictors of Primary Care Physician Beliefs that Vaccines in General are Safe, Effective, and Important.

VARIABLES	(Model 1) Vaccines are Safe	(Model 2) Vaccines are Effective	(Model 3) Vaccines are Important
Female	0.92	0.82	0.84
	(0.62, 1.36)	(0.54, 1.26)	(0.54, 1.30)
Age	1.01	1.00	1.00
	(0.99; 1.03)	(0.98, 1.02)	(0.98, 1.03)
Conservative	0.86**	0.84**	0.90
	(0.76; 0.98)	(0.73, 0.97)	(0.78, 1.04)
Hispanic	0.65	0.67	0.65
	(0.36, 1.17)	(0.35, 1.29)	(0.33, 1.25)
Black	0.80	1.65	1.04
	(0.30, 2.09)	(0.46, 5.93)	(0.33, 3.27)
Asian	1.04	1.08	0.97
	(0.67, 1.62)	(0.66, 1.75)	(0.59, 1.60)
Religiosity	0.99	0.99	0.94
	(0.86, 1.13)	(0.85, 1.15)	(0.81, 1.10)
Income	1.14***	1.08	1.03
	(1.04, 1.25)	(0.98, 1.19)	(0.93, 1.14)
PCP Had COVID	0.48***	0.52**	0.45***
	(0.28, 0.80)	(0.30, 0.90)	(0.26, 0.79)
Observations	560	561	556
Pseudo R-Squared	0.03	0.02	0.02

95% Confidence Intervals in Parentheses.
*** p < 0.01, ** p < 0.05, * p < 0.10.
Notes: Results based on ordered logit models using odds ratios. Quantities in parentheses indicate 95% confidence intervals. Explanatory measures for Female, Hispanic, Black, Asian, and PCP Had COVID are dichotomous. Measures for Conservative, Religiosity, and Income are categorical. The measure for age is continuous.

4. Discussion

Most Americans place high levels of trust in their personal physicians [41]. Correspondingly, many media and scholarly

Table 3
Physician Confidence in Safety of Each COVID-19 Vaccine in the United States.

	Percentage of Physicians
Moderna (N = 620)	
Very Confident	68.7% [65.1, 72.4]
Confident	21.8% [18.5, 25.0]
Somewhat Confident	6.3% [4.4, 8.2]
Not at all Confident	3.2% [1.8, 4.6]
Pfizer (N = 616)	
Very Confident	72.7% [69.2, 76.3]
Confident	18.7% [15.6, 21.8]
Somewhat Confident	5.4% [3.6, 7.1]
Not at all Confident	3.3% [1.8, 4.6]
Johnson and Johnson (N = 616)	
Very Confident	32.1% [28.4, 35.8]
Confident	35.9% [32.1, 39.7]
Somewhat Confident	23.7% [20.3, 27.1]
Not at all Confident	8.3% [6.1, 10.5]

Notes: Quantities in brackets indicate 95% confidence intervals.

Table 4
Correlates of Primary Care Physicians Having More Confidence in mRNA-based COVID-19 Vaccines.

VARIABLES	(Model 4) Moderna over J&J	(Model 5) Pfizer over J&J
Female	1.06	1.07
	(0.73, 1.55)	(0.73, 1.56)
Age	0.98*	0.98*
	(0.97, 1.00)	(0.97, 1.00)
Conservative	1.02	1.02
	(0.90, 1.14)	(0.90, 1.14)
Hispanic	0.65	0.67
	(0.36, 1.18)	(0.37, 1.20)
Black	1.35	1.29
	(0.49, 3.72)	(0.47, 3.56)
Asian	1.04	1.15
	(0.69, 1.57)	(0.76, 1.75)
Religiosity	0.98	0.97
	(0.86, 1.11)	(0.86, 1.11)
Income	0.98	0.98
	(0.90, 1.07)	(0.90, 1.07)
PCP Had COVID	0.61*	0.54**
	(0.35, 1.07)	(0.30, 0.95)
Vaccines are Effective	1.38*	1.31*
	(1.00, 1.89)	(0.96, 1.79)
Vaccines are Safe	0.81	0.85
	(0.58, 1.12)	(0.61, 1.17)
Constant	1.89	1.98
	(0.37, 9.60)	(0.39, 10.09)
Observations	556	553
Pseudo R-Squared	0.02	0.02

95% Confidence Intervals in Parentheses.
*** p < 0.01, ** p < 0.05, * p < 0.10.
Notes: Results based on binary logit models using odds ratios. Quantities in parentheses indicate 95% confidence intervals. The 'vaccines are important' measure was excluded due to a high variance inflation factor indicating potential multicollinearity. An alternative to Table 4 including 'vaccines are important' is available in the appendix. Explanatory measures for Female, Hispanic, Black, Asian, and PCP Had COVID are dichotomous. Measures for Conservative, Religiosity, and Income are categorical. The measure for age is continuous.

narratives – as well as the Centers for Disease Control and Prevention – have suggested that primary care physicians should build on their trusted role in individuals' lives to serve as COVID-19 vaccine promotion advocates [42,43]. Our study reveals an under-studied complication with that approach. COVID-19 vaccination among primary care physicians is widespread, and much higher than both the general public and for other health care workers. Yet, beliefs that vaccines are safe, effective, and important are *lower* than we might have anticipated; with approximately 10% of physicians not agreeing with these three statements, and a larger proportion not strongly expressing vaccine confidence.

These findings suggest that it may not always be possible to rely on physicians to encourage vaccination for COVID-19, let alone other vaccine preventable diseases. In fact, our analyses demonstrate that some of the factors that influence vaccine confidence in the general public (e.g., ideological conservatism) similarly affect vaccine confidence among physicians. Conservatives (in the public) with vaccine hesitancy, served by physicians who share their political views, may therefore miss out on opportunities to be presented with information about the benefits of vaccination; especially in rural areas where both hesitancy and self-identification with right-leaning political views are particularly high.

In the context of COVID-19, our analysis further reveals that while the majority of primary care physicians are confident in mRNA vaccines, 9.5% and 8.6% of PCPs are only 'somewhat confident' or 'not at all confident' in the Moderna and Pfizer vaccines, respectively. To the extent that physicians are most likely to pursue promotion activities when they have complete confidence in the vaccines, our findings suggest that a troubling share of physicians may not want to engage in these efforts.

Our findings for the Johnson & Johnson adenovirus vaccine are also notable. Even as the Johnson & Johnson vaccine has clear benefits as a convenient single-dose vaccine easing efforts to vaccinate hard to reach and vulnerable populations, only 32.1% of primary care physicians were very confident in the vaccine and just 68.0% showed any degree of confidence. This lack of confidence suggests that physicians may be less likely to promote the Johnson & Johnson vaccine, which could help to explain its decline in use in the United States in recent months [44]. On one level, this lack of physician confidence makes sense. The Johnson & Johnson vaccine, after all, was subject to a short government-recommended administrative pause due to safety concerns and has seen more severe side effects than the mRNA vaccines [45]. Still, as we document in Table 4, primary care physicians' attitudes toward the J&J vaccine are influenced by experiential factors not related to the pause.

4.1. Policy implications

Combined, our results serve to complicate media narratives and governmental initiatives encouraging primary care physicians to serve as leading vaccine promotors. While a majority of doctors are well positioned to take on this role, a troubling proportion of physicians lack high levels of confidence both in vaccines in general and COVID-19 vaccines in particular. For example, if we take a conservative approach and remove those who 'somewhat agree' that vaccines are safe from the proportion of physicians that lack vaccine confidence and use the total number of PCPs from the AMA Masterfile as our baseline for PCPs nationwide, our findings still suggest that almost 25,000 primary care physicians nationwide could disagree with the basic belief that in general, vaccines are safe.

These findings suggest that we cannot take it for granted that all physicians are well positioned to serve as vaccine promotors and furthermore, that interventions may be needed to increase vaccine confidence among some physicians. This is particularly true because these physicians could have an outsized impact on public health, with a single physician lacking trust in vaccine safety capable of writing large numbers of medical exemptions from non-COVID-19 vaccination, reducing the effectiveness of vaccine mandates [46,47]. Identifying appropriate interventions is an important direction for future research and could include improving virology and vaccine biology education in medical school or echoing existing approaches for the general public by identifying trusted individuals in physicians lives to improve their confidence in vaccines. Furthermore, while it is intuitive to suspect that physicians with less confidence in vaccines will be less likely to recommend vaccinating, our results are unable to speak to that question directly. For that reason, future work should build on our findings to investigate the relationship between physician vaccine confidence and physician vaccine recommendations.

4.2. Limitations

While our findings provide important new insight into primary care physician vaccine confidence, there are several limitations of our research that are worth note. First, our analysis is based on a national non-probability sample of physicians. Even as our appendix demonstrates that our national sample charac-

teristics approximate population benchmarks, it remains possible that some findings could vary with a nationally representative sample of primary care physicians. Next, our study relies on physician self-reports of vaccination behaviors and attitudes. Thus, due to the possibility of social desirability concerns, reports of vaccine uptake could be higher than actual levels of uptake and actual beliefs in vaccine safety, effectiveness, and importance could vary as well. In addition, our analysis relies on data from a snapshot of a single moment in time. Physician confidence in both vaccines in general as well as the COVID-19 vaccines in particular, could continue to evolve over time, which our cross-sectional dataset cannot capture.

Fourth, while we include an explanatory measure of whether each physician had contracted COVID-19, our analysis is unable to assess whether this happened before or after the physician had been vaccinated. This represents a potential limitation, because physicians who got COVID-19 after getting vaccinated could potentially have less faith in the COVID-19 vaccines or vaccines in general. Next, it is important to acknowledge that our analysis was conducted before any vaccines had received full approval. It remains possible that COVID-19 vaccine confidence among some PCPs could have increased in the wake of the Pfizer and Moderna vaccines gaining full BLA FDA authorization. Lastly, while we feel it is important to use the best available nationally representative data on the American public's attitudes towards vaccine safety, effectiveness, and importance as a point of comparison, that data was collected before the COVID-19 pandemic in 2018. Wellcome's follow-up survey in 2020 did not include the same survey items so we could not use them as a comparison to our sample. Although recent research suggests that general attitudes toward vaccination have not changed since 2018, we are nevertheless open to the possibility that the ongoing pandemic may alter public vaccine confidence in the future [34].

Despite these limitations, our analysis still represents an important step forward in our understanding. Primary care physicians have vaccinated against COVID-19 at much higher rates than the general public, but a troubling proportion lack vaccine confidence.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Institutional Review Board: This research was approved by the institutional review board at Texas A&M University.

Appendix A. Additional Results

See Tables A1-A8.

Table A1
Comparison of Primary Care Physician Sample to National Benchmarks.

Variable	Physician Survey	National Benchmark	Benchmark Source
Female (N = 182)	30.33%	39.47%	AMA Physician Masterfile via AAMC 2018
Hispanic (N = 57)	9.48%	7.61%	AAMC 2018
Black (N = 17)	2.82%	7.31%	AAMC 2018
Asian (N = 135)	22.43%	21.14%	AAMC 2018
White (N = 408)	67.77%	61.39%	AAMC 2018
Mean Income	$200,000–249,999	$242,000	Medscape 2021
Median Age	53	N/A	N/A

Notes: This table compares demographic characteristics from our sample of primary care physicians with population benchmarks for primary care physicians. National benchmarks for gender and race were obtained from the Association of American Medical Colleges (AAMC) publicly available physician workforce data for 2018 [48,49]. AAMC notes that physician sex was obtained from the AMA Physician Masterfile and that data on race was obtained from a variety of sources. Data on physician income was obtained from the Medscape 2021 Physician Salary Report as detailed by Wilcox 2021 [50]. Our survey data includes physicians specializing in family medicine, internal medicine, and general practice; these categories were used for national benchmarks as well. We rely on mean income to maintain consistency with national benchmark data although the median income of our sample is also $200,000–249,999.

Table A2
Replication of Table 2 Including Patient Demographics.

VARIABLES	(Model 1) Vaccines are Safe	(Model 2) Vaccines are Effective	(Model 3) Vaccines are Important
Female	0.88	0.90	1.10
	(0.54, 1.42)	(0.52, 1.54)	(0.63, 1.91)
Age	1.01	1.01	1.01
	(0.99, 1.04)	(0.98, 1.03)	(0.98, 1.04)
Conservative	0.86**	0.79***	0.88
	(0.74, 0.99)	(0.67, 0.94)	(0.75, 1.05)
Hispanic	0.96	0.82	0.84
	(0.47, 1.95)	(0.38, 1.80)	(0.37, 1.87)
Black	0.69	1.88	1.01
	(0.23, 2.02)	(0.44, 8.04)	(0.28, 3.72)
Asian	1.12	1.23	1.08
	(0.67, 1.90)	(0.69, 2.20)	(0.60, 1.96)
Religiosity	0.99	0.99	0.90
	(0.84, 1.16)	(0.82, 1.18)	(0.75, 1.08)
Income	1.17***	1.13**	1.06
	(1.05, 1.30)	(1.00, 1.27)	(0.94, 1.19)
PCP Had COVID	0.48**	0.45**	0.44**
	(0.26, 0.92)	(0.23, 0.88)	(0.22, 0.88)
Prop. Patients Female	1.00	1.00	1.00
	(0.99, 1.02)	(0.98, 1.02)	(0.98, 1.02)
Prop. Patients Black	1.00	0.99	1.00
	(0.99, 1.01)	(0.98, 1.01)	(0.98, 1.01)
Prop. Patients Hispanic	0.99**	0.98***	0.98**
	(0.98, 0.99)	(0.97, 0.99)	(0.97, 0.99)
Prop. Patients on Medicaid	1.00	0.99	0.99
	(0.99, 1.01)	(0.98, 1.00)	(0.98, 1.01)
Prop. Patients on Medicare	1.00	1.00	1.00
	(0.99, 1.01)	(0.99, 1.02)	(0.98, 1.01)
Prop. Patients Uninsured	1.00	1.01	1.01
	(0.98, 1.01)	(0.99, 1.03)	(0.99, 1.03)
Observations	415	416	412
Pseudo R-Squared	0.04	0.06	0.04

95% Confidence Intervals in Parentheses.
*** p < 0.01, ** p < 0.05, * p < 0.10.
Notes: Results based on ordered logit models using odds ratios. Quantities in parentheses indicate 95% confidence intervals. Patient Demographic variables based on questions that asked physicians what proportion of their patients fell into each demographic group on 0–100 scales.

Table A3
Replication of Table 4 Including Vaccines are Important.

VARIABLES	(Model 4) Moderna over J&J	(Model 5) Pfizer over J&J
Female	1.06	1.06
	(0.73, 1.55)	(0.73, 1.55)
Age	0.98*	0.98*
	(0.96, 1.00)	(0.96, 1.00)
Conservative	1.01	1.01
	(0.90, 1.13)	(0.90, 1.14)
Hispanic	0.62	0.64
	(0.34, 1.14)	(0.35, 1.16)
Black	1.36	1.30
	(0.49, 3.76)	(0.47, 3.59)
Asian	1.01	1.12
	(0.66, 1.54)	(0.73, 1.71)
Religiosity	0.97	0.97
	(0.86, 1.11)	(0.85, 1.10)
Income	0.99	0.99
	(0.91, 1.08)	(0.91, 1.08)
PCP Had COVID	0.61*	0.53**
	(0.35, 1.07)	(0.30, 0.95)
Vaccines are Effective	1.22	1.16
	(0.85, 1.77)	(0.81, 1.65)
Vaccines are Safe	0.67*	0.68
	(0.42, 1.05)	(0.43, 1.08)
Vaccines are Important	1.38	1.43
	(0.81, 2.35)	(0.84, 2.42)
Constant	1.76	1.83
	(0.34, 9.14)	(0.35, 9.55)
Observations	552	549
Pseudo R-Squared	0.02	0.02

95% Confidence Intervals in Parentheses.
*** p < 0.01, ** p < 0.05, * p < 0.10.
Notes: Results based on binary logit models using odds ratios. Quantities in parentheses indicate 95% confidence intervals.

Table A4
Replication of Table 4 Including Patient Demographics.

VARIABLES	(Model 4) Moderna over J&J	(Model 5) Pfizer over J&J
Female	1.10	1.06
	(0.68, 1.78)	(0.66, 1.72)
Age	0.98	0.98
	(0.96, 1.01)	(0.96, 1.01)
Conservative	1.05	1.05
	(0.92, 1.21)	(0.91, 1.21)
Hispanic	0.67	0.61
	(0.34, 1.31)	(0.31, 1.20)
Black	1.21	1.19
	(0.38, 3.80)	(0.38, 3.75)
Asian	1.27	1.45
	(0.77, 2.10)	(0.87, 2.40)
Religiosity	0.94	0.92
	(0.80, 1.09)	(0.79, 1.07)
Income	0.96	0.96
	(0.87, 1.07)	(0.86, 1.07)
PCP Had COVID	0.61	0.51*
	(0.31, 1.20)	(0.25, 1.04)
Vaccines are Effective	1.88***	1.62**
	(1.18, 2.99)	(1.04, 2.53)
Vaccines are Safe	0.56**	0.65*
	(0.34, 0.90)	(0.41, 1.02)
Prop. Patients Female	1.00	1.00
	(0.98, 1.01)	(0.98, 1.01)
Prop. Patients Black	1.00	1.00
	(0.99, 1.01)	(0.99, 1.01)
Prop. Patients Hispanic	1.01	1.01
	(0.99, 1.02)	(0.99, 1.02)
Prop. Patients on Medicaid	1.00	1.00
	(0.99, 1.01)	(0.99, 1.01)
Prop. Patients on Medicare	1.00	1.00
	(0.99, 1.01)	(0.99, 1.01)
Prop. Patients Uninsured	0.99	0.99
	(0.97, 1.00)	(0.97, 1.00)
Constant	2.51	3.04
	(0.29, 21.93)	(0.35, 26.65)
Observations	411	408
Pseudo R-Squared	0.04	0.04

95% Confidence Intervals in Parentheses; *** p < 0.01, ** p < 0.05, * p < 0.10.
Notes: Results based on logit models using odds ratios. Quantities in parentheses indicate 95% confidence intervals. Patient Demographic variables based on questions that asked physicians what proportion of their patients fell into each demographic group on 0–100 scales.

Table A5
Replication of Table 2 using Holm-Adjusted P-Values.

VARIABLES	(Model 1) Vaccines are Safe	(Model 2) Vaccines are Effective	(Model 3) Vaccines are Important
Female	0.92	0.82	0.84
	(0.62, 1.36)	(0.54, 1.26)	(0.54, 1.30)
Age	1.01	1.00	1.00
	(0.99; 1.03)	(0.98, 1.02)	(0.98, 1.03)
Conservative	0.86*	0.84*	0.90
	(0.76; 0.98)	(0.73, 0.97)	(0.78, 1.04)
Hispanic	0.65	0.67	0.65
	(0.36, 1.17)	(0.35, 1.29)	(0.33, 1.25)
Black	0.80	1.65	1.04
	(0.30, 2.09)	(0.46, 5.93)	(0.33, 3.27)
Asian	1.04	1.08	0.97
	(0.67, 1.62)	(0.66, 1.75)	(0.59, 1.60)
Religiosity	0.99	0.99	0.94
	(0.86, 1.13)	(0.85, 1.15)	(0.81, 1.10)
Income	1.14**	1.08	1.03
	(1.04, 1.25)	(0.98, 1.19)	(0.93, 1.14)
PCP Had COVID	0.48**	0.52*	0.45**
	(0.28, 0.80)	(0.30, 0.90)	(0.26, 0.79)
Observations	560	561	556
Pseudo R-Squared	0.03	0.02	0.02

95% Confidence Intervals in Parentheses.
*** p < 0.01, ** p < 0.05, * p < 0.10 (Holm-Adjusted).
Notes: Results based on ordered logit models using odds ratios. Quantities in parentheses indicate 95% confidence intervals. Explanatory measures for Female, Hispanic, Black, Asian, and PCP Had COVID are dichotomous. Measures for Conservative, Religiosity, and Income are categorical. The measure for age is continuous.

Table A6
Replication of Table 2 using Bonferroni-Adjusted P-Values.

VARIABLES	(Model 1) Vaccines are Safe	(Model 2) Vaccines are Effective	(Model 3) Vaccines are Important
Female	0.92	0.82	0.84
	(0.62, 1.36)	(0.54, 1.26)	(0.54, 1.30)
Age	1.01	1.00	1.00
	(0.99; 1.03)	(0.98, 1.02)	(0.98, 1.03)
Conservative	0.86	0.84*	0.90
	(0.76; 0.98)	(0.73, 0.97)	(0.78, 1.04)
Hispanic	0.65	0.67	0.65
	(0.36, 1.17)	(0.35, 1.29)	(0.33, 1.25)
Black	0.80	1.65	1.04
	(0.30, 2.09)	(0.46, 5.93)	(0.33, 3.27)
Asian	1.04	1.08	0.97
	(0.67, 1.62)	(0.66, 1.75)	(0.59, 1.60)
Religiosity	0.99	0.99	0.94
	(0.86, 1.13)	(0.85, 1.15)	(0.81, 1.10)
Income	1.14**	1.08	1.03
	(1.04, 1.25)	(0.98, 1.19)	(0.93, 1.14)
PCP Had COVID	0.48**	0.52	0.45**
	(0.28, 0.80)	(0.30, 0.90)	(0.26, 0.79)
Observations	560	561	556
Pseudo R-Squared	0.03	0.02	0.02

95% Confidence Intervals in Parentheses.
*** p < 0.01, ** p < 0.05, * p < 0.10 (Holm-Adjusted).
Notes: Results based on ordered logit models using odds ratios. Quantities in parentheses indicate 95% confidence intervals. Explanatory measures for Female, Hispanic, Black, Asian, and PCP Had COVID are dichotomous. Measures for Conservative, Religiosity, and Income are categorical. The measure for age is continuous.

Table A7
Replication of Table 4 using Holm-Adjusted P-Values.

VARIABLES	(Model 4) Moderna over J&J	(Model 5) Pfizer over J&J
Female	1.06	1.07
	(0.73, 1.55)	(0.73, 1.56)
Age	0.98	0.98
	(0.97, 1.00)	(0.97, 1.00)
Conservative	1.02	1.02
	(0.90, 1.14)	(0.90, 1.14)
Hispanic	0.65	0.67
	(0.36, 1.18)	(0.37, 1.20)
Black	1.35	1.29
	(0.49, 3.72)	(0.47, 3.56)
Asian	1.04	1.15
	(0.69, 1.57)	(0.76, 1.75)
Religiosity	0.98	0.97
	(0.86, 1.11)	(0.86, 1.11)
Income	0.98	0.98
	(0.90, 1.07)	(0.90, 1.07)
PCP Had COVID	0.61	0.54
	(0.35, 1.07)	(0.30, 0.95)
Vaccines are Effective	1.38	1.31
	(1.00, 1.89)	(0.96, 1.79)
Vaccines are Safe	0.81	0.85
	(0.58, 1.12)	(0.61, 1.17)
Constant	1.89	1.98
	(0.37, 9.60)	(0.39, 10.09)
Observations	556	553
Pseudo R-Squared	0.02	0.02

95% Confidence Intervals in Parentheses.
*** p < 0.01, ** p < 0.05, * p < 0.10.
Notes: Results based on binary logit models using odds ratios. Quantities in parentheses indicate 95% confidence intervals. The 'vaccines are important' measure was excluded due to a high variance inflation factor indicating potential multicollinearity. An alternative to Table 4 including 'vaccines are important' is available in the appendix. Explanatory measures for Female, Hispanic, Black, Asian, and PCP Had COVID are dichotomous. Measures for Conservative, Religiosity, and Income are categorical. The measure for age is continuous.

Table A8
Replication of Table 4 using Bonferroni-Adjusted P-Values.

VARIABLES	(Model 4) Moderna over J&J	(Model 5) Pfizer over J&J
Female	1.06	1.07
	(0.73, 1.55)	(0.73, 1.56)
Age	0.98	0.98
	(0.97, 1.00)	(0.97, 1.00)
Conservative	1.02	1.02
	(0.90, 1.14)	(0.90, 1.14)
Hispanic	0.65	0.67
	(0.36, 1.18)	(0.37, 1.20)
Black	1.35	1.29
	(0.49, 3.72)	(0.47, 3.56)
Asian	1.04	1.15
	(0.69, 1.57)	(0.76, 1.75)
Religiosity	0.98	0.97
	(0.86, 1.11)	(0.86, 1.11)
Income	0.98	0.98
	(0.90, 1.07)	(0.90, 1.07)
PCP Had COVID	0.61	0.54**
	(0.35, 1.07)	(0.30, 0.95)
Vaccines are Effective	1.38	1.31
	(1.00, 1.89)	(0.96, 1.79)
Vaccines are Safe	0.81	0.85
	(0.58, 1.12)	(0.61, 1.17)
Constant	1.89	1.98
	(0.37, 9.60)	(0.39, 10.09)
Observations	556	553
Pseudo R-Squared	0.02	0.02

95% Confidence Intervals in Parentheses.
*** p < 0.01, ** p < 0.05, * p < 0.10.
Notes: Results based on binary logit models using odds ratios. Quantities in parentheses indicate 95% confidence intervals. The 'vaccines are important' measure was excluded due to a high variance inflation factor indicating potential multicollinearity. An alternative to Table 4 including 'vaccines are important' is available in the appendix. Explanatory measures for Female, Hispanic, Black, Asian, and PCP Had COVID are dichotomous. Measures for Conservative, Religiosity, and Income are categorical. The measure for age is continuous.

Appendix B. Survey Questions

Qualifying Questions

Which of the following best describes your current job?

- ○ Registered Nurse (RN) (1)
- ○ Physician (MD/DO) (2)
- ○ Nurse Practitioner (NP) (3)
- ○ Licensed Practical Nurse (LPN) (4)
- ○ Physician Assistant (PA) (5)
- ○ Researcher (6)
- ○ Other (Please specify) (7) _____

Which one of the following best describes your specialty? [if prior question=2]

- ○ Endocrinologist (1)
- ○ Gastroenterologist (2)
- ○ Primary Care Physician (Family Medicine, General Practitioners, Internal Medicine) (3)
- ○ Cardiologist (4)
- ○ Pediatrician (5)
- ○ Other (Please specify) (6) _____

Dependent Variable Questions

Have you been vaccinated against COVID-19?

- ○ Yes, I have been fully vaccinated against COVID-19 (1)
- ○ Yes, I have been partially vaccinated against COVID-19 (2)
- ○ No, I have not been vaccinated against COVID-19 (3)

Thinking about vaccines in general, please give your opinion on the following statements.

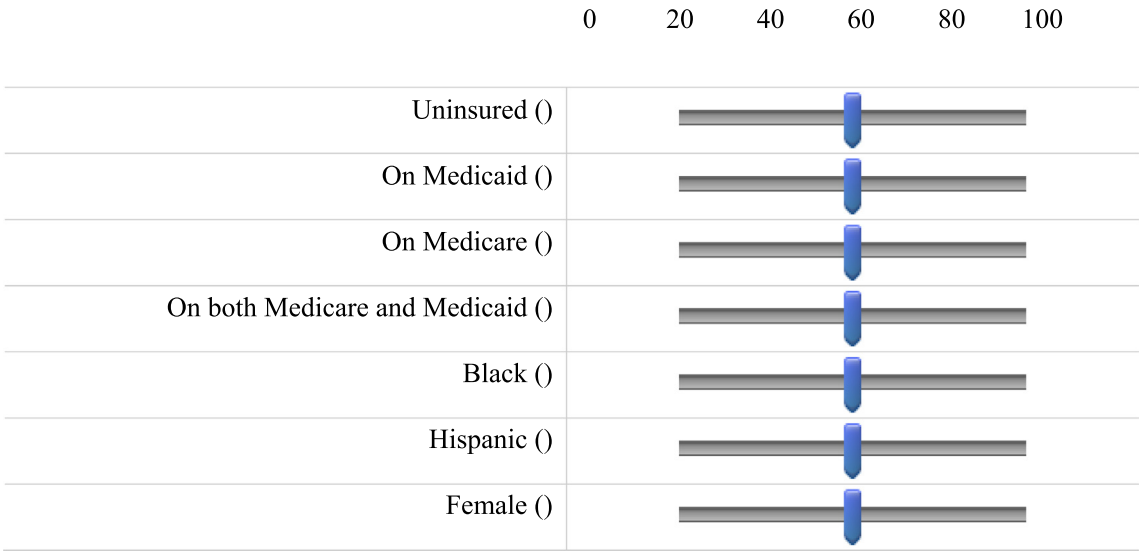
	Strongly Disagree (1)	Somewhat Disagree (2)	Neither Agree nor Disagree (3)	Somewhat Agree (4)	Strongly Agree (5)
Vaccines are effective (1)	○	○	○	○	○
Vaccines are important for my health (2)	○	○	○	○	○
Vaccines are safe (3)	○	○	○	○	○

How confident are you that the following COVID-19 vaccines are safe?

	Very confident (1)	Confident (2)	Somewhat confident (3)	Not at all confident (4)
Moderna (1)	○	○	○	○
Pfizer (2)	○	○	○	○
Johnson & Johnson (3)	○	○	○	○

Explanatory Measures

What percent of your patients are:



What is your gender?

- ○ Male (1)
- ○ Female (2)
- ○ Other (3)

What is your age?

_____

We hear a lot of talk these days about liberals and conservatives. Here is a seven-point scale on which the political views that people might hold are arranged from extremely liberal to extremely conservative. Where would you place yourself on this scale?

- ○ Extremely Liberal (1)
- ○ Liberal (2)
- ○ Slightly Liberal (3)
- ○ Moderate; Middle of the road (4)
- ○ Slightly Conservative (5)
- ○ Conservative (6)
- ○ Extremely Conservative (7)

Do you consider yourself Spanish, Hispanic, or Latino?

- ○ No (1)
- ○ Yes (2)

What is your race?

- ○ White (1)
- ○ Black or African-American (2)
- ○ American Indian or Alaska Native (3)
- ○ Asian (4)
- ○ Native Hawaiian or Pacific Islander (5)
- ○ Other (6)

How would you classify your level of involvement with your religion or spirituality?

- ○ Very active (1)
- ○ Moderately active (2)
- ○ Neither active nor inactive (3)
- ○ Moderately inactive (4)
- ○ Very inactive (5)

What state do you work in?

▼ Alabama (1) ... I do not reside in the United States (53)

What is the 5-digit zip code *where you work*?

_____

The next question is about the total income of YOUR HOUSEHOLD for the PAST 12 MONTHS. Please include your income PLUS the income of all members living in your household (including cohabiting partners and armed forces members living at home). Please

count income BEFORE TAXES, including income from all sources (such as wages, salaries, tips, net income from a business, interest, dividends, child support, alimony, and Social Security, public assistance, pensions, or retirement benefits). Please round your best guess to the nearest $10,000.

- ○ Less than $25,000 (1)
- ○ $25,000 to $49,999 (2)
- ○ $50,000 to $74,999 (3)
- ○ $75,000 to $99,999 (4)
- ○ $100,000 to $149,999 (5)
- ○ $150,000 to $199,999 (6)
- ○ $200,000 to $249,999 (7)
- ○ $250,000 to $299,999 (8)
- ○ $300,000 to $400,000 (9)
- ○ More than $400,000 (10)

At any point since the start of the COVID-19 pandemic, have you tested positive for having COVID-19?

- ○ Yes (1)
- ○ No (2)

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