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U.S. frontline workers and COVID-19 inequities

D. Phuong Do [a],[*], Reanne Frank [b]

[a] Public Health Policy & Administration, University of Wisconsin Zilber School of Public Health, USA
[b] Sociology and Faculty Affiliate of the Institute for Population Research, Ohio State University, USA

ABSTRACT

We overcome a lack of frontline worker status information in most COVID-19 data repositories to document the extent to which occupation has contributed to COVID-19 disparities in the United States. Using national data from over a million U.S. respondents to a Facebook-Carnegie Mellon University survey administered from September 2020 to March 2021, we estimated the likelihoods of frontline workers, compared to non-frontline workers, 1) to ever test positive for SARs-Cov-2 and 2) to test positive for SARs-Cov-2 within the past two weeks. Net of other covariates including education level, county-level political environment, and rural residence, both healthcare and non-healthcare frontline workers had higher odds of having ever tested positive for SARs-Cov-2 across the study time period. Similarly, non-healthcare frontline workers were more likely to test positive in the previous 14 days. Conversely, healthcare frontline workers were less likely to have recently tested positive. Our findings suggest that occupational exposure has played an independent role in the uneven spread of the virus. In particular, non-healthcare frontline workers have experienced sustained higher risk of testing positive for SARs-Cov-2 compared to non-frontline workers. Alongside more worker protections, future COVID-19 and other highly infectious disease response strategies must be augmented by a more robust recognition of the role that structural factors, such as the highly stratified U.S. occupational landscape, have played in the uneven toll of the COVID-19 pandemic.

1. Introduction

The U.S. faces a national reckoning with respect to how the SARS-CoV-2 virus spread and enacted such an uneven deadly toll. Since its inception, the pandemic has been marked by stark inequities across population sub-groups (Kawachi, 2020; Maani and Galea, 2020). While considerable attention has been given to the racialized nature of these patterns (Garcia et al., 2021), the role that frontline work has played in the uneven spread of COVID-19 across U.S. social groups has been less investigated (Chen et al., 2021).

Population health scholars have long sought to draw attention to the role of occupation in contributing to social disparities in health (Syme, 1988). In the case of COVID-19, it seems likely that occupation is again operating to socially pattern both the disease and its treatment. Because SARs-Cov-2 is a respiratory virus that spreads through human contact, the workplace has the potential to be a key site in determining who is exposed to risk (Cevik and Baral, 2021).

Yet we know surprisingly little about the extent to which occupational exposure has contributed to the uneven spread of COVID-19.

Despite innumerable commentaries (e.g., Dubay et al., 2020; Kinder, 2020; Melissa and Pardue, 2020; Afifi et al., 2020), the extent to which frontline workers have borne a disproportionate amount of the COVID-19 disease burden nationally is unknown. A major obstacle has been the lack of socioeconomic data, including occupation, in most data repositories upon which we base our knowledge about impacts (Kawachi, 2020). What little we know about workplace exposure comes largely from health care settings (Barrett et al., 2020; Kambhampati, 2020; Nguyen et al., 2020), specific work-site studies (Bui, 2020; Dyal, 2020; Steinberg, 2020; Waltenburg, 2020), other country contexts (European CDPC, 2020), or a small number of state-specific analyses (Chen et al., 2021; Washington State, 2020). Lacking is a national individual-level assessment of how occupational exposure, in particular frontline worker status (i.e., whereby one must report to work in person), has been associated with SARs-Cov-2 positivity in the United States.

From the onset of the pandemic, health care workers (HCWs) have been the public face of the risks faced by frontline workers (National Academies Press, 2020). Accordingly, the vast majority of COVID-19 workplace risk assessments focus on health care settings, with mixed

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findings. While some have found no discernable difference in SARs-Cov-2 positive rates among HCWs compared to the general public (Kambhampati, 2020), and no evidence of direct transmission in hospitals (Sikkema et al., 2020), others suggest that health care settings have been sites of heighted transmission, particularly in the early months of the pandemic when personal protective equipment (PPE) was scarce (Nguyen et al., 2020). Other hospital-based studies have also documented higher risk for workers, particularly among nurses (Barrett et al., 2020).

Beyond HCWs, evidence of COVID-19's toll on other frontline workers in the U.S. has largely been limited to ecological county or sub-county-level associations (Fielding-Miller et al., 2020; Reitsma et al., 2021; Sung, 2021), specific worksite outbreaks (Bui, 2020; Dyal, 2020; Steinberg, 2020; Waltenburg, 2020), or reliant on sparse state-level data (Washington State, 2020). One of the first pieces of evidence to suggest elevated risk was a July 2020 Centers for Disease Control study of 802 adults that found that among those who had visited an outpatient testing facility and tested positive for SARs-Cov-2, the percent who reported teleworking was significantly lower (35%) than among those who did not telework (53%) (Fisher et al., 2020). Only one study has directly assessed the disproportionate impact of COVID-19 by occupation with a focus on excess mortality, and only in the state of California (Chen et al., 2021). Using state death records from March–October 2020 and comparing to pre-pandemic time, the authors document considerable excess mortality among high-risk occupational sectors (e.g. food/agriculture, transportation, facilities and manufacturing) in California. But data limitations have precluded a broader assessment of the degree of occupational variation in SARs-Cov-2 positivity at the national level.

Information on national patterns in occupational risk is essential for applying a health equity framework to mitigating the starkly disparate impacts of COVID-19. Fortunately, a survey conducted by the Delphi Research Group at Carnegie Mellon University that monitors the spread and impact of the COVID-19 pandemic includes information on occupation and thus permits a direct assessment on how occupation shapes the patterning of SARs-Cov-2 spread. The aim of our study is to determine whether frontline workers are more likely to test positive for SARs-Cov-2 compared to non-frontline workers.

2. Methods

2.1. Data

Data come from a set of online cross-sectional surveys (Delphi's COVID-19 Trends and Impact Surveys, CTIS) administered through Facebook in collaboration with the Delphi Research Group at Carnegie Mellon University (Reinhart and Tibshirani, 2020; The Delphi Group, 2021). Since the beginning of April 2020, Facebook has sent out invitations to its U.S. users ages 18 and over to participate via a link to the survey on top of the user's Facebook News Feed. There was no compensation for completing the survey. Eligible Facebook users in low density areas may take the survey a maximum of once every 30 days, while users in high density areas are sampled every 2–6 months. Roughly 1% of the approximately 100 million monthly invitations are accepted, yielding the approximately 1 million respondents targeted each month (Barkay et al., 2020). The survey employs a stratified random sampling framework using geographic boundaries (i.e., states). Survey weights adjust for non-response and coverage bias via, respectively, inverse propensity score weighting and post-stratification by age, gender, and geography (Barkay et al., 2020).

The COVID-19 Symptom Survey has been used widely (Lessler et al., 2021; Bilinski et al., 2021; Rebeiro et al., 2021; Delphi Group, 2021), and important for our purposes, beginning in September 2020 (Wave 4), the survey began asking a set of questions on occupation. These include whether the respondent worked for pay in the past 4 weeks and, if so, their occupation. Our primary interest is documenting whether there is a difference in SARs-Cov-2 positivity depending on whether an individual

is a frontline worker. Accordingly, we restrict our sample to working age adults (18–64) who reported that they worked for pay in the past 4 weeks and provided information on their occupation. Further restricting the samples to those who had ever tested for SARs-Cov-2 and those who had tested within the last 14 days with known test results, as well as those with information on the full set of covariates, yielded analytical sample sizes of 1,603,002 and 396,067 respectively.

The research protocol was reviewed by the Institutional Review Board (IRB) at the University of Wisconsin-Milwaukee and was granted exempt status.

2.2. Measures

Our outcome measure, SARs-Cov-2 positivity, is captured in two ways. Binary indicators were used to indicate whether respondents had ever tested positive for SARs-Cov-2 and whether they had tested positive within 14 days prior to the survey. The ever-tested outcome captures the cumulative risk profile up to and including the month assessed whereas the 14-day outcome better reflects the specific month's risk profile. Hence, each outcome may reveal unique patterning and inferences. We model both outcomes and how they relate to occupation type. Each question has its own strengths and limitations. Because the ever-tested outcome captures SARs-Cov-2 positivity at any time since the start of the pandemic, this outcome is more likely to contain errors in the occupation response if the current occupation is not the same as the occupation held when the respondent contracted SARs-Cov-2, perhaps months before. The occupation for the 14-day outcome is more likely to reflect the respondent's occupation when infected; however, the analytical sample is more likely to miss those who reported that they did not work for pay in the four weeks prior to the survey due to having COVID-19. Although this limitation is true for both outcomes, this is more likely, proportionally, in the 14-day group due to the more extensive overlap in COVID-19 and work for pay time periods. Further, a higher percent of the 14-day group (7% for those tested within 14 days vs. 1% for those ever tested) were excluded from the analyses because they did not know whether they had tested positive or negative, presumably because of the lag time between testing and receiving their results.

Our main variable of interest is frontline occupation status. Occupation in the Facebook survey is based on the Bureau of Labor Statistics 6-digit Standard Occupational Classification System (SOC) (U.S. Bureau of Labor Statistics, 2021). We assign a teleworking score to each respondent's identified occupation (e.g. firefighter, food preparation worker, telemarketer) by matching SOC occupations in Dingel and Neiman's (2020) dataset, which provides teleworking scores by occupation (Dingel and Neiman, 2020a). Briefly, Dingel and Neiman's (2020) teleworking scores are based on responses to two questionnaires included in the 24.2 (February 2020) release by the Occupational Information Network (O*NET), a federally sponsored program with the objective of identifying and maintaining current information on the characteristics of workers and occupations (O*NET, 2020). Dingel and Neiman's scoring system relied on job characteristics that clearly ruled out the possibility of working from home entirely (e.g. majority of time wearing protective or safety equipment) and thus their classification for non-teleworking friendly occupations (i.e. frontline workers) is conservative (Dingel and Neiman, 2020b).

Dingel and Neiman's teleworking scores are continuous, ranging from 0 to and 1, with 1 representing maximum feasibility of being able to work from home. We reversed coded the score so that a value of 1 equates to minimum feasibility of being able to work from home, which we consider for this study's purpose as frontline occupations. We then generated a binary indicator of not being able to work from home (i.e. frontline worker), which included those who were in an occupation with non-teleworking friendly scores greater than 0.5. All others were assigned a non-teleworking friendly score of 0 (i.e. non-frontline worker).

Our set of covariates include: gender (male/female), age (18–24, 25–34, 25–44, 45–54, 55–64), education level (high school or less, some college or 2 year degree, 4 year college degree, graduate degree), rurality based on the U.S. Department of Agriculture's county-level 2013 Rural-Urban Continuum Codes (metropolitan, urban non-metropolitan, rural) (USDA, 2021a), and county political environment (percent of Donald Trump voters in the 2020 presidential election) (MIT Election Data and Science Lab, 2021).

2.3. Statistical analysis

We conduct a series of logistic regression models assessing SARs-Cov-2 positivity (ever SARs-Cov-2 positive and SARs-Cov-2 positive within past 14 days) as a function of frontline worker status. We assess all frontline workers as a group and then re-estimate the models differentiating health care workers (HCWs) from non-HCWs to determine whether inferences differ. We allow temporal variation in the relationship between occupation and SARs-Cov-2 positivity by interacting frontline worker status by month of the survey. Although repeat respondents cannot be identified, we assume that most repeat respondents reside in the same zip code during the 7-month study period. Hence, to account for the possible correlation of repeat respondents, all analyses are clustered by zip code. This strategy provides conservative standard error estimates, compared to clustering on repeat respondents alone. In addition, all analyses include the full set of covariates and apply survey weights in order to reduce sample selection bias so that the Facebook sample population is more representative of the targeted adult U.S. population (i.e., adult U.S. workers who had tested for SARs-Cov-2) (Barkay et al., 2020).

We also conduct a series of sensitivity analyses by re-running models with different specifications of frontline workers to assess the robustness of our inferences to our choice of using 0.5 as the teleworking score cutoff point. In the first set of sensitivity analyses, we changed the cutoff point by re-classifying those with 0.5 scores as not having teleworking friendly occupations. Consequently, in this set of analyses, those with a 0.5 score were now considered as frontline workers. In the second set of sensitivity analyses, we specified the teleworking score as continuous instead of binary. All patterns and major inferences remained unchanged.

3. Results

Table 1 provides weighted descriptive statistics for the ever-tested and 14-day samples. In addition, the full CTIS sample without the testing, age, and work restrictions are also presented to provide a profile of those who responded to the survey. Compared to the full CTIS sample, those included in our analytical outcome samples are younger (due to the age restriction) and more educated. Approximately 36 to 40% of those in our analytical samples are non-frontline workers, which corresponds to Dingel and Neiman's (2020) estimate of 37% of jobs, nationally, that can be worked from home (Dingel and Neiman, 2020a; Dingel and Neiman, 2020b). 17 and 14% tested positive for SARs-Cov-2 in the ever-tested and 14-day samples, respectively. Rural residents represented 1% of all samples, which reflects a substantial underrepresentation given that nationally, approximately 14% of the population reside in rural areas (USDA, 2021b).

Bivariate analyses (not shown) indicated that in the period September 2020–March 2021, frontline workers were overrepresented in ever-tested positive cases (19% for frontline workers vs. 14% for non-frontline workers) and among 14-day positive cases (15% vs. 13%). In the multiple regression models, we allowed the relationship between frontline workers and SARs-Cov-2 positivity to differ each month and adjusted for the full set of covariates. Fig. 1 demonstrates that in September 2020, frontline workers had over 21% higher odds of having ever tested positive, compared to non-frontline workers in the same month. Those higher odds remained relatively stable over the study

Table 1
Weighted descriptive statistics of the CTIS Analytical Sample.

	Tested positive for SARs-Cov-2 (ever)	Tested positive for SARs-Cov-2 (within past 14 days)	CTIS sample (without testing, age, and work restrictions)
N	1,603,002	396,067	6,698,774
Tested positive for SARs-Cov-2 (ever)	17.24	–	–
Tested positive for SARs-Cov-2 (within past 14 days)	–	13.91	–
Gender			
Male	45.44	44.63	44.87
Female	54.56	55.37	53.31
Non-binary/prefer not to answer			1.82
Age group			
18–24	13.68	15.15	10.07
25–34	23.25	23.51	15.92
25–44	22.36	21.91	16.36
45–54	22.9	22.43	17.38
55–64	17.81	17.00	17.72
65–74	–	–	15.89
75+	–	–	6.66
Education level			
High school or lower	13.92	14.83	21.69
Some college or 2 year degree	35.27	36.42	36.50
4 year degree	29.10	27.80	23.75
Graduate degree	21.71	20.96	18.06
Rural/urban category			
Metropolitan	86.92	86.54	85.24
Non metro, urban	11.99	12.29	13.45
Rural	1.09	1.17	1.31
Percentage of county voters who voted for trump	46.18 (0.02)	45.52 (0.03)	47.54 (0.01)
Occupation			
Nurse or Physician assistant	5.66	7.57	2.21
Other healthcare	14.11	17.89	6.11
Cook, janitor, Housekeeping Cleaner	1.36	1.56	0.78
Childcare	0.39	0.34	0.21
Cashier	1.12	1.00	0.70
Construction	1.37	1.26	0.89
Food processing	0.37	0.32	0.19
Motor vehicle operator	1.32	1.14	1.04
Other frontline	34.59	32.67	19.8
Non-frontline	39.71	36.26	21.71
No work for pay in last 4 weeks	–	–	46.37

period. The elevated odds are not entirely driven by health care workers (HCWs). Non-HCWs frontline workers have similarly elevated odds of having ever tested positive (e.g., in September 2021, non-HCWs frontline workers had 16% higher odds of having ever tested positive compared to 21% for all frontline workers). While HCW's had a higher risk of SARs-Cov-2 positivity than non-HCWs during the start of the study, the relationship flips between January and February 2021. That is, the steep decline in cumulative SARs-Cov-2 positivity among HCWs starting between December 2020 and January 2021 resulted in their positivity risk profile being less than that of non-health care workers.

Fig. 2 presents results for the 14-day group. At the beginning of the period, the risk for recently testing positive for SARs-Cov-2 was comparable for frontline and non-frontline workers. By January 2021, frontline workers began to experience an advantage, with a 7% lower odd of testing positive. However, once frontline workers are separated into HCWs and non-HCWs, it becomes apparent that the advantage is only among the HCWs. Non-health care frontline workers still had

Fig. 1. Odds Ratios, with 95% Confidence Intervals, from Logistic Regression Models estimating Likelihood to ever have tested positive for SARs-Cov-2.
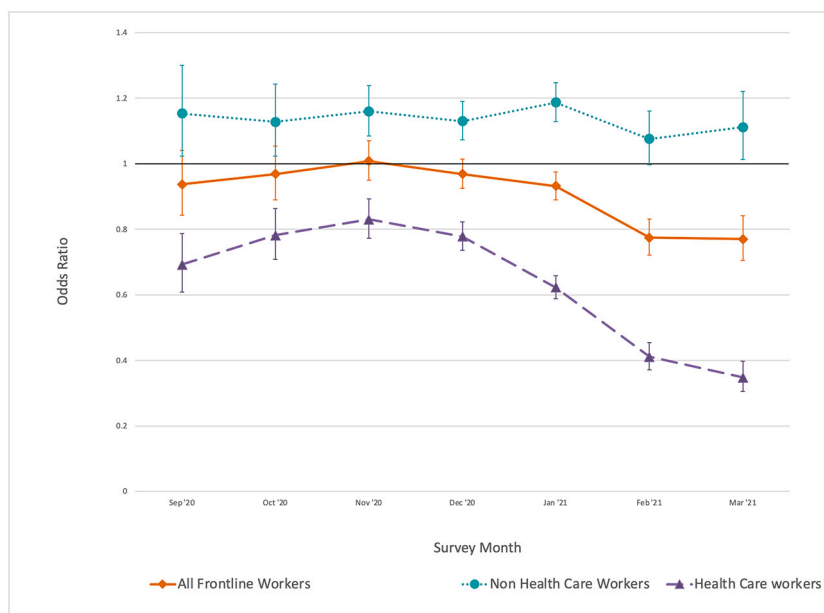Note: Reference group is non-Frontline Workers.

Fig. 2. Odds Ratios, with 95% Confidence Intervals, from Logistic Regression Models estimating Likelihood to have tested positive for SARs-Cov-2 within the past 14 days.
Note: Reference group is non-Frontline Workers.

higher odds, ranging from 13% to 19%, of having recently tested positive for SARs-Cov-2. The substantial drop in risk between January and February 2021 for the HCW sample corresponds to the period of the initial vaccine rollout, when health care workers were prioritized to receive the vaccines. In contrast, frontline non-HCWs remained at an elevated risk of receiving a recent positive test, compared to HCWs. These observed patterns are consistent with HCWs facing higher risk of reporting SARs-Cov-2 positive test during the beginning of the pandemic and then facing much lower risks after being vaccinated.

Because frontline workers are not a homogenous group and their risks vary across specific occupations, we analyze eight frontline occupations that are likely at higher risk of SARs-Cov-2 exposure (Fig. 3) (U.

S. Department of Labor Occupational Safety and Health Administration, 2020). Food processing workers have the highest odds of ever having tested positive for SARs-Cov-2 relative to non-frontline workers, with 45% higher odds. In terms of having tested positive in the last 14 days, those working in construction have 41% higher odds of recently receiving a positive SARs-Cov-2 result. Nurses and other health care workers are more likely to have ever had tested positive than non-frontline workers, but not as likely as those working in the food processing. Additionally, nurses and other HCWs are significantly less likely to have had a positive SARs-Cov-2 test in the past 14 days.
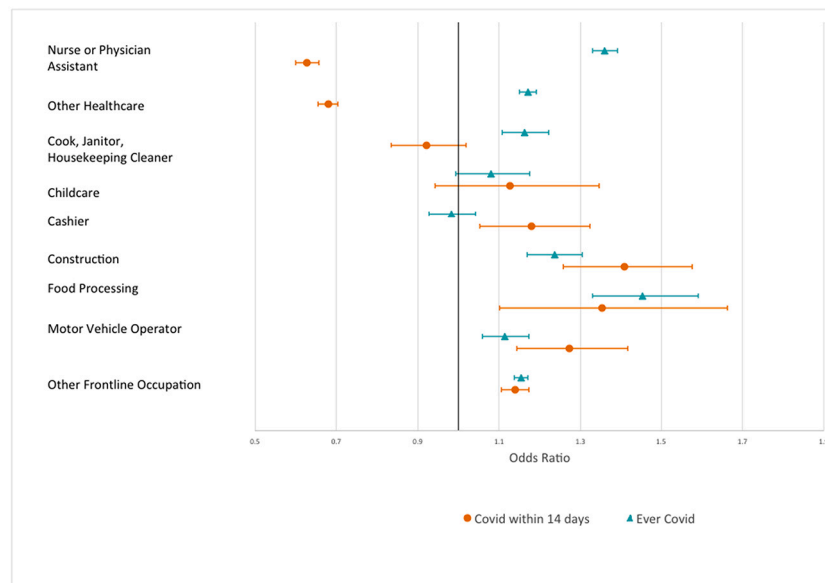
Fig. 3. Odds Ratios, with 95% Confidence Intervals, from Logistic Regression Models estimating Likelihood to have ever tested positive for SARs-Cov-2 and tested positive for SARs-Cov-2 within the past 14 days, by occupation.

Note: Reference group is non-Frontline Workers.

4. Discussion

As the U.S. finds itself in the midst of yet another wave of the COVID-19 pandemic, with cases, hospitalizations, and deaths all increasing again and the pace of vaccinations slowing, many epidemiologists predict that COVID-19 is likely to become endemic (Phillips, 2021). Under this scenario, whereby SARs-Cov-2 becomes a virus that we need to maintain control over chronically, public health interventions will be increasingly important in managing, not only the virus, but also any inequities related to its spread. We argue that a central component of these interventions must include the recognition of the fundamental role of occupational risk in transmission.

Owing to data constraints, there has been no direct evidence at the national level of how occupation matters for SARs-Cov-2. Our analysis shows that the virus is more common among frontline workers and has been for a substantial portion of the pandemic, at least since Fall 2020 when our data window begins. Additionally, we find that heightened susceptibility to the virus is not exclusive to HCWs but is present across a range of frontline occupations, with the highest risk observed among those in food preparation and construction occupations.

The Facebook survey data is subject to several limitations. First, the SARs-Cov-2 positivity data is self-reported and therefore is subject to self-reporting error. Further, if frontline workers were more likely to be tested, it may overestimate the SARs-Cov-2 positivity disparity between frontline and non-frontline workers. We examined this possibility in two ways. First, we calculated the proportions of frontline and non-frontline workers that were tested (Appendix, Table A.1). We found that 52% of frontline workers were ever tested, compared to 51% of non-frontline workers. Testing within 14 days yielded a slightly larger, but still small difference: 15% vs. 13% for frontline and non-frontline, respectively. Second, we conducted a sensitivity analysis and augmented the category of those who tested positive for SARs-Cov-2 within the past 14 days to include those who reported COVID-19 like symptoms within the past 24 h. Inferences remained unchanged.

Second, particularly for the 14-day outcome measure, some positive respondents may not have been included in the analysis because of not working for pay in the four weeks prior to the survey. It may be that some respondents were not able to work shortly before the survey because they had COVID-19. For these reasons, we evaluated whether respondents ever had tested positive for SARs-Cov-2 alongside the 14-day measure. In addition, we did not include those with unknown test results. This is more likely among the 14-day respondents due to the time lag between testing and receiving results. However, at 7%, those with unknown results represented a relatively small proportion of the 14-day test group (Appendix, Table A.2).

Third, due to reidentification risk concerns, Facebook has not released race/ethnicity data. Given the U.S. racialized occupational structure, workplace exposure may account for a substantial amount of the racial inequality characterizing the pandemic. Resolving data constraints that enable an assessment of this possibility is an important next step.

Lastly, there are two considerations that should be taken into account with respect to the generalizability of the observed patterns. First, temporal differences in those who responded may make comparisons across time difficult. However, we assessed the distribution of frontline versus non-frontline occupations by month to see if there were large differences (Appendix Table A.3). Across the 7-month study time-period, the proportion of the analytical sample who worked in non-frontline occupations remained roughly consistent at approximately 39% to 41% and 35% to 38% for the ever sample and 14-day sample, respectively. Second, rural residents were substantially underrepresented in the Facebook survey sample. While we apply survey weights and control for rural/urban residency (in addition to a host of other characteristics) in all our models to minimize sampling bias, results may still not be generalizable nationally if our models were not correctly specified (i.e. including appropriate nonlinear terms). Hence, inferences may be more applicable to urban areas.

5. Conclusions

At a minimum, these documented differences in the SARs-Cov-2 virus by frontline worker status underscore the importance of ensuring vaccine coverage among frontline workers. As vaccine uptake rates have begun to slow across the country, identifying and resolving the barriers to vaccine receipt for working Americans must be prioritized (Harmon and Holder, 2021). Recent vaccine mandates linked to employment will undoubtedly improve uptake (President Biden's COVID-19 Plan, 2021). The powerful role of vaccines in lowering occupational risk is evident in our data on HCWs, who were significantly less likely to have recently tested positive once they became eligible for vaccines at the start of

2021.

But our findings also have broader implications. Beyond vaccine distribution and uptake, higher positivity among frontline workers means that the workplace and workplace policies have to be focused on in a way they have not yet been since the beginning of the pandemic. These policies include not only workplace protections and robust testing protocols, but also paid leave, both sick leave and family leave. One of the early failures of the federal government was a failure to enforce workplace safety (Scheiber, 2020; U.S. Department of Labor, 2021). Employers, and the institutions charged with monitoring them, need to strengthen worker safety standards. If COVID-19 does indeed become endemic, workplace protections and policies that better protect workers will be critical factors in not only containing the spread, but also in minimizing the inequities around which groups are negatively impacted. This includes U.S. racial minority groups who have been disproportionately impacted since the pandemic's onset. Given the racialized U.S. occupational structure whereby U.S. minority groups are overrepresented in frontline work, any efforts to ameliorate COVID-related racial/ethnic disparities must also center the role of work and occupational exposure (Do and Frank, 2021).

Even more broadly, our results have implications for how response strategies to COVID-19 are framed, which, so far, have been primarily around individual behavioral changes aimed at disrupting transmission chains (Cevik and Baral, 2021). Our finding regarding the role of occupational exposure in virus transmission reveals the limits of such an individualized approach. It suggests that we need to recognize the ways in which contact patterns are structured by frontline worker status, which is, in turn, determined by broader societal inequities. Moving forward, existing response strategies focused on individual behavior change must be augmented by a more robust recognition of the role that structural factors, including the highly stratified U.S. occupational landscape, have played in the uneven toll of the COVID-19 pandemic.

Credit author statement

D. Phuong Do: Conceptualization, Data curation, Methodology, Formal analysis, Writing - original draft, Writing- review & editing. **Reanne Frank**: Conceptualization, Investigation, Writing – original draft, Writing – review & editing.

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Appendix A. Supplementary data

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