Preventive Medicine Reports 32 (2023) 102136

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Short communication

Lack of access to personal protective equipment is associated with severe COVID-19 symptoms among in-person workers

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ARTICLE INFO

Keywords:
COVID-19
Personal protective equipment
Severity

ABSTRACT

The use of personal protective equipment (PPE) at work can greatly reduce risk of SARS-CoV-2 transmission. However, it is unclear whether adequate PPE reduces disease severity if transmission occurs. This study investigated associations between workplace access to adequate PPE and self-reported COVID-19 symptom severity among in-person workers. We used data from the Michigan COVID-19 Recovery Surveillance Study (MI CReSS), a population-based survey of Michigan adults with a PCR-confirmed positive SARS-CoV-2 test. The sample was restricted to employed, in-person respondents with COVID-19 onset on or before November 15, 2020 (n = 893). Access to adequate PPE at work was categorized as often/always, sometimes, or rarely/never. Self-reported symptom severity was dichotomized as severe (severe or very severe) or not severe (mild, moderate, or asymptomatic). We used modified Poisson regression to estimate prevalence ratios for the relationship between adequate PPE at work and severe COVID-19 symptoms. We examined effect modification of the relationship by occupation by including a multiplicative interaction term for healthcare worker versus other occupations. After adjusting for sociodemographic and clinical covariates, respondents who rarely/never had access to PPE at work had a 24.7 % higher prevalence of self-reported severe COVID-19 symptoms (PR: 1.25, 95 % CI 1.03–1.51, p-value = 0.024) compared to respondents who often/always had access to PPE at work. Healthcare worker status did not modify the association between access to PPE and symptom severity. The findings from this study suggest an added benefit of PPE in reducing prevalence of severe COVID-19 among all in-person workers.

1. Introduction

It is widely accepted that SARS-CoV-2 transmission can occur through respiratory droplets and that the use of personal protective equipment (PPE), such as face masks and shields, gloves, and gowns, can greatly reduce the risk of transmission (Lerner et al., 2020). Particularly in high-exposure settings (e.g., high-occupancy, indoor work environments with direct patient contact), the use of PPE has been proven essential in reducing risk of infection among in-person workers during the COVID-19 pandemic (Kim et al., 2021).

However, many studies have focused solely on the relationship between PPE and reduced SARS-CoV-2 transmission and have not examined the impact of PPE use on COVID-19 severity if transmission occurs. This is particularly important given that workers in high-exposure settings, such as healthcare workers, are at higher risk of SARS-CoV-2 infection (Nguyen et al., 2020) and developing severe COVID-19 symptoms if infected (Mutambudzi et al., 2020). One potential cause of these patterns is that exposure to a higher viral load may lead to worse outcomes (Guallar et al., 2020). Because PPE can reduce viral load exposure (Guallar et al., 2020), adequate PPE may also reduce the risk of severe disease.

Using a population-based study of COVID-19 recovery in the state of Michigan, we investigated the relationship between workplace access to adequate PPE and self-reported symptom severity among SARS-CoV-2 positive in-person workers. Additionally, we investigated whether healthcare worker status modified the association between workplace access to adequate PPE and COVID-19 symptom severity.

2. Methods

2.1. Michigan COVID-19 recovery surveillance study (MI CReSS)

MI CReSS is a population-based study of Michigan residents ages 18 and older with a PCR-confirmed SARS-CoV-2 test in the Michigan

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https://doi.org/10.1016/j.pmedr.2023.102136
Received 13 June 2022; Received in revised form 8 February 2023; Accepted 9 February 2023
Available online 11 February 2023

Disease Surveillance System. Eligibility criteria included being non-institutionalized, having a valid phone number and zip code or county, and being alive at time of sample draw. We drew a stratified, random sample of 6,000 adults with COVID-19 onset on or before November 15, 2020. Sampled individuals were recruited by mail and invited to take our survey over the phone with a trained interviewer in English, Spanish, or Arabic or online in English. Of the 6,000 selected, 1,839 participated in the study, resulting in a response rate of 31.8 % (American Association for Public Opinion Research (AAPOR) Response Rate #6) (American Association for Public Opinion Research, 2016). This study met the University of Michigan's guidelines for protection of human subjects concerning their safety and privacy.

Thirteen geographic areas in Michigan were included as sampling strata (Services, Laskaris et al.). A base sample of 50–70 individuals from each stratum was drawn and the remainder of the sample was drawn proportionally from each stratum. Using generalized regression estimators (Deville and Särndal, 1992), sampling weights were generated so that the weighted distribution of the sample matched the age and sex distribution by geographic region of the sampling frame.

2.2. Exposure and outcome measures

Our primary exposure of interest was workplace access to adequate PPE. All in-person workers (employed respondents who reported that their physical presence was required at work prior to their illness) were asked "prior to your illness, how often did you have adequate equipment to protect yourself from contracting COVID-19 at work?" and response options included always, often, sometimes, rarely, or never. Type of equipment was not further defined for respondents. We categorized access to adequate PPE as always/often, sometimes, or rarely/never.

Our primary outcome of interest was self-reported COVID-19 symptom severity when symptoms were at their worst. Respondents were asked "overall, when your symptoms were at their worst, how bad or bothersome were they?" and response options included no symptoms, mild, moderate, severe, or very severe. Self-report symptom severity was dichotomized as severe (severe or very severe) or not severe (no symptoms, mild, or moderate).

2.3. Covariates

We adjusted for a variety of sociodemographic and relevant clinical covariates: sex (male or female), age group (18–34, 35–44, 45–54, 55–64, 65 and over), race/ethnicity (Hispanic, Non-Hispanic White, Non-Hispanic Black, and Another Race/Ethnicity), annual household income (<$35,000, $35,000-$74,999, $75,000 and over), body mass index (BMI; underweight or normal weight (BMI $<$ 25), overweight (BMI 25–30), and obese (BMI $\geq$ 30)), admittance to hospital (yes or no), and number of comorbidities (0, 1, 2, or 3 +). If respondents were missing responses for all 14 comorbidities questions, they were excluded from the analysis. We additionally adjusted for sample wave (samples 1–5) and survey mode (telephone or online).

Our effect modifier of interest was healthcare worker status. All respondents employed at the time of their COVID-19 onset provided their job title. Self-reported occupations were then categorized into 2018 Standard Occupation Classification major occupation groups (U.S. Bureau of Labor Statistics, 2018) using the National Institute for Occupational Health and Safety Industry and Occupation Computerized Coding System (NIOCCS) (NIOSH Industry and Occupation Computerized Coding System (NIOCCS), 2021). Healthcare workers included 'healthcare practitioners and technical assistance' and 'healthcare support' major occupation groups.

2.4. Analysis

There were 988 in-person workers in our dataset, but we excluded 95 with missing values for the outcome, exposure, or covariates, yielding a final analytic dataset of 893 for a complete case analysis. We used modified Poisson regression models to estimate unadjusted and adjusted associations between access to PPE and self-reported symptom severity among in-person workers. We also included an interaction term between healthcare worker status and access to PPE to test for potential effect modification on the multiplicative scale. Annual household income had the highest amount of missingness in the original dataset; we used a weighted sequential hot deck method (Cox, 1980) and hot deck propensity score imputation (Mayer, 2013) under the missing at random assumption to impute annual household income so the income measurement was complete in the analytic dataset. The analyses presented in this study were performed using Stata version 15 and accounted for the complex sampling design.

Table 1
Description of analytic sample of all in-person workers from MI CReSS (n = 893).

Variables	Total n (weighted %)
Total n	**893**
Access to Adequate PPE	
Often-Always	621 (69.9 %)
Sometimes	111 (12 %)
Never-Rarely	161 (18.1 %)
Self-reported severity	
Not severe	526 (60.1 %)
Severe	367 (39.9 %)
Healthcare worker status	
No	605 (69.9 %)
Yes	288 (30.1 %)
Sex	
Male	379 (47.1 %)
Female	514 (52.9 %)
Age Group	
18–34	270 (34.3 %)
35–44	203 (23.1 %)
45–54	204 (21.8 %)
55–64	171 (16.6 %)
65+	45 (4.2 %)
Race/ethnicity	
Hispanic	83 (11.5 %)
Non-Hispanic White	620 (67.7 %)
Non-Hispanic Black	92 (9.5 %)
Another Race/Ethnicity	98 (11.3 %)
Annual household income	
<$35,000	225 (26.5 %)
$35,000 - $74,999	274 (30.1 %)
$75,000	394 (43.3 %)
Body Mass Index	
Underweight/normal weight (BMI < 25)	200 (22.3 %)
Overweight (BMI 25 to < 30)	285 (33.5 %)
Obese (BMI 30 +)	408 (44.2 %)
Number of Comorbidities	
0	344 (41.5 %)
1	272 (30.1 %)
2	154 (16.1 %)
3+	123 (12.3 %)
Admittance to Hospital	
Yes	799 (90.5 %)
No	94 (9.5 %)
Sample Wave	
1	300 (32.8 %)
2	133 (15.2 %)
3	165 (18 %)
4	137 (15.5 %)
5	158 (18.6 %)
Survey Type	
Phone	395 (44.8 %)
Online	498 (55.2 %)

3. Results

A description of the study population (n = 893) and demographic and clinical covariates are shown in Table 1. For access to PPE at work, 69.9 %, 12.0 %, and 18.1 % of in-person workers reported having

Table 2
Unadjusted and adjusted[a] prevalence ratios for self-reported COVID-19 symptoms severity by access to PPE, healthcare worker, and sociodemographic and clinical covariates, MI CReSS (n = 893).

Variables	Unadjusted Prevalence Ratio (95 % CI)	P value	Adjusted[a] Prevalence Ratio (95 % CI)	P value	Adjusted[a] with Interaction Prevalence Ratio (95 % CI)	P value
Access to Adequate PPE						
Often-Always	1.00 (ref)	–	1.00 (ref)	–	1.00 (ref)	–
Sometimes	1.32 (1.02–1.72)	**0.036**	1.21 (0.93–1.58)	0.148	1.26 (0.90–1.77)	0.174
Never-Rarely	1.91 (1.59–2.28)	**<0.001**	1.25 (1.03–1.51)	**0.024**	1.37 (1.10–1.72)	**0.006**
Healthcare Worker Status						
No	1.00 (ref)	–	1.00 (ref)	–	1.00 (ref)	–
Yes	1.02 (0.85–1.23)	0.803	0.96 (0.79–1.17)	0.705	1.07 (0.83–1.39)	0.607
Healthcare Worker Status*Access to PPE		*0.122 (joint)*				*0.260 (joint)*
Often-Always	1.00 (ref)	–	–	–	1.00 (ref)	–
Sometimes	0.81 (0.47–1.39)	0.445	–	–	0.89 (0.53–1.48)	0.649
Never-Rarely	0.67 (0.45–1.00)	0.047	–	–	0.73 (0.49–1.09)	0.122
Sex						
Male	1.00 (ref)	–	1.00 (ref)	–	1.00 (ref)	–
Female	1.04 (0.87–1.24)	0.672	1.03 (0.86–1.24)	0.758	1.03 (0.85–1.23)	0.782
Age Group						
18–34	1.00 (ref)	–	1.00 (ref)	–	1.00 (ref)	–
35–44	1.25 (0.95–1.64)	0.119	1.05 (0.81–1.37)	0.707	1.06 (0.81–1.38)	0.688
45–54	1.54 (1.19–1.98)	**0.001**	1.22 (0.95–1.57)	0.113	1.23 (0.96–1.57)	0.105
55–64	1.78 (1.38–2.29)	**<0.001**	1.21 (0.94–1.55)	0.145	1.23 (0.96–1.59)	0.105
65+	1.71 (1.16–2.51)	**0.006**	1.40 (0.95–2.07)	0.091	1.40 (0.95–2.08)	0.091
Race/ethnicity						
Non-Hispanic White	1.00 (ref)	–	1.00 (ref)	–	1.00 (ref)	–
Hispanic	1.25 (0.93–1.66)	0.137	1.15 (0.86–1.52)	0.348	1.13 (0.85–1.50)	0.386
Non-Hispanic Black	1.83 (1.50–2.24)	**<0.001**	1.22 (0.98–1.53)	0.077	1.20 (0.96–1.50)	0.111
Another Race/Ethnicity	1.25 (0.95–1.63)	0.107	1.26 (0.97–1.63)	0.078	1.25 (0.97–1.62)	0.080
Annual household income						
<$35,000	1.00 (ref)	–	1.00 (ref)	–	1.00 (ref)	–
$35,000 - $74,999	0.98 (0.79–1.22)	0.887	0.99 (0.81–1.22)	0.954	0.99 (0.80–1.22)	0.913
$75,000	0.79 (0.63–0.98)	**0.034**	0.82 (0.67–1.02)	0.069	0.81 (0.66–1.01)	0.056
Body Mass Index						
Underweight/normal weight (BMI < 25)	1.00 (ref)	–	1.00 (ref)	–	1.00 (ref)	–
Overweight (BMI 25 to < 30)	1.59 (1.17–2.17)	**0.003**	1.39 (1.04–1.87)	**0.027**	1.39 (1.04–1.87)	**0.025**
Obese (BMI 30 +)	1.98 (1.48–2.64)	**<0.001**	1.45 (1.09–1.93)	**0.011**	1.45 (1.09–1.93)	**0.012**
Number of Comorbidities						
0	1.00 (ref)	–	1.00 (ref)	–	1.00 (ref)	–
1	1.37 (1.09–1.72)	**0.007**	1.23 (0.99–1.53)	0.061	1.22 (0.98–1.52)	0.074
2	1.49 (1.15–1.92)	**0.003**	1.21 (0.94–1.54)	0.134	1.19 (0.93–1.53)	0.159
3+	1.85 (1.45–2.35)	**<0.001**	1.24 (0.97–1.59)	0.089	1.23 (0.96–1.57)	0.107
Admittance to Hospital						
No	1.00 (ref)	–	1.00 (ref)	–	1.00 (ref)	–
Yes	2.47 (2.16–2.82)	**<0.001**	1.65 (1.40–1.95)	**<0.001**	1.65 (1.40–1.95)	**<0.001**

[a] Adjusted for all covariates: healthcare worker status, age, sex, race/ethnicity, body mass index, annual household income, number of comorbidities, admittance to hospital, survey mode, and sample wave.

adequate PPE often/always, sometimes, or never/rarely, respectively. About 40 % of the study population had self-reported severe symptoms and 30.1 % were in healthcare occupations.

Compared to respondents who often/always had adequate PPE while at work, respondents who rarely/never had adequate PPE had a 24.7 % higher prevalence of self-reported severe symptoms in the adjusted regression model (adjusted prevalence ratio (aPR): 1.25, 95 % CI 1.03–1.51, Table 2). Additionally, we found no evidence for effect modification between healthcare worker status and access to PPE while at work for self-reported symptom severity in either the unadjusted or adjusted models (joint p-value: 0.260, Table 2).

4. Discussion

4.1. Summary of findings

Using a population-based study of in-person workers diagnosed with COVID-19 in the state of Michigan, we found that workers without access to adequate PPE at work had a higher prevalence of self-reported severe COVID-19 symptoms. We did not find any evidence that healthcare worker status modified this association. These results suggest that adequate PPE may protect against severe COVID-19 illness if viral transmission occurs.

The majority of studies investigating the impact and benefits of PPE have focused on its role in reducing SARS-CoV-2 transmission alone (Lerner et al., 2020). However, consistent with our findings, one such study found that less access to PPE was associated with more severe and prolonged COVID-19 illness among healthcare workers (Kim et al., 2021). A potential mechanism for reduced symptom severity may be due to the reduced viral load during exposure. Studies on COVID-19 have shown that appropriate and adequate use of PPE reduced viral load at exposure (Guallar et al., 2020). Furthermore, several subsequent studies have investigated the relationship between SARS-CoV-2 viral load and clinical outcomes, including severity, hospitalizations, and mortality (Guallar et al., 2020; Ra et al., 2021; Shenoy, 2021; Argyropoulos et al., 2020).

While some studies did not find an association between viral load at exposure and specific clinical markers of severity, one study found that a greater viral load at exposure was associated with higher risk of severe COVID-19 illness (Guallar et al., 2020) and a systematic review provides support for the use of quantifying viral load in determining COVID-19 clinical prognoses (Shenoy, 2021). The observed impact of adequate PPE at work and reduced prevalence of severe symptoms in our study suggests an important benefit of PPE beyond reducing transmission risk.

We did not find that healthcare worker status modified the association between adequate PPE at work and severe symptoms. This finding suggests that the impact of PPE in reducing prevalence of severe symptoms does not diminish even for workers in high-risk settings with repeated SARS-CoV-2 exposure. This further strengthens the notion that access to adequate PPE, regardless of occupation, provides benefits to individuals even in extremely high-risk workplace settings.

4.2. Strengths and limitations

Because our sample only includes people who survived COVID-19, we were unable to assess any potential impact that differential mortality had on our results or measurement of severity. Similarly, we lacked a sufficient sample size to use a more clinical marker of severity such as hospitalization as our outcome measure, and instead used self-reported symptom severity. The portion of our sample with COVID-19 onset in the spring of 2020 was likely biased to more severe cases, as PCR-testing was limited at this time. Given our response rate of 31.8 %, our results may be subject to non-response bias. We also only have information regarding a respondent's access to PPE, and not the type of PPE available or whether the PPE was actually used appropriately, potentially leading to an overestimate of the effect of PPE on the outcome. Interpretation of "adequate" PPE may have differed by occupation type. The effect of PPE may be overestimated if respondents with severe symptoms were more likely to associate their illness with lack of PPE than respondents with mild symptoms. While we were able to investigate the effect of healthcare worker status, we were unable to explore differences among other occupations due to insufficient sample sizes. We were also unable to differentiate healthcare workers who worked directly with COVID-19 patients from healthcare workers who did not, as COVID-19 patients are often isolated in healthcare settings. Nevertheless, our study is unique in that our sample was not restricted to healthcare workers alone, as the majority of studies on this topic do. The population-based approach to our study sample allows our study to be more representative of all Michigan in-person workers diagnosed with COVID-19.

4.3. Conclusions

The majority of the studies on the benefits of PPE focus on risk of transmission alone. However, it is well known that PPE, including N95 masks and respirators, may not entirely eliminate the risk of transmission. Here, we showed that among in-person workers with COVID-19, lack of access to adequate PPE was associated with a higher prevalence of self-reported severe COVID-19 symptoms. This implies that the benefits of PPE extended beyond reducing transmission alone and affirms that access to adequate PPE was critical among in-person workers in both healthcare and non-healthcare settings.

Funding statement

Funding for the research presented in this manuscript is from: Michigan Department of Health and Human Services, Michigan Public Health Institute, University of Michigan Rogel Cancer Center, University of Michigan Institute for Data Science, and the University of Michigan School of Public Health Epidemiology Department.

CRediT authorship contribution statement

Elizabeth Slocum: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Project administration, Validation, Visualization. **Zoey Laskaris:** Conceptualization, Methodology, Data curation, Formal analysis, Validation, Visualization, Writing – original draft, Writing – review & editing. **Jana L. Hirschtick:** Conceptualization, Methodology, Writing – review & editing. **Patricia McKane:** Conceptualization, Methodology, Funding acquisition, Writing – review & editing. **Nancy L. Fleischer:** Conceptualization, Supervision, Methodology, Funding acquisition, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing.

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.

Data availability

The authors do not have permission to share data.

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