

American Frontline Healthcare Personnel's Access to and Use of Personal Protective Equipment Early in the COVID-19 Pandemic

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Objectives: To quantify adequacy of personal protective equipment (PPE) for U.S. healthcare personnel (HCP) at the outset of the COVID-19 pandemic and its association with infection risk. **Methods:** March–May 2020 survey of the national Nurses' Health Studies and the Growing Up Today study regarding self-reported PPE access, use, and reuse. COVID-19 endpoints included SARS-CoV-2 tests and COVID-19 status predicted from symptoms. **Results:** Nearly 22% of 22,232 frontline HCP interacting with COVID-19 patients reported sometimes or always lacking PPE. Fifty percent of HCP reported not needing respirators, including 13% of those working in COVID-19 units. Lack of PPE was cross-sectionally associated with two-fold or greater odds of COVID-19 among those who interacted with infected patients. **Conclusion:** These data show the need to improve the U.S. infection prevention culture of safety when confronting a novel pathogen.

Keywords: COVID-19, epidemiology, healthcare personnel, occupational health, personal protective equipment

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The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention. The authors report no conflicts of interest.

Clinical significance: In Spring 2020, many frontline HCP lacked access to or believed they did not need PPE that would protect them from COVID-19. The infection prevention culture of safety in the U.S. needs revisiting to ensure HCP are protected at the outset of the next epidemic with a novel pathogen. Supplemental digital contents are available for this article. Direct URL citation appears in the printed text and is provided in the HTML and PDF versions of this article on the journal's Web site (www.joem.org).

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Healthcare personnel (HCP) carry a heavy burden in the COVID-19 pandemic.^{1–3} In July 2020, HCP accounted for 18% of COVID-19 cases reported to the U.S. Centers for Disease Control and Prevention (CDC).⁴ The World Health Organization reported in September 2020 that one in seven cases worldwide were among HCP.⁵ A study in the U.K. and U.S. found that HCP were three times more likely than the general public to contract SARS-CoV-2, even after adjusting for their increased probability of receiving a test.⁶

However, research into factors affecting the risk of HCP acquiring COVID-19 has been scant. A lack of personal protective equipment (PPE) has been cited as a concern of HCP during the COVID-19 pandemic.⁷ Widespread shortages of PPE⁸ led both the U.S. Food and Drug Administration and CDC to issue emergency authorizations or guidance for extended use, reuse, or substitution of foreign-certified PPE in healthcare facilities when conventional strategies, such as reducing face-to-face interactions and using barriers, were insufficient to reduce the burn rate of PPE below the anticipated supply rate.^{9,10}

Anecdotal reports suggest PPE shortages and reuse exist,¹¹ principally for N95 respirators. However, there are few peer-reviewed national surveys of PPE access, use, and reuse in the United States,^{6,12,13} and no systematic information on where in the healthcare system shortages exist. We conducted a survey of PPE access, use, and reuse by clinical worksite and the association of these exposure controls with risk of COVID-19 within three large U.S. cohorts of working and retired nurses and their families.

METHODS

Study Population

In April 2020, we launched a series of surveys regarding participants' experiences during the pandemic within three longitudinal national cohorts: NHSII, NHS3, and the GUTS (see Supplemental Digital Methods, <http://links.lww.com/JOM/A954>).¹⁴ During April 21–May 16, 2020, we invited participants who had returned the most recent primary cohort questionnaires to complete a supplementary COVID-19 survey. Exclusions, such as lack of a valid email address, are detailed in Figure 1. Reminders were sent to non-respondents after 3 and 10 days. Of 105,662 invited participants, 58,606 (55%) completed the baseline survey. We restricted this analysis to 56,756 participants living in the United States and its territories who returned their survey by May 31, 2020.

Measurement of Covariates

Using residential zip-code and date of survey completion, we used county- and date-specific COVID-19 mortality data from the COVID-19 Data Repository by the Center for Systems Science and Engineering at Johns Hopkins University¹⁵ to derive a measure of local COVID-19 burden at the time of questionnaire completion. Based on an estimated 13-day median hospital stay for fatal COVID-19,¹⁶ we reasoned that the COVID-19 mortality over the next 13 days would represent the burden on local healthcare systems

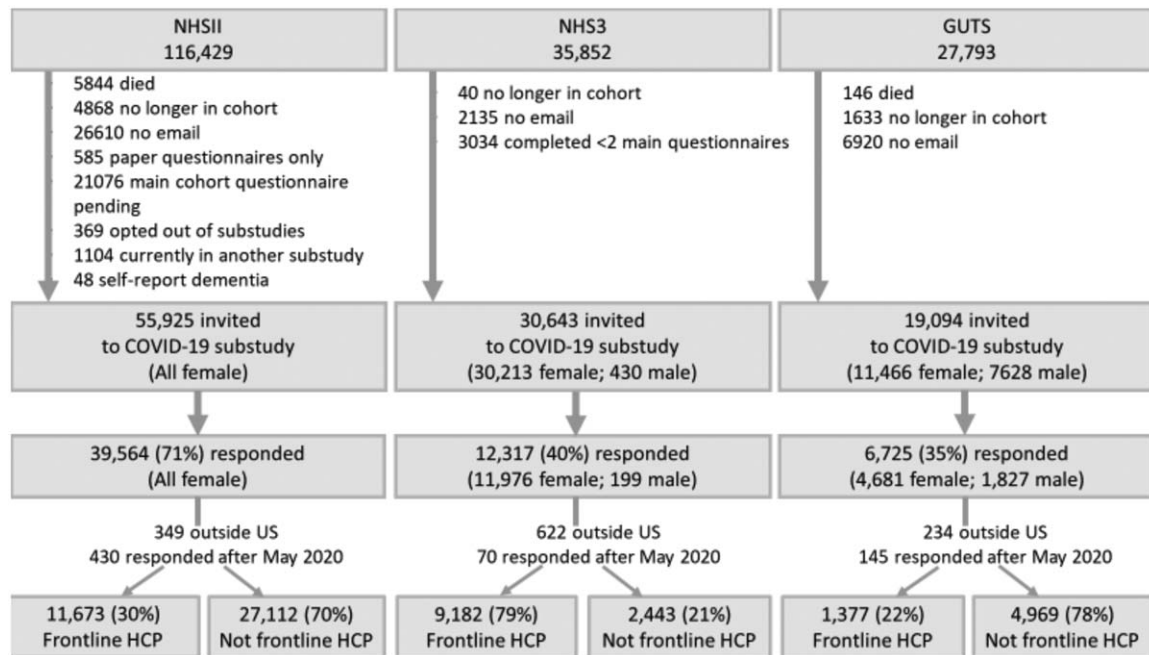


FIGURE 1. Participant flow for invitation to COVID-19 survey and inclusion in the current analysis.

on any given date. This measure was chosen over counts of COVID-19 cases (as testing was limited) or hospitalization rates (as data quality was inconsistent).

Participants indicated their occupational status and type of clinical worksite between March 1 and survey return. Frontline HCP were considered those who physically worked or volunteered at a worksite providing clinical care, regardless of the extent of their patient interaction. Although frontline HCP were predominantly nurses, they also included other licensed clinicians and healthcare providers. We asked frontline HCP to report their interaction with patients with documented or presumed COVID-19, and all participants about their interaction with people (other than patients) with COVID-19.

We assessed PPE access, use, and reuse—including gloves, protective gowns, face shield or goggles, N95 respirators, powered air-purifying respirators (PAPRs), and surgical masks (sometimes called medical masks) from March 1, 2020 to when the participant returned the survey during April–May 2020 (see Supplemental Digital Methods for questions, <http://links.lww.com/JOM/A954>). We considered respiratory protection to include N95s and PAPRs; while surgical masks prevent spread to others and can protect the wearer from large droplets, they are not designed to protect the wearer from inhaling airborne viruses.¹⁷ Participants who indicated they “sometimes” or “never” used an item were asked whether this was because they did not need it or it was unavailable. Lack of a PPE item was defined if it was sometimes or never used and it was unavailable. A summary variable representing overall PPE access was defined as “Always” if no PPE item was lacking; “Sometimes” if any item was used inconsistently because it was lacking; and “Never” if any item was never used because it was lacking (details in Supplemental Digital Methods, <http://links.lww.com/JOM/A954>). We also queried whether PPE was reused with or without disinfection.

Only 7.4% of participants reported having been tested for SARS-CoV-2 infection (test of current infection or antibodies indicating recent infection); we combined reports of positive infection and antibody tests as a composite endpoint. Participants indicated COVID-19 symptoms experienced since March 1, 2020; from this, we derived a symptom-predicted COVID-19 status predictive of a positive

SARS-CoV-2 test, following the method of Menni and colleagues (Supplemental Digital Methods, <http://links.lww.com/JOM/A954>).¹⁸

Statistical Analysis

Fisher’s exact test was used to compare distribution of PPE access, use, and reuse across categories. We examined the odds of SARS-CoV-2 infection/antibodies and of symptom-predicted COVID-19 by frontline HCP status and PPE access using logistic regression models adjusted for COVID-19 risk factors, including age, sex, race, body mass index, current cigarette smoking, and history of interaction with people other than patients with COVID-19 (parameterizations in table footnotes); in sensitivity analyses we replaced the interaction history variable with county COVID-19 mortality rate. We also examined the joint exposure of PPE access and interaction with patients with COVID-19; for these models to converge, we dichotomized race into White or other and excluded the small numbers of men. Interaction between these exposures was measured by comparing the likelihood ratio test of nested models with PPE access and patient interaction as independent exposures versus jointly modeled categories of PPE access/patient interaction. Analyses were performed using SAS 9.4 (SAS Institute, Cary, NC); *P*-values < 0.05 were considered statistically significant.

Ethical Approval

The study was approved as Protocol 2020P001020 of the Institutional Review Board of Brigham and Women’s Hospital in Boston, Massachusetts, which allowed voluntary survey completion to represent participant consent. This activity was reviewed by CDC and was conducted consistent with applicable federal law and CDC policy.¹⁹

RESULTS

Population Characteristics

Age-standardized characteristics of survey respondents are shown in Table 1 and their geographic distribution in Supplemental Digital Figure 1, <http://links.lww.com/JOM/A955>. The mean age of frontline HCP was 52 years; 90% (*n* = 20,297) were nurses. Because

TABLE 1. Age-standardized* Characteristics of Participants to Baseline COVID-19 Survey During April–May 2020 Regarding Their Occupational Exposures Since March 1, 2020

	Frontline Healthcare Personnel Since March 1, 2020	Not Frontline Healthcare Personnel Since March 1, 2020
<i>n</i> (%)	22,232 (39%)	34,524 (61%)
Age (mean years, s.d.) [†]	51.7 (12.9)	59.8 (13.4)
Cohort, <i>N</i> (%)		
Nurses' Health Study II	11,673 (68)	27,112 (68)
Nurses' Health Study 3	9,182 (26)	2,443 (15)
Growing Up Today Study	1,377 (5)	4,969 (16)
Sex, race, and ethnicity, <i>N</i> (%)		
Women	21,959 (99)	33,024 (95)
White	21,307 (96)	33,433 (97)
Hispanic	118 (0.4)	78 (0.3)
Black	312 (1)	370 (1)
Asian	342 (1)	411 (1)
Other race	153 (1)	232 (1)
Clinical site of frontline Healthcare personnel (HCP), <i>N</i> (%)		
ER, OR, ICU	4,975 (19)	–
Other hospital inpatient	5,087 (22)	–
Dedicated COVID-19 unit	943 (4)	–
Outpatient clinic in hospital	2,911 (13)	–
Outpatient clinic outside hospital	3,628 (17)	–
Group care facility	1,056 (7)	–
Home health	1,110 (6)	–
School clinic	827 (4)	–
Other clinical site	1,695 (9)	–
Current or most recent occupation, <i>N</i> (%)		
LPN or ADN	248 (1)	250 (1)
BSN or RN	13,470 (67)	24,460 (72)
Advanced practice nurse (NP or CNM)	2,708 (12)	1,718 (5)
Nurse, unknown type	3,871 (11)	787 (5)
Other licensed clinician (MD, DDM, PA, other licensed clinician)	479 (2)	362 (1)
Other HCP (MA, EMT, EMR, paramedic, other HCP, HCP of unknown type)	1,456 (7)	408 (1)
Other or Never worked in healthcare	–	4,067 (12)
Missing	–	2,472 (8)
Next 13-day county COVID-19 mortality/10,000, <i>N</i> (%) [‡]		
0	4,135 (19)	6,681 (19)
>0 to <0.25	6,367 (29)	10,789 (32)
0.25 to <0.75	5,122 (24)	8,256 (24)
0.75 to <2	4,258 (20)	6,397 (19)
2 to <4	1,625 (7)	1,408 (4)
4–7.80	357 (2)	470 (1)
Missing	368 (2)	523 (2)
Interaction of frontline HCP with patients with COVID-19 infection, <i>N</i> (%)		
Patients with documented infection	2,658 (10)	–
Patients with presumed infection	5,092 (19)	–
Not that I know of	12,210 (58)	–
Do not work directly with patients	2,196 (12)	–
Missing	76 (0.4)	–
Interaction with individuals (other than patients) with COVID-19 infection, <i>N</i> (%)		
People with documented infection	2,841 (11)	1,130 (4)
People with presumed infection	1,283 (5)	1,074 (4)
Not that I know of	17,999 (83)	32,204 (92)
Missing	109 (1)	116 (0.3)
COVID-19 status, <i>N</i> (%)		
Tested for SARS-CoV-2 antibodies or infection	2,900 (12)	1,325 (4)
Positive test for SARS-CoV-2 antibodies or infection	321 (1)	89 (0.3)
Symptom-predicted COVID-19 case	1,037 (5)	1,074 (3)

ADN, associate degree in nursing; BSN, bachelor of science in nursing; CNM, certified nurse midwife; DDM, doctor of dental medicine; EMR, emergency medical responder; EMT, emergency medical technician; ER, emergency room; HCP, healthcare personnel; ICU, intensive care unit; LPN, licensed practical nurse; MA, medical assistant; MD, medical doctor; NP, nurse practitioner; OR, operating room; PA, physician's assistant; RN, registered nurse; s.d., standard deviation.

*Means and percentages are standardized to the age distribution of the study population.

[†]Value is not age-adjusted.

[‡]Dong E, Du H, Gardner L. An interactive web-based dashboard to track COVID-19 in real time. *Lancet Inf Dis.* 20(5):533–534. doi: 10.1016/S1473-3099(20)30120-1.

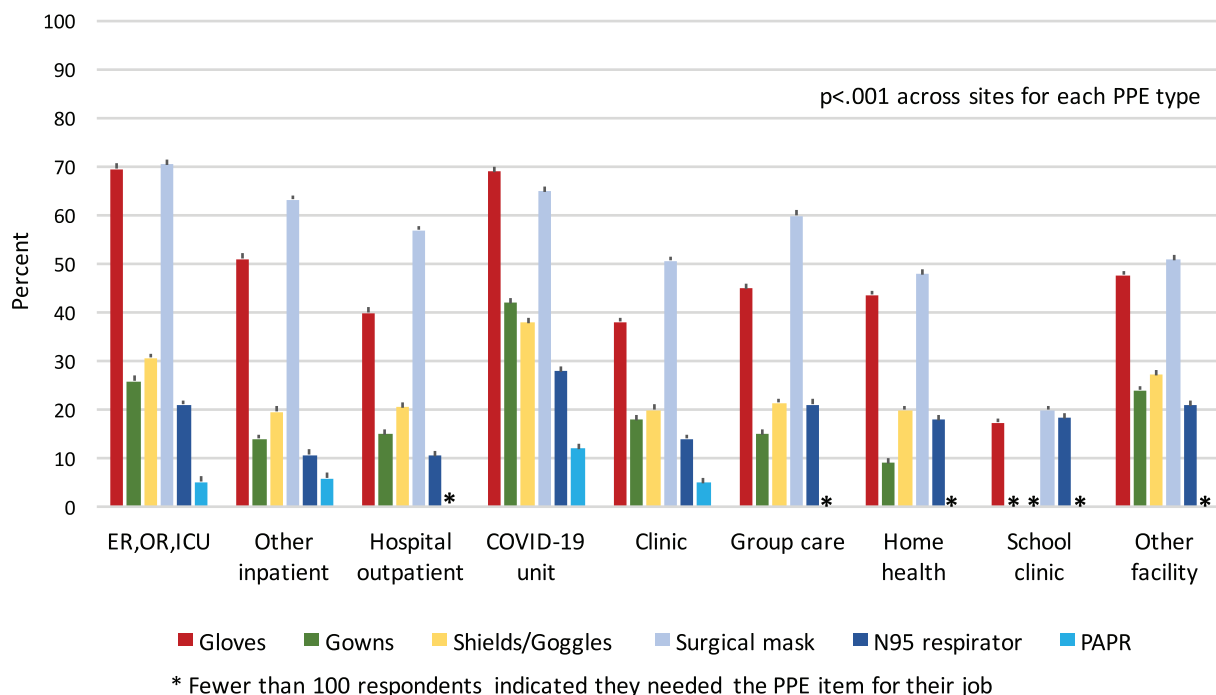


FIGURE 2. Proportion (S.E.) of frontline healthcare personnel during March–May 2020 who always used personal protective equipment (PPE) items, among those who indicated they needed the item for their job, by worksite.

NHSII and NHS3 are predominantly female cohorts, almost all (97%, $n = 54,740$) of participants were female. Among those who were not frontline HCP, 79% ($n = 27,215$) were nurses who were retired, on leave, or working remotely. Ten percent ($n = 2658$) of frontline HCP reported interacting with patients with documented COVID-19 infection. Frontline HCP were more likely than participants who were not frontline HCP to report having interacted with people, other than patients, with COVID-19. Twelve percent ($n = 2900$) of frontline HCP and 4% ($n = 1325$) of those who were not frontline HCP had been tested for SARS-CoV-2 infection or antibodies, with 1% ($n = 321$) of frontline HCP reporting a positive test. Five percent ($n = 1037$) of frontline HCP and 3% ($n = 1074$) of the other survey respondents were positive for symptom-predicted COVID-19.

Use of PPE

Figure 2 displays the proportion of frontline HCP in each clinical setting who reported that they always used specific PPE items. This proportion varied by clinical setting (Fig. 2, $P < 0.001$ for each PPE item), and was generally higher in hospitals and dedicated COVID-19 units, and lowest in home health and school clinics. “Always use” of gloves ranged from 51% to 70% (n ranged from 609 to 3341) at hospital inpatient sites and dedicated COVID-19 units, compared with 38% to 45% (n ranged from 359 to 1153) in outpatient clinics, group care, and home health settings. Only 17% ($n = 113$) of participants working in school clinics reported they always used gloves. Face shields and/or goggles were always used by less than 30% of frontline HCP, except those working in the emergency room (ER), operating room (OR), intensive care unit (ICU), or in dedicated COVID-19 units.

Figure 3 displays, for each clinical site, the proportions of frontline HCP who reported that they always, sometimes, or never used an N95 respirator or PAPR at work, as well the proportions who indicated that they did not need either type of respirator for their job. Of all frontline HCP, 13% ($n = 2774$) reported they always used and another 33% ($n = 7384$) reported they sometimes used respiratory protection. Use of respirators varied by work setting (Fig. 3).

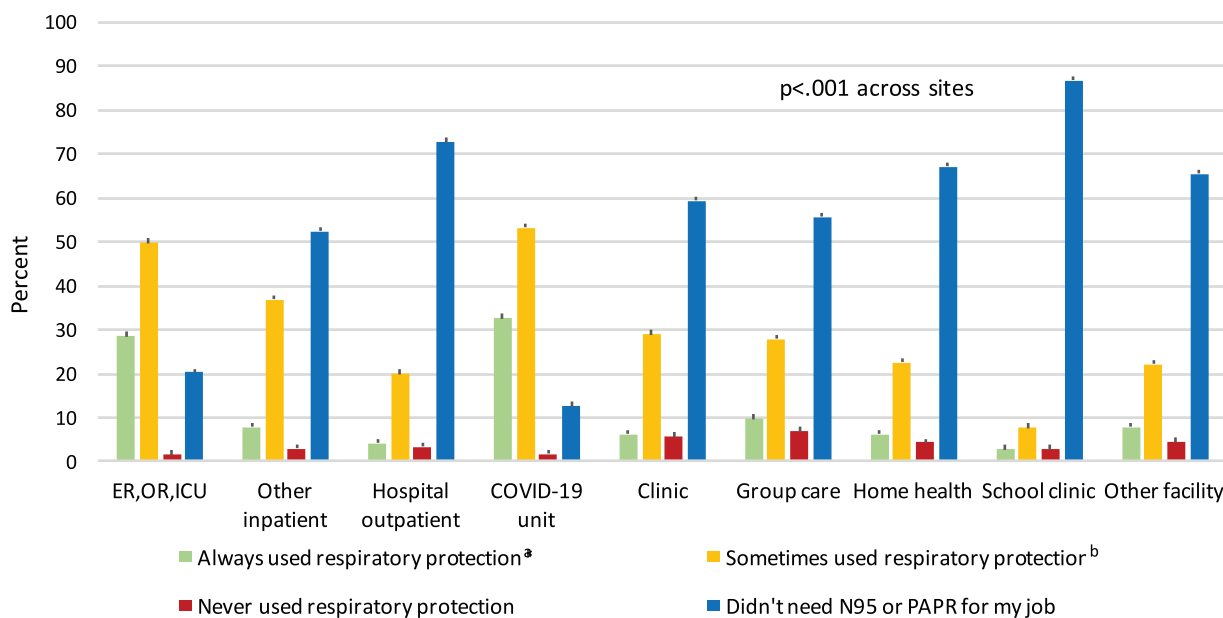
“Always use” ranged from 3% ($n = 23$) in schools to 33% ($n = 304$) in COVID-19 units, and combined “sometimes or always use” ranged from 11% (schools, $n = 86$) to 86% (COVID-19 units, $n = 799$). The proportions of frontline HCP who reported “never use” of respirators were small compared to the proportions who instead reported they did not need respirators at work. During March to May 2020, 50% ($n = 11,093$) of HCP indicated they did not need respirators. This included 20% ($n = 997$) of HCP in ER, OR, or ICU sites and 13% ($n = 117$) in COVID-19 units, as well as 52% to 73% of HCP in other hospital inpatient, outpatient and group care sites (Fig. 3, n ranged from 582 to 2641). Sixty-seven percent ($n = 736$) of HCP in home health and 87% ($n = 709$) in school clinics reported they did not need either surgical masks or respirators.

Access to PPE

The proportion of frontline HCP who sometimes or always lacked needed PPE varied by worksite, and exceeded 20% (n ranged from 789 to 4239) in COVID-19 units, group care settings, and ER, OR, and ICU units (Supplemental Digital Fig. 2, <http://links.lww.com/JOM/A955>, $P < 0.001$). Fewer than 3% (n ranged from 4 to 119) of HCP at any site reported lacking gloves (Supplemental Digital Fig. 3, <http://links.lww.com/JOM/A955>). Across all settings, 11% to 29% (n ranged from 24 to 405) of HCP reported they sometimes or always lacked N95 respirators necessary for their duties. In hospital inpatient settings and dedicated COVID-19 units, 35% to 45% (n ranged from 82 to 444) reported they sometimes or always lacked PAPRs (Supplemental Digital Fig. 3, <http://links.lww.com/JOM/A955>); in most other settings, few indicated they needed a PAPR for their job (Supplemental Digital Fig. 4, <http://links.lww.com/JOM/A955>). Reuse of PPE ranged widely (Table 2), including 60% ($n = 11,704$) who reused surgical masks and 79% ($n = 8077$) who reused N95s, usually without disinfection.

PPE Fitting and Training

Among frontline HCP who indicated they needed an N95 (regardless of whether it was currently available), 51% ($n = 10,356$)



^aIndicated always used N95 respirator or always used PAPR or that they sometimes used both N95 and PAPR
^bIndicated sometimes used N95 and did not use PAPR, or sometimes used PAPR and did not use N95

FIGURE 3. Proportion (S.E.) for use of N95 respirator and/or PAPR (powered air-purifying respirator) among frontline healthcare personnel, during March–May 2020, by worksite.

reported being fit-tested in the past year, 33% (*n* = 6677) more than a year ago, and 17% (*n* = 3456) had never been fit-tested. Most (63%, *n* = 13,432) had been trained in PPE donning and doffing procedures within the past year, 31% (*n* = 6487) longer than a year ago, and 6% (*n* = 1292) had never been trained.

PPE Use and Access by COVID-19 Contact

Of frontline HCP who worked directly with patients, most (61%, *n* = 12,210) reported that they had not treated patients with COVID-19 that they knew of, 13% (*n* = 2658) had treated patients with documented infection, and 26% (*n* = 5092) with presumed infection. “Always use” of PPE was highest among HCP who interacted with patients with documented infection (Supplemental Digital Fig. 5, <http://links.lww.com/JOM/A955>, *P* < 0.001 for gloves, gowns, N95 respirators and PAPRs; *P* = 0.04 for surgical masks); however, more than 30% (*n* ranged from 705 to 859) reported that they did not always use gloves, gowns, or face shields/goggles. Nearly 22% (*n* = 542) of HCP treating patients

with documented COVID-19 reported that they sometimes or always lacked at least one type of PPE needed for work (Supplemental Digital Fig. 6, <http://links.lww.com/JOM/A955>).

SARS-Cov-2 Infection

Among survey respondents tested for SARS-CoV-2 infection or antibodies, frontline HCP had 84% (95% confidence interval [CI] for odds ratio, 1.43 to 2.38) higher odds of having received a positive test compared with respondents who were not frontline HCP (Supplemental Digital Table 1, <http://links.lww.com/JOM/A955>). The association weakened (odds ratio 1.45; 95% CI, 1.12 to 1.89) after accounting for interactions with people (other than patients) with COVID-19. Among the entire baseline cohort, frontline HCP had a fully adjusted odds ratio of 1.34 (95% CI, 1.22 to 1.48) for symptom-predicted COVID-19 compared with those who were not frontline HCP.

Among frontline HCP, those who always lacked at least one item of PPE had a fully adjusted odds ratio of 1.60 (95% CI, 1.10 to

TABLE 2. Reuse of Personal Protective Equipment Among Frontline Healthcare Personnel (A) and Among Frontline Healthcare Personnel Who Sometimes or Always Lacked Each Item of Personal Protective Equipment (B)

	Never Had to Reuse Item	Reused Items After Disinfection	Reused Items Without Disinfection
A. Among frontline healthcare personnel			
Gloves	18,069 (97%)	290 (2%)	243 (1%)
Gowns	9,598 (78%)	646 (5%)	2,052 (17%)
Surgical masks	7,211 (39%)	749 (4%)	10,325 (56%)
N95 respirators	2,174 (21%)	1,755 (17%)	6,322 (62%)
B. Among frontline healthcare personnel who sometimes or always lacked the item			
Gloves	83 (80%)	12 (12%)	9 (9%)
Gowns	298 (48%)	42 (7%)	278 (45%)
Surgical masks	172 (15%)	38 (3%)	976 (82%)
N95 respirators	316 (21%)	138 (9%)	1,085 (70%)

TABLE 3. Odds Ratio (95% CI) For COVID-19 Outcomes Among U.S. Frontline Healthcare Personnel by Lack of PPE and Interaction With Patients With COVID-19 Infection, March–May 2020

	Interaction With Patients With COVID-19 Infection					
	No Known Interaction		Interaction With Presumed Cases		Interaction With Documented Cases	
	Cases/n	OR (95% CI)*	Cases/n	OR (95% CI)*	Cases/n	OR (95% CI)*
Outcome: Tested positive for SARS-CoV-2 infection or antibodies						
Never lack PPE	59/864	1.0 (ref)	81/569	1.95 (1.35–2.82)	56/460	1.40 (0.94–2.09)
Sometimes lack PPE	4/94	0.57 (0.20–1.63)	19/137	2.01 (1.13–3.57)	14/89	2.07 (1.08–3.96)
Always lack PPE	10/74	2.03 (0.97–4.25)	19/108	2.33 (1.30–4.19)	14/73	2.22 (1.15–4.30)
<i>P</i> -value for interaction < 0.001						
Outcome: Symptom-predicted COVID-19						
Never lack PPE	298/9116	1.0 (ref)	188/3472	2.69 (1.89–3.83)	115/1909	2.75 (1.87–4.04)
Sometimes lack PPE	40/861	0.66 (0.24–1.84)	53/731	3.14 (1.83–5.41)	26/282	5.00 (2.70–9.27)
Always lack PPE	45/654	2.30 (1.17–4.54)	55/575	3.51 (2.04–6.05)	38/252	4.69 (2.53–8.69)
<i>P</i> -value for interaction < 0.001						

CI, confidence interval; OR, odds ratio; PPE, personal protective equipment; ref, reference group.

*Adjusted for age (continuous), race (White or other), body mass index (continuous), current smoking (yes/no), and interaction with people other than patients with presumed or documented COVID-19 (yes, documented; yes, presumed; not that I know of). Men were excluded to permit model convergence.

2.31) for positive SARS-CoV-2 test and 1.85 (95% CI, 1.32 to 2.60) for symptom-predicted COVID-19 (Supplemental Digital Table 2, <http://links.lww.com/JOM/A955>). HCP who treated patients with presumed or documented COVID-19 infection had odds ratios of 1.96 (95% CI, 1.42 to 2.71) and 1.56 (95% CI, 1.10 to 2.20) for positive SARS-CoV-2 results, respectively, and roughly three-fold odds of symptom-predicted COVID-19 compared with HCP without known interaction with COVID-19 patients (Supplemental Digital Table 3, <http://links.lww.com/JOM/A955>).

Compared with those who never lacked PPE and had no known interaction with patients with COVID-19, every group of HCP who sometimes or always lacked PPE and treated patients with presumed or documented infection had double the odds of testing positive for SARS-CoV-2 and three to five times the odds of symptom-predicted COVID-19 (Table 3); these exposures had a synergistic effect ($P < .001$), so that the 1% to 3% (n ranged from 73 to 252) of frontline HCP who always lacked PPE and had treated patients with documented COVID-19 had an odds ratio of 2.22 (95% CI, 1.15 to 4.30) for testing positive and 4.69 (95% CI, 2.53 to 8.69) for symptom-predicted COVID-19.

Models controlled for county-level mortality rather than self-reported interaction with people with COVID-19 infection almost always yielded higher odds ratios for SARS-CoV-2 infection or COVID-19 than models adjusted for self-reported interaction (Supplemental Digital Table 4, <http://links.lww.com/JOM/A955>).

DISCUSSION

In our cross-sectional survey of 22,232 frontline HCP in the U.S. during March to May 2020, access to PPE and PPE use varied widely across clinical settings and was less consistently available in non-hospital settings. Among frontline HCPs in every setting, 11% to 29% reported they did not use N95s because they were unavailable. Frontline HCP who reported lacking PPE access, particularly those reporting having interacted with infected patients, were at increased risk of COVID-19.

In our sample, nearly 80% of frontline HCP reported reusing N95s, and 62% reused N95s without disinfection. This is similar to results reported by the ANA in two large online convenience sample surveys (in a non-peer-reviewed online publication).^{11,20} In May 2020, 45% of 14,328 nurses reported PPE shortages, with 79% reusing single-use PPE like N95s.¹¹ Two months later, PPE

shortages increased, reported by 63% of 23,207 nurses; 68% reported reusing N95s without disinfection.²⁰ A survey of 91 residency program directors in New York City in early April 2020 found that 99% reported their program was reusing masks or extending their use beyond the normal period.²¹ A small ($n = 192$) survey of emergency medical service workers from across the U.S. conducted in April 2020 found that only 48% reported access to N95 respirators when needed, and only 15% reported being able to change the respirator after each patient encounter.²² Shortages of PPE were common across the globe; an April 2020 survey of 2711 HCP on five continents found that 52% reported that at least one piece of standard PPE was not available when needed, and 30% reported reusing single-use PPE.¹³ Our survey showed higher shortages and reuse of PPE compared to a survey of over 100,000 healthcare professionals in the UK and US in March 2020, in which 17% of those working in nursing homes and 12% of those working in inpatient or outpatient hospital facilities reported having inadequate access to PPE; however, data were not reported by country (85.4% of participants were from the U.K.).⁶ Consistent with patterns of availability in our study, PPE use was especially low in outpatient clinics, group care facilities, home health care, and schools. Even in dedicated COVID-19 units, only 33% reported they always used N95 or higher-level respiratory protection as recommended. We did not identify any other studies in the United States that examined PPE use among HCP in these settings.

Limited PPE access contributed to the “sometimes” or “never” use of recommended PPE, but additional reasons are suggested by the data. At this early point in the pandemic, 20% of frontline HCP in the ER, OR, or ICU, and 13% in dedicated COVID-19 units indicated they did not need respiratory protection. A 2007 CDC guideline recommended respiratory protection for HCP in the face of emerging infectious diseases²³; however, the broad guidance, meant to cover all infectious disease, left room for interpretation of which HCP roles required respiratory protection. In January 2020, the CDC guidance was updated to be explicit for HCP entering rooms with COVID-19 patients. In April 2020, interim CDC guidance recommended that HCP who interact with patients wear surgical masks or respirators, with specific PPE requirements dependent on risk of infection associated with HCP tasks and on PPE availability.²⁴ This evolving guidance, based on available evidence at the time, might partially explain why, during our survey

in March to May, many HCP indicated they did not think facemasks were needed for their jobs. At that point, most (61%) frontline HCP reported they had not treated patients with COVID-19 that they knew of, suggesting that a lower perceived risk, as well as lack of PPE, might have contributed to the incomplete use of PPE. It is possible that some HCP, knowing a shortage existed, reported they did not need PPE because they perceived other coworkers were prioritized as needing it more. A convenience sample of HCP in June–July of 2020 in the United States found that adherence to recommended PPE (based on type of patient contact) ranged from 42.5% to 86.5% depending on state, HCP role, and type of contact¹²; however, this survey did not assess whether PPE was available to these staff. As many factors contribute to worker awareness and adherence, these surveys suggest the need to revisit policy, guidance, and education at all levels—institutional, federal, and global—to promote a culture of safety that anticipates the spread of a virus that threatens HCP interacting with infectious but asymptomatic patients.^{25,26}

As observed elsewhere, frontline HCP were at increased risk of testing positive for SARS-CoV-2 infection or having symptoms consistent with COVID-19, although we found lower relative risk than reported by the U.S./U.K. study.⁶ Similar to our findings, a German study found that HCP who reported contact with COVID-19 patients without adequate PPE had higher seroprevalence than HCP who did not report unprotected contact (odds ratio 4.77; 95% CI, 3.09 to 7.22).²⁷ In our cohort, frontline HCP who always lacked PPE access were 60% and 85% more likely, respectively, to have tested positive or to have had symptom-predicted COVID-19, compared to those who never lacked PPE. This is consistent with the U.S./U.K. study's report of a 31% increased risk of infection among frontline workers with inadequate PPE,⁶ especially considering that their definition of inadequate PPE likely included those we defined as “sometimes” lacking PPE.

Caution must be exercised in interpreting the associations of occupational exposures and COVID-19 outcomes as causal. Exposures and outcomes “since March 1, 2020” were collected on the same baseline questionnaire. Thus, recall of PPE availability and patient contact might be biased by knowledge of one's own COVID-19 status, possibly explaining these associations. However, the magnitude of observed associations was comparable with, or weaker than, those reported elsewhere. This was particularly true after adjusting for contact with people with COVID-19 other than patients; to the extent that this adjusted for interaction with colleagues with COVID-19, it might be a conservative estimate of workplace risk. The higher odds ratios we observed when we adjusted for county mortality instead of non-patient interaction suggest this might be true. It should also be noted that our comparison group of non-frontline HCP was comprised mostly of nurses who were either retired or working remotely. This well-informed comparison group might be less likely than the general public to contract COVID-19; our estimates might be dampened compared with those with the general public as comparator.

This work has several limitations. We lacked data on specific tasks, such as aerosol-generating medical procedures. We asked participants to recall exposures that were likely changing during the survey's 6- to 8-week recall period. Participants applied their own interpretation of always, sometimes, or never PPE use, limiting conclusions that can be drawn using those categorizations. Nevertheless, even combined “sometimes” and “always” use was often low. Our definition of lacking necessary PPE was conservative, as we excluded from the definition any item that participants indicated they did not need.

Strengths of the study include its very large sample size, variation in work setting, assessment of various types of PPE, national representation, and the adjustment for county-level COVID-19 mortality as well as participant contact with people

other than patients with COVID-19. Although testing was not widely available during this period, we derived a symptom-predicted measure of COVID-19 infection that could be applied to the entire cohort. To our knowledge, this is the most complete survey in the U.S. of PPE use and access early in the COVID-19 pandemic; the ongoing survey will determine the extent to which these early conditions are generalizable over time. While the reasons underlying the shortages of PPE were complex,^{28,29} this information demonstrates the impact on workers of PPE shortages early in a pandemic and can help inform discussions on preventing future shortages during public health emergencies.

CONCLUSION

This study suggests that many frontline HCP in the early part of the pandemic lacked PPE, and those who reported lacking PPE were more likely to have had COVID-19. Furthermore, many frontline HCP in Spring 2020 did not feel they needed respiratory protection. These findings underscore the need to revisit the infection prevention culture of safety in U.S. healthcare delivery to ensure nurses and other HCP are protected by PPE at the outset of the next epidemic with a novel pathogen.

REFERENCES

- Rudberg A-S, Havervall S, Månberg A, et al. SARS-CoV-2 exposure, symptoms and seroprevalence in healthcare workers in Sweden. *Nat Commun*. 2020;11:5064. DOI 10.1038/s41467-020-18848-0.
- Vahidy FS, Bernard DW, Boom ML, et al. Prevalence of SARS-CoV-2 infection among asymptomatic health care workers in the Greater Houston, Texas, area. *JAMA Netw Open*. 2020;3:e2016451. DOI 10.1001/jamanetworkopen.2020.16451.
- Iversen K, Bundgaard H, Hasselbalch RB, et al. Risk of COVID-19 in health-care workers in Denmark: an observational cohort study. *Lancet Infect Dis*. 2020;20:1401–1408.
- Hughes MM, Groenewold MR, Lessem SE, et al. Update: characteristics of health care personnel with COVID-19—United States, February 12–July 16, 2020. *Morb Mort Wkly Rep*. 2020;69:1364–1368.
- World Health Organization. *Keep Health Workers Safe to Keep Patients Safe*. WHO Geneva: World Health Organization; 2020 [cited 2020 11/23/2020]. Available from: <https://www.who.int/news/item/17-09-2020-keep-health-workers-safe-to-keep-patients-safe-who>.
- Nguyen LH, Drew DA, Graham MS, et al. Risk of COVID-19 among front-line health-care workers and the general community: a prospective cohort study. *Lancet Public Health*. 2020;5:e475–e483.
- Arnetz JE, Goetz CM, Arnetz BB, Arble E. Nurse reports of stressful situations during the COVID-19 pandemic: qualitative analysis of survey responses. *Int J Environ Res Public Health*. 2020;17:8126. DOI 10.3390/ijerph17218126. Epub 2020/11/07.
- World Health Organization. *Shortage of Personal Protective Equipment Endangering Health Workers Worldwide [Internet]. WHO Calls on Industry and Governments to Increase Manufacturing by 40 Per cent to Meet Rising Global Demand; 03/03/2010 [cited 06/09/2021]*. Geneva, Switzerland: World Health Organization; 2020 , Available from: <https://www.who.int/news/item/03-03-2020-shortage-of-personal-protective-equipment-endangering-health-workers-worldwide>.
- National Center for Immunization and Respiratory Diseases (NCIRD). *Strategies for Optimizing the Supply of N95 Respirators: Centers for Disease Control and Prevention; [updated 11/23/2020; cited 2020 12/14/2020]*; 2020, Available from: <https://www.cdc.gov/coronavirus/2019-ncov/hcp/respirators-strategy/>.
- United States Food and Drug Administration. *Personal Protective Equipment EUAs: [updated 12/14/2020; cited 2020 12/14/2020]*; 2020, Available from: <https://www.fda.gov/medical-devices/coronavirus-disease-2019-covid-19-emergency-use-authorizations-medical-devices/personal-protective-equipment-euas>.
- American Nurses Association. *Personal Protective Equipment Survey – May 2020 [Internet]. American Nurses Association; 06/03/2020 [cited 12/04/2020]*; 2020, Available from: <https://www.nursingworld.org/news/news-releases/2020/ana-survey-of-14k-nurses-finds-access-to-ppe-remains-a-top-concern/>.
- Darwish OA, Aggarwal A, Karvar M, et al. Adherence to personal protective equipment guidelines during the COVID-19 pandemic among healthcare personnel in the United States. *Disaster Med Public Health Prep*. 2021;1–3. DOI 10.1017/dmp.2021.12. Epub 2021/01/09.

13. Tabah A, Ramanan M, Laupland KB, et al. Personal protective equipment and intensive care unit healthcare worker safety in the COVID-19 era (PPE-SAFE): an international survey. *J Crit Care.* 2020;59:70–75.
14. Bao Y, Bertoia ML, Lenart EB, et al. Origin, methods, and evolution of the three Nurses' Health Studies. *Am J Public Health.* 2016;106:1573–1581.
15. Dong E, Du H, Gardner L. An interactive web-based dashboard to track COVID-19 in real time. *Lancet Infect Dis.* 2020;20:533–534.
16. Lewnard JA, Liu VX, Jackson ML, et al. Incidence, clinical outcomes, and transmission dynamics of severe Coronavirus Disease 2019 in California and Washington: prospective cohort study. *BMJ.* 2020;369:m1923. DOI 10.1136/bmj.m1923.
17. United States Centers for Disease Control and Prevention. *Personal Protective Equipment: Questions and Answers*; [updated 08/08/2020; cited 2021 02/01/2021]; 2020, Available from: <https://www.cdc.gov/coronavirus/2019-ncov/hcp/respirator-use-faq.html>.
18. Menni C, Valdes AM, Freidin MB, et al. Real-time tracking of self-reported symptoms to predict potential COVID-19. *Nat Med.* 2020;26:1037–1040.
19. Office of the Federal Register and Government publishing Office. Electronic code of federal regulations. 45 C.F.R. Part 46.102(L)(2), 21 C.F.R. Part 56; 42 U.S.C. §241(D); 5 U.S.C. §552a; 44 U.S.C. §3501 Et Seq 2021 [updated 01/29/2021; cited 2021 02/02/2021]. Available from: <https://www.ecfr.gov/cgi-bin/ECFR?page=browse>.
20. American Nurses Association. *Survey of 14k Nurses Finds Access to PPE Remains a Top Concern*; 06/03/2020 [cited 12/04/2020]; 2020, Available from: <https://www.nursingworld.org/news/news-releases/2020/ana-survey-of-14k-nurses-finds-access-F17to-ppe-remains-a-top-concern/>.
21. Breazzano MP, Shen J, Abdelhakim AH, et al. New York City COVID-19 resident physician exposure during exponential phase of pandemic. *J Clin Investig.* 2020;130:4726–4733.
22. Gibson C, Ventura C, Collier GD. Emergency Medical Services resource capacity and competency amid COVID-19 in the United States: preliminary findings from a national survey. *Heliyon.* 2020;6:e03900. DOI 10.1016/j.heliyon.2020.e03900.
23. Siegel JD, Rhinehart E, Jackson M, Chiarello L. 2007 Guideline for isolation precautions: preventing transmission of infectious agents in health care settings. *Am J Infect Control.* 2007;35:S65–S164.
24. United States Centers for Disease Control and Prevention. *Interim Infection Prevention and Control Recommendations for Patients With Suspected or Confirmed Coronavirus Disease 2019 (COVID-19) in Healthcare Settings: CDC*; [updated 04/12/2020; cited 2021 01/22/2021]; 2020, Available from: <https://web.archive.org/web/20200414205034/https://www.cdc.gov/coronavirus/2019-ncov/hcp/infection-control-recommendations.html>.
25. Institute of Medicine. In: Goldfrank LR, Liverman CT, editors. *Preparing for an Influenza Pandemic: Personal Protective Equipment for Healthcare Workers*. Washington, DC: The National Academies Press; 2008. p. 206.
26. Braun B I, Tschurtz B A, Hafiz H, et al. Opportunities to bridge gaps between respiratory protection guidance and practice in US health care. *Infect Control Hosp Epidemiol.* 2019;40:476–481.
27. Erber J, Kappler V, Haller B, et al. Strategies for infection control and prevalence of anti-SARS-CoV-2 Igg in 4,554 employees of a university hospital in Munich, Germany. *medRxiv.* 2020.
28. Bhaskar S, Tan J, Bogers M, et al. At the epicenter of COVID-19 – the tragic failure of the global supply chain for medical supplies. *Front Public Health.* 2020;8:562882. DOI 10.3389/fpubh.2020.562882. Epub 2020/12/19. PubMed PMID: 33335876; PubMed Central PMCID: PMCPCMC7737425.
29. Cohen J, Rodgers YVM. Contributing factors to personal protective equipment shortages during the COVID-19 pandemic. *Prev Med.* 2020;141:106263. DOI 10.1016/j.ypmed.2020.106263. Epub 10/02. PubMed PMID: 33017601.