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# ORIGINAL RESEARCH

### Infectious Disease

# An international survey of healthcare workers use of personal protective equipment during the early stages of the COVID-19 pandemic

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## Abstract

**Objective:** Little is known regarding the specific ways personal protective equipment (PPE) has been used and reused during the coronavirus disease 2019 (COVID-19) pandemic. The objective of this study was to evaluate the patterns of PPE use and the impact of PPE availability on the attitudes and well-being of an international population of healthcare workers.

**Methods:** This was an online, cross-sectional survey of healthcare workers. The survey was disseminated internationally using social media, specialty society list-serves, and email augmented by snowball sampling to healthcare workers who provided direct care to patients with suspected or confirmed COVID-19. The survey was conducted between April 13 and May 1, 2020. The primary outcome was self-reported PPE use during aerosol-generating medical procedures. Other outcomes included PPE use during care for respiratory patients in general, PPE reuse, PPE decontamination, and healthcare worker impressions related to their work and the pandemic.

**Results:** A total of 2227 healthcare workers from 23 countries completed the survey. The N95 was the most common respirator among the 1451 respondents who performed aerosol-generating procedures (n = 1050, 72.3%). Overall, 1783 (80.1%) of providers reported general reuse of PPE, which was similar across US regions but less common in Canada, Italy, and Spain. The most commonly reused item of PPE was the N95 respirator, with the majority of respondents who reused PPE reporting N95 reuse (n = 1157, 64.9%). Of the 1050 individuals who wore an N95 mask while performing an aerosol-generating medical procedure, 756 (72%) reported re-using an N95, and 344 (45.5%) reported reuse for >3 days. Qualitative results identified several common themes, including (1) lack of availability of PPE, (2) fear and anxiety as a result of inadequate PPE, (3) potential exposure to family members, and (4) concerns regarding workload and pay.

**Conclusions:** This international survey of healthcare workers found that N95 respirators were commonly used to care for patients with respiratory symptoms with and without aerosol-generating medical procedures. Healthcare workers reported an unprecedented need to reuse PPE that was designed for single-use, specifically the N95 respirator. The reuse of PPE increased the perceived risk for COVID-19 infection and harmed mental health.

# 1 | INTRODUCTION

## 1.1 | Background

The novel coronavirus disease 2019 (COVID-19) global pandemic has had a remarkable impact on healthcare practice worldwide. A critical element of the global pandemic response is protecting healthcare workers from contracting the virus. This is important both on an individual level for healthcare workers who wish to avoid infection in themselves and to their families, and collectively for healthcare systems to reduce disruptions in care caused by an ill workforce. Several studies have documented increased risk of COVID-19 infections among healthcare workers, with healthcare workers accounting for 4%–11% of total infections with a hazard ratio of over 11 for COVID-19 infection compared to the general community.[1–3] One report indicated that 10% of cases in Italy could be in healthcare workers.[4]

## 1.2 | Importance

Limited personal protective equipment (PPE) availability has been an ever-present concern among healthcare workers and is associated with increased risk of COVID-19 infection.[2] Due to severe shortages, healthcare organizations rapidly developed PPE use and reuse protocols. Previous studies have reported increased stress, anxiety, and depression among healthcare workers associated with the pandemic, with some reporting inadequate PPE as a contributor.[5–8] However, the patterns of PPE use, reuse, and the specific personal impact of PPE scarcity on healthcare workers are poorly described.

## 1.3 | Goals of investigation

The objective of this study is to evaluate the patterns of PPE use during the COVID-19 pandemic and the impact of PPE availability on the attitudes and wellbeing of an international population of healthcare workers.

# 2 | METHODS

## 2.1 | Study design

This was an international survey conducted between April 13 and May 1, 2020, using snowball sampling to reach as many healthcare workers as possible. The study was approved by the university's Institutional Review Board. Informed consent was obtained within the survey before completing the questions.

## 2.2 | Survey development

The survey was initially developed by BK and MH. It was then revised with input from our larger study team. A group of 10 emergency physicians pilot-tested the survey, which was modified based on their feedback. We also made additional modifications based on feedback received during the first day it was deployed, primarily to clarify specific questions. We included our contact information in the survey to facilitate feedback. The survey included 2 open-ended questions. The

first was: "Please comment on what your normal practice is and what you are doing outside of that scope" and the second was: "Any additional thoughts or concerns related to your work and COVID-19 you would like to share. These questions were intended to complement the survey questions related to PPE. The final survey included 36 total questions, the first 34 were discreet and the final 2 were open-ended. Several of the questions had sub-questions and some included branching logic. A total of 65 survey elements were possible when including all sub-questions. The open-ended questions were designed to provide personal insights and context to the structured elements.

## 2.3 | Measures

Our analysis included the following demographic variables: age, race, gender, prior history of asthma (y/n), pregnancy status, training status, medical specialty, physician specialty, geographic location, general work setting, and hospital work setting if applicable. PPE-related variables included use of the Powered Air-Purifying Respirator (PAPR), P100 respirator, N95 respirator, surgical mask, face shield, goggles, gown, hair covering, booties, and full head-to-toe suit. PPE reuse variables included whether or not PPE was reused at all, and if it was reused if the duration was 1 day, 2–3 days, or >3 days. Variables used to stratify the analyses included the geographic location, and PPE use scenarios including (1) use during an aerosol-generating medical procedure, (2) use during a non-aerosol-generating medical procedure in patients with respiratory symptoms, and (3) use when working with patients without respiratory symptoms.

## 2.4 | Data collection

We used primarily social media and email distribution lists to disseminate the survey. We selected snowball sampling to efficiently reach as many healthcare workers as quickly as possible over a wide geographic area. Snowball sampling is a method of non-probability sampling where participants are invited to share the survey with additional individuals.[9] We used Twitter, Facebook groups (ie, Essential Workers, COVID-19, Physicians Mom's Group), specialty listservs (Pediatric Emergency Medicine, Critical Care Medicine), specialty societies, and personal contacts to share the survey. We specifically asked that the survey be forwarded to healthcare workers who had tested positive for COVID-19. The snowball sampling approach precludes the calculation of a response rate. The survey was conducted using the Qualtrics (Provo, UT) platform.

## 2.5 | Analysis

Respondents were included if they indicated they were healthcare workers with direct patient contact since January 2020. We excluded respondents who had not "completed the survey" in Qualtrics, which means they had clicked through each page of the survey. The only

### The Bottom Line

This study's authors surveyed healthcare workers worldwide during the early COVID-19 pandemic. They found limited availability of personal protective equipment and extensive reuse of N95 respirators. The authors noted an increased perceived risk of COVID-19 infection, concerns about workload/pay, and a negative impact on mental health.

required question was the first one, asking if they were a healthcare worker.

We first evaluated demographic variables using descriptive statistics. We then described PPE used by participants stratified by region and PPE use-cases. We then analyzed PPE reuse and cleaning and stratified this analysis by region. Data management was conducted in R (version 3.6.0; R Foundation for Statistical Computing, Vienna, Austria), and analyses were conducted in Stata (version 14.2; StataCorp, College Station, TX).

Qualitative data were included if respondents answered one or both of the questions about scope of practice or additional thoughts. Analysis of qualitative data was conducted iteratively through (1) thematic analysis and (2) text analysis in a mixed-methods approach. Grounded theory guided the thematic analysis, in that the data was approached inductively.[10] However, the number of potential themes was limited as the data was extracted from survey text boxes and not from narrative. The thematic analysis was conducted iteratively. The research team read qualitative survey responses for each of the 2 open-ended questions to identify initial codes and develop a codebook to share with the research team for review. Coding and sub-coding then was done in a spreadsheet, using the survey data export. Broader codes, such as *PPE*, were assigned sub-codes. Responses were analyzed all together, as well as by medical specialty (physicians, registered nurses [RNs], and paramedics). The research team also analyzed intersecting codes together within the same question. For example, within the *additional thoughts* question, mental health, and PPE codes were overlaid to better understand potential mental health considerations in the context of PPE availability or reuse. A set of relevant themes emerged from the codes and subcodes. These were reviewed by the research team for prioritization, aggregation of qualitative results, and overall discussion.

To complement the thematic analysis, text mining was applied to the responses for both open-ended questions.[11,12] All words were initially singularized, and common stop words such as "the" were removed. Words referring to survey prompt or location (such as states and countries) were also removed. Text responses were then tokenized into bigrams (patterns of 2 consecutive words that occur within the text). The bigrams were then analyzed by the prioritized themes, using a ratio of bigram frequency by thematic code over the frequency of thematic codes present. Results were then stratified by specialty and placed into subgroups by qualitative themes that emerged from the qualitative analysis. If a specialty did not contain any bigrams for a

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given thematic code, the result was recorded as "no response." Textual cleaning and analysis were conducted in R using the *tidytext* and *textclean* packages to clean the text and the *SamNetCleaner* package to singularize the text.[13–15]

## 3 | RESULTS

### 3.1 | Participant demographics

Table 1 summarizes the demographics of the survey respondents. A total of 2232 healthcare workers completed the survey, with a mean age of 40.3 years (SD = 10.7). More respondents were female (1309 [59%]) and 1704 (76.3%) reported white race, 122 (5.5%) Latino/Hispanic, and 356 (15.9%) other. Physicians accounted for the majority of respondents (1331 [59.6%]), followed by nurses (362 [16.2%]), and prehospital providers (337 [15.1%]). A total of 227 (14.4%) respondents identified themselves as trainees. We received responses from the following countries: Australia, Canada, France, Germany, India, Ireland, Italy, Japan, Kuwait, Lebanon, Mexico, Oman, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Switzerland, Thailand, United Arab Emirates, United Kingdom, United States of America, and Uzbekistan.

### 3.2 | Personal protective equipment use

There was a wide range of PPE use among the 1451 providers who reported performing aerosol-generating medical procedures. Table 2 summarizes PPE use among all survey respondents divided by geographic areas. The N95 was the most common respirator reported for aerosol-generating medical procedures (n = 1050, 72.4%). Few providers reported using foot booties or head-to-toe coverings, although foot coverings and head coverings were more common in Italy. Generally, there was little regional variability in PPE use within the United States; internationally, there was some limited variability. Providers in Italy were using the powered air-purifying respirator (PAPR) less frequently (1 of 39 Italian respondents, 2.6%) than other areas (20%). The N95 respirator was reported to be used by 965 (55.9%) respondents when caring for a patient with respiratory symptoms without an aerosol-generating medical procedure being performed and by 582 (28.3%) respondents when providing care for patients without any respiratory symptoms.

### 3.3 | Personal protective equipment reuse and cleaning

Overall, 1783 (80.1%) of providers reported reuse of PPE, which was similar across US regions but less common in Canada, Italy, and Spain (Table 3). The most commonly reused item of PPE was the N95 respirator, with the majority of respondents reporting reuse (n = 1157,

**TABLE 1** Participant demographics

| Total responses | n = 2227 |
| --- | --- |
| Characteristic | No. (%) |
| Age, mean (SD) | 40.3 (10.7) |
| Race | |
| White | 1702 (76.4) |
| Latino/Hispanic | 121 (5.4) |
| Other | 356 (15.9) |
| Gender | |
| Male | 899 (40.4) |
| Female | 1307 (58.7) |
| History of asthma | 242 (10.9) |
| Pregnant | 33 (1.5) |
| Stage of training | |
| Practicing independently | 1441 (64.7) |
| Trainee | 277 (12.3) |
| Other | 469 (21.1) |
| Medical specialty | |
| Provider | 1328 (59.6) |
| Nurse/CNA | 362 (16.3) |
| EMT/paramedic | 337 (15.1) |
| Other[d] | 185 (8.3) |
| Physician specialty[a] | |
| Emergency medicine | 803 (67.6) |
| Family medicine/internal medicine | 115 (9.7) |
| Other | 269 (22.7) |
| Geography | |
| Country (top 4 responding countries) | |
| US | 1923 (86.3) |
| Canada | 78 (3.5) |
| Spain | 64 (2.9) |
| Italy | 60 (2.7) |
| Other | 82 (3.7) |
| US regions[b] | |
| East | 277 (14.6) |
| Midwest | 381 (20.1) |
| South | 395 (20.9) |
| West | 839 (44.4) |
| Work setting | |
| Hospital | 1586 (71.2) |
| EMS | 339 (15.2) |
| Clinic | 209 (9.4) |
| Other | 82 (3.7) |

(Continues)

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**TABLE 1** (Continued)

| Total responses | n = 2227 |
|---|---|
| Hospital work setting[c] | |
| Emergency department | 1145 (72.3) |
| ICU | 142 (9.0) |
| OR | 97 (6.1) |
| Step-down unit | 25 (1.6) |
| Ward | 163 (10.3) |

US, United States.

[a]Relative to 1187 total physicians.

[b]Relative to 1892 US responses.

[c]Relative to 1586 hospital workers.

[d]Other physician specialties included: critical care, anesthesia, cardiology, endocrinology, gastroenterology, immunology, infectious disease, obsetrics and gynecology, radiology, neurology, surgery, oncology, ophthalmology, orthopedics, rheumatology, urology, and pediatrics.

64.9%). The highest rates of N95 respirator reuse were seen in the US East region (81.7%). Of the 1050 individuals who wore an N95 mask while performing an AGP, 756 (72%) reported re-using an N95 mask at some point. Of these 756 participants, 344 (45.5%) reused for >3 days.

Eye protection also was commonly reported as reused, with 830 (46.6%) respondents indicating that goggles were reused. A total of 791 respondents (44.4%) reported reusing PPE for >3 days. Of the 1157 respondents who reported reuse of an N95 respirator, 620 (53.6%) reported no cleaning procedures were implemented between uses. Of the remaining 491 (42.4%) respondents who reused an N95 respirator, the most commonly reported cleaning procedure was wiping with disinfectant wipes (183, [37.3%]), followed by placing the respirator in sunlight (103, [21.0%]), and using ultraviolet light (94, [19.1%]).

## 3.4 | Qualitative analyses

In total, 634 comments were analyzed for the *scope* question, and 477 were analyzed for the *additional thoughts* question. Analysis of the *scope* question results by specialty (physician, RN, paramedic) produced 11 themes. Most respondents indicated that their scope remained the same as it was prior to COVID-19. There were, however, a few changes, such as a pediatric emergency physician who reported working in an adult step-down unit. Also, an increase in administrative work was a strong theme. Some reported a decrease in patient volume or work hours. For example, a nurse reported that low census and canceled elective procedures reduced work hours. A physician respondent noted the following:

"It's unfair that those of us in EDs are having our hours and pay cut because volumes are down. Also, there is no differentiation between providers on the frontlines actually treating COVID-19 patients and any other provider when it comes to aid. It's not fair that I have to worry both about getting ill and paying my bills at the same time."

Another physician respondent stated:

"Nearly everyone I know is working longer hours, taking more personal health risk, taking more medical malpractice liability risk, and getting less compensation for their work."

The remaining, less prevalent themes included PPE, changes in patients or patient demographics, and telework, telemedicine, or any integration of technology and work.

The *additional thoughts* question prompted a wide range of responses, and 9 themes and 15 sub-themes emerged through the analysis. The most prominent overarching theme was PPE availability. Many respondents indicated limited availability of PPE, reuse of PPE, and self (personal) supply of PPE. A nurse respondent indicated:

"Concerned about the reuse of our N95s. They are using UVC to disinfect up to 7 times. It doesn't fit like it used to and I'm concerned about the quality of the mask after so many reuses."

A paramedic respondent noted:

"We need better PPE. Reusing surgical masks every day on every call for weeks until they finally break does not feel safe and scares me."

Mental and physical health/illness were also noteworthy themes. For example, respondents described mental health effects such as stress/anxiety, emotional exhaustion, frustration, concern, or fear.

One respondent indicated:

"Fear and anxiety [are] overwhelming."

While another commented:

"It is terrifying because I don't feel I am fully protected against the virus, I am constantly thinking as I am doing my job,' Who's this person been in contact with, did they remain isolated at home or have they been out, do they have the virus, am I going to go home and infect my family?' Before the pandemic I never felt this way when I had to work with a patient and their family."

Many expressed concerns about increasing the risk of infection among their own family members. Potential exposures, risks of contracting or spreading COVID-19, and experiences of symptoms and illness arose as prominent sub-themes for physical health. Some reported physical exhaustion, or conversely, the ability to sleep more as a result of workload changes. Another prominent theme was that of compensation. Many respondents indicated a desire for "hazard pay," pay raises, or other benefits for healthcare workers during the pandemic. Some noted decreases in pay, or deferral of normal pay raises. A few respondents noted inequity in workload and compensation with nurses "getting paid to be sent home" while paramedics were "asked to use vacation to compensate for low volume." We evaluated these

**TABLE 2** PPE use for different procedures

| | HCW completing aerosol-generating procedure | | | | | HCW completing non-aerosol-generating procedure | | | | | HCW interacting with patient without respiratory symptoms | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All | US | Canada | Italy | Spain | All | US | Canada | Italy | Spain | All | US | Canada | Italy | Spain |
| Total n | 1451 | 1273 | 61 | 39 | 35 | 1726 | 1511 | 68 | 43 | 50 | 2054 | 1797 | 73 | 46 | 57 |
| **PPE type: N (%)[a]** | | | | | | | | | | | | | | | |
| **Facial protective equipment** | | | | | | | | | | | | | | | |
| PAPR | 296 (20.40) | 282 (22.2) | 0 (0.0) | 1 (2.6) | 6 (17.1) | 100 (5.8) | 88 (5.8) | 0 (0.0) | 2 (4.7) | 7 (14.0) | 42 (2.0) | 35 (2.0) | 0 (0.0) | 0 (0.0) | 3 (5.3) |
| P100 | 102 (7.03) | 97 (7.62) | 1 (1.6) | 1 (2.6) | 2 (5.7) | 100 (5.8) | 94 (6.2) | 0 (0.0) | 2 (4.7) | 3 (6.0) | 85 (4.1) | 79 (4.4) | 0 (0.0) | 1 (2.2) | 4 (7.0) |
| N95 | 1050 (72.36) | 908 (71.3) | 57 (93.4) | 31 (79.5) | 25 (71.4) | 965 (55.9) | 869 (57.5) | 4 (5.9) | 30 (69.8) | 34 (68.0) | 582 (28.3) | 517 (28.8) | 3 (4.11) | 15 (32.6) | 27 (47.4) |
| Surgical mask | 499 (34.39) | 446 (35.0) | 13 (21.3) | 6 (15.4) | 22 (62.9) | 978 (56.7) | 850 (56.3) | 51 (75.0) | 9 (20.9) | 37 (74.0) | 1597 (77.8) | 1398 (77.8) | 58 (79.5) | 30 (65.2) | 44 (77.2) |
| Face mask with attached eye shield | 98 (6.75) | 74 (5.8) | 13 (21.3) | 7 (17.9) | 2 (5.7) | 146 (8.5) | 98 (6.5) | 34 (50.0) | 5 (11.6) | 4 (8.0) | 126 (6.1) | 78 (4.3) | 36 (49.3) | 3 (6.5) | 2 (3.5) |
| Face Shield | 662 (45.62) | 558 (43.8) | 42 (68.9) | 33 (84.6) | 10 (28.6) | 728 (42.2) | 623 (41.2) | 34 (50.0) | 31 (72.1) | 14 (28.0) | 450 (21.9) | 388 (21.6) | 22 (30.1) | 14 (30.4) | 5 (8.8) |
| Goggles | 833 (57.41) | 736 (57.8) | 34 (55.7) | 17 (43.6) | 24 (68.6) | 1030 (59.7) | 912 (60.4) | 35 (51.5) | 17 (39.5) | 37 (74.0) | 790 (38.5) | 685 (38.1) | 33 (45.2) | 17 (37.0) | 29 (50.9) |
| **Other protective equipment** | | | | | | | | | | | | | | | |
| Gown | 1137 (78.36) | 1005 (79.0) | 52 (85.3) | 27 (69.2) | 24 (68.6) | 1258 (72.9) | 1093 (72.3) | 60 (88.2) | 27 (62.8) | 34 (68.0) | 490 (23.9) | 382 (21.3) | 22 (30.1) | 19 (41.3) | 28 (49.1) |
| Hair net | 600 (41.35) | 481 (37.8) | 39 (63.9) | 35 (89.7) | 27 (77.1) | 647 (37.5) | 523 (34.6) | 29 (42.7) | 34 (79.1) | 39 (78.0) | 510 (24.8) | 416 (23.2) | 22 (30.1) | 20 (43.5) | 33 (57.9) |
| Booties | 200 (13.78) | 155 (12.2) | 3 (4.9) | 27 (69.2) | 8 (22.9) | 180 (10.4) | 138 (9.2) | 2 (2.9) | 27 (62.8) | 7 (14.0) | 105 (5.1) | 84 (4.7) | 1 (1.4) | 12 (26.1) | 5 (8.8) |
| Full head-to-toe covering | 66 (4.55) | 47 (3.7) | 0 (0.0) | 10 (25.6) | 6 (17.1) | 60 (3.5) | 43 (2.9) | 0 (0.0) | 7 (16.3) | 5 (10.0) | 39 (1.9) | 30 (1.7) | 0 (0.0) | 5 (10.9) | 2 (3.5) |
| Other | 105 (7.24) | 73 (5.7) | 14 (23.0) | 6 (15.4) | 5 (14.3) | 114 (6.6) | 83 (5.5) | 17 (25.0) | 4 (9.3) | 4 (8.0) | 102 (5.0) | 79 (4.4) | 15 (20.6) | 3 (6.5) | 3 (5.3) |
| None | 80 (5.51) | 69 (5.4) | 3 (4.9) | 1 (2.6) | 1 (2.9) | 49 (2.8) | 44 (2.9) | 1 (1.5) | 1 (2.3) | 1 (2.0) | 135 (6.6) | 120 (6.7) | 1 (1.4) | 2 (4.3) | 3 (5.3) |

PAPR, powered air-purifying respirator; PPE, personal protective equipment; US, Unites States.

[a]Participants could select > 1 response so totals may not equal 100%.

**TABLE 3** PPE reuse

| | All countries | US East | US Midwest | US South | US West | Canada | Italy | Spain |
|---|---|---|---|---|---|---|---|---|
| Total n (%) | 2227 (100) | 277 (12) | 381 (17) | 395 (18) | 839 (38) | 78 (4) | 60 (3) | 64 (3) |
| **Reuse of PPE** | | | | | | | | |
| Yes | 1783 (80.1) | 240 (86.6) | 330 (86.6) | 339 (85.8) | 690 (82.2) | 52 (66.7) | 25 (41.7) | 41 (64.1) |
| No | 338 (15.2) | 28 (10.1) | 30 (7.9) | 39 (9.9) | 119 (14.2) | 22 (28.2) | 32 (53.3) | 18 (28.1) |
| Unknown | 106 (4.8) | 9 (3.2) | 21 (5.5) | 17 (4.3) | 30 (3.6) | 4 (5.1) | 3 (5.0) | 5 (7.8) |
| **Length of reuse** | | | | | | | | |
| >3 days | 791 (44.4) | 117 (48.8) | 138 (41.8) | 176 (51.9) | 302 (43.8) | 7 (13.5) | 4 (16.0) | 17 (41.5) |
| 2–3 days | 273 (15.3) | 54 (22.5) | 46 (13.9) | 46 (13.6) | 91 (13.2) | 1 (1.9) | 4 (16.0) | 8 (19.5) |
| 1 day | 701 (39.3) | 67 (27.9) | 143 (43.3) | 102 (30.1) | 292 (42.3) | 43 (82.7) | 16 (64.0) | 16 (39.0) |
| **Items reused** | | | | | | | | |
| PAPR | 176 (9.9) | 30 (12.5) | 22 (6.7) | 19 (5.6) | 93 (13.5) | 0 (0.0) | 0 (0.0) | 6 (14.6) |
| P100 | 97 (5.4) | 7 (2.9) | 11 (3.3) | 10 (2.9) | 60 (8.7) | 1 (1.9) | 0 (0.0) | 3 (7.3) |
| N95 | 1157 (64.9) | 196 (81.7) | 209 (63.3) | 270 (79.6) | 396 (57.4) | 12 (23.1) | 14 (56.0) | 26 (63.4) |
| Gown | 127 (7.1) | 20 (8.3) | 21 (6.4) | 17 (5.0) | 49 (7.1) | 2 (3.8) | 5 (20.0) | 10 (24.4) |
| Goggles | 830 (46.6) | 119 (49.6) | 188 (57.0) | 136 (40.1) | 313 (45.4) | 22 (42.3) | 4 (16.0) | 24 (58.5) |
| Surgical mask | 995 (55.8) | 108 (45.0) | 221 (67.0) | 197 (58.1) | 382 (55.4) | 30 (57.7) | 9 (36.0) | 18 (43.9) |
| Face shield | 688 (38.6) | 97 (40.4) | 89 (27.0) | 167 (49.3) | 272 (39.4) | 21 (40.4) | 12 (48.0) | 10 (24.4) |
| Face mask with attached eye shield | 88 (4.9) | 11 (4.6) | 12 (3.6) | 15 (4.4) | 26 (3.8) | 23 (44.2) | 0 (0.0) | 1 (2.4) |
| Hair net | 207 (11.6) | 43 (17.9) | 25 (7.6) | 34 (10.0) | 77 (11.2) | 9 (17.3) | 7 (28.0) | 10 (24.4) |
| Booties | 33 (1.9) | 7 (2.9) | 2 (0.6) | 6 (1.8) | 9 (1.3) | 0 (0.0) | 6 (24.0) | 3 (7.3) |
| Full head-to-toe covering | 35 (2.0) | 10 (4.2) | 1 (0.3) | 3 (0.9) | 14 (2.0) | 0 (0.0) | 1 (4.0) | 4 (9.8) |
| Other | 48 (2.7) | 1 (0.4) | 5 (1.5) | 7 (2.1) | 22 (3.2) | 2 (3.8) | 4 (16.0) | 3 (7.3) |

PAPR, powered air-purifying respirator; PPE, personal protective equipment; US, United States.

themes by different types of healthcare workers (specialty) and displayed the most common themes by physicians, registered nurses, and paramedics in Figure 1. PPE was the most common theme across all the groups included, with sub-themes of PPE availability/shortage and PPE reuse. Another prominent theme, especially for physicians, was work changes (including changes in workload, hours, types of work, or work procedures). Other remaining themes across the *additional thoughts* question included the following: organizational, governmental, social, or individual responsiveness, and reported satisfaction levels of response; COVID-19 testing, including shortage of testing and testing follow-up processes; degree of preparedness and satisfaction with preparedness for COVID-19; and barriers (such as inconsistency or lack of transparency) and facilitators (such as frequency and transparency) of COVID-19 communication.

Discussion with the research team, which included providers, informed the parameters for the text analysis, including the clustering of the bigram analysis by 3 prioritized qualitative themes: (1) compensation and work changes, (2) mental health and physical health, and (3) mental health and PPE. These themes were prioritized by the overall research team after review of the qualitative analysis. This analysis was performed only for the *additional thoughts* question. The text analysis yielded the top-ranking bigrams for each combination

of specialty and the combined themes of mental health/PPE, mental health/physical health, and compensation and work changes. These results are illustrated in Figure 2, a high frequency ratio score indicates a uniquely high bigram frequency within groups, thus implying high relative bigram importance. These results helped to identify key concerns for each group beyond the combined themes from the thematic analysis. For example, under mental health/PPE, physician bigrams commonly included references to pay cuts. The bigram "emergency medicine" appears under mental health/physical health and compensation/work changes. One contextual example of this result can be seen in the following response: "The fact that we were told we are getting a pay cut for the next 3 months. It is disheartening. The media uses this punch line of front line heroes but in the end, we are undervalued. In the midst of this crisis and the added stress of working emotionally and physically, even emergency medicine physicians on the front line aren't seen any different by administration as the dermatologist sitting at home."

Nursing bigrams included topics that were both personal and practical in nature. Personal topics included bigrams related to feelings of guilt, loss of sleep, and stress, while practical topics included bigrams related to COVID-19 testing. Specific mention of antibody testing reveals more context about fears of infection: "I would like to get an
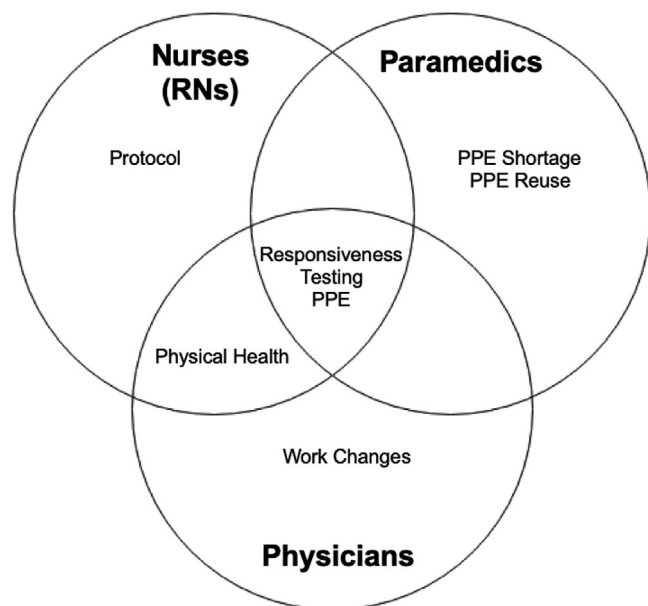
**FIGURE 1** Venn diagram of common qualitative themes from the additional thoughts question by healthcare worker group. N = 477 total comments analyzed. These results are from a textual bigram (group of 2 words together) analysis. The bigrams were analyzed by prioritized themes, using a ratio of bigram frequency by thematic code over the frequency of thematic codes present. *"No response" indicates that there were no textual bigrams from healthcare workers in the specific subgroup that overlapped with the specific theme

antibody testing to see if I already had the virus. I was sick in late February and got better at the start of March. What if the virus was already here before the Pandemic started?"

High frequency bigrams for paramedics include worries about compensation and low volumes. Paramedics are also concerned about risk of exposure, with these bigrams occurring under mental health/physical health.

## 3.5 | Limitations

This survey took place early during the pandemic, when PPE and testing were extremely limited, although PPE shortages have persisted. This survey also was available only in English, which limited response rates from non-English speaking countries. This was an international survey with a large number of countries responding, however, the vast majority of responses originated from North America, with a notable number of responses from Italy and Spain and very few from other countries limiting the generalizability. Although the survey was sent to healthcare providers worldwide, response rates were too low in many countries to capture the true picture of the local landscape for healthcare workers in that area. This study is not able to determine if the high rate of N95 reuse in the Eastern US was causative in increasing the rates of healthcare worker infection in this area, although it is a concerning hypothesis that deserves further investigation. Snowball sampling can lead to bias, because it may not represent

the entire population of interest. Individuals with more interest in reporting their thoughts on PPE and the COVID-19 pandemic are likely over-represented. Pilot testing of the survey was conducted among emergency physicians that could have caused bias in the questions among non-physicians. Missing data were not imputed, but were left missing for the analyses. Finally, when reporting rates of healthcare worker acquisition of COVID-19, it is typically not clear if the disease was acquired at work or in the community.

## 4 | DISCUSSION

In this large, international survey study of 2232 frontline healthcare workers from 23 countries, there was significant variability in PPE use internationally, with less reuse of PPE in Canada, Spain, and Italy. We found expectedly high use of the N95 respirator for aerosol-generating medical procedures, but also noted high use of the N95 while caring for patients with respiratory symptoms without any aerosol-generating medical procedures being performed, as well as caring for patients without respiratory symptoms. This finding was somewhat unexpected given recommendations by the CDC and World Health Organization prior to this survey to use a surgical mask in scenarios where an AGP was not being performed (March 2020).[16,17] This could represent rational measures to increase protection given uncertainty around the role of airborne transmission. It could also be due to the extended use of these masks, where a mask is worn for as long as possible from patient-to-patient during a shift. We noted relatively low use of elastomeric masks with P100 filters, despite them being designed for reuse with sanitization, though scarcity of the masks and filters may have contributed.

Our study shows that, due to severe shortages, healthcare workers across the world were forced to use PPE in unprecedented ways that altered the best practices long taught for occupational safety. Specific examples include: (1) reuse of PPE designed to be single-use (especially the N95 mask), (2) reuse of masks without attempts to decontaminate given lack of evidence on decontamination, (3) attempting decontamination with wipes, and (4) acquiring their own PPE to bring in to work. Healthcare workers as a group have significantly elevated risk of developing COVID-19 compared to the general population.[1,2,18] Although much of this may be interpreted as a function of increased exposure risk inherent in the line of duty chosen by the providers, our study suggests that occupational factors may also be contributing to elevated risk.

The significant shortages of PPE resulted in extensive reuse of disposable PPE, which has rapidly diminishing effectiveness with repeated use-cycles. Even though it is not intended for reuse, the N95 respirator was the most commonly reused item in our study. This is concerning given the correlation with N95 extended-use, reuse, and fit failure, increasing risk of user contamination.[19,20] In this study, 72% of individuals who wore an N95 respirator for an aerosol-generating medical procedure reused the respirator, with 45.5% of those reusing reporting >3 days of reuse. One previous study found the risk of fit failure of the N95 respirator after 4 days of use was alarmingly high
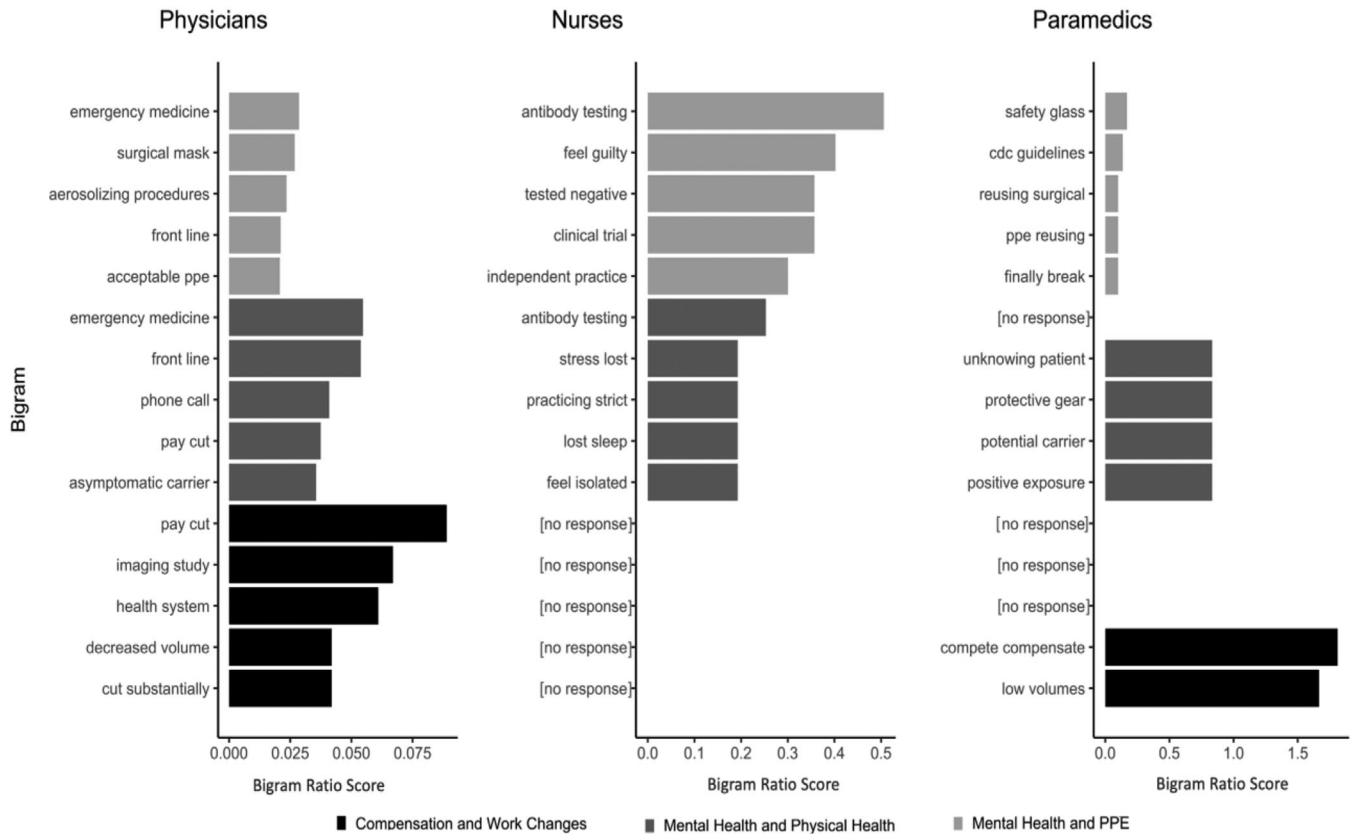
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**FIGURE 2**    Results of the bigram ratio frequency analysis

at 46%, while another found that fit tests failed after a median of 2 use-sterilization cycles.[21,22] In our study, nearly half of the respondents indicated they reused the N95 respirator for >3 days, likely resulting in loss of adequate protection for many users. Further, most respirators were not decontaminated, and COVID-19 is reported to be stable on a surgical mask for 1 week although there is limited data on the N95.[23] The PPE was reused during high-risk procedures, such as endotracheal intubation, and may contribute to the high rate of COVID-19 infections among healthcare workers. We noted the highest rate of N95 respirator reuse in the Eastern US, which also corresponds to the US area at highest risk for COVID-19 among healthcare workers.[2]

The free-text responses indicate that healthcare workers experienced fear and anxiety as they reused PPE that was designed to be disposable. Other responses indicated that people were worried about reductions in pay and spreading infection to their family members at home. This study highlights the multifaceted nature of healthcare worker occupational risk during the pandemic includes infectious exposure risk, fear, anxiety, family risk, and reductions in pay. In addition to increasing the risk of COVID-19 infection, the scarcity of PPE may have a considerable impact on healthcare workers' mental health and wellbeing. This burden continues, and has not been adequately addressed. We recommend that health systems and gov-

ernments consider all aspects of healthcare provider wellness during the pandemic to minimize the negative impacts on our healthcare workforce.

Our large, international survey of healthcare workers indicates that the worldwide supply of PPE was not adequate for a global pandemic. We identified extensive reuse of PPE, specifically the N95 respirator (that is intended to be disposable), with highly variable approaches to disinfection between uses. This underscores the ongoing urgent need to improve the availability of PPE that meets the highest standards of protection for our healthcare workforce. As COVID-19 cases continue to rise in various communities around the world and others enter a second wave, protecting healthcare workers will be essential to protect the community. Finally, efforts to prepare for future pandemics must ensure an adequate supply of N95-equivalent respirators will be available when needed.

## AUTHORS CONTRIBUTION

BK, MH, AL, JC, CC contributed to the conception and design of the study. BK, MH, JC, CC, BC, MP, JP, CA, BCV, GC contributed to the collection of the data. BK, AJ, MH, AL, JL, AW and AZ contributed to the analysis of the data. BK and MH drafted the manuscript. All authors critically revised the manuscript and agree to be responsible for the final draft.

## REFERENCES

1. CDCMMWR. Characteristics of health care personnel with COVID-19 — United States. *MMWR Morb Mortal Wkly Rep.* 2020;69.
2. 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(9):e475-e483.
3. Wu Z, McGoogan JM. Characteristics of and important lessons from the Coronavirus Disease 2019 (COVID-19) outbreak in China: summary of a report of 72 314 cases from the Chinese center for disease control and prevention. *JAMA.* 2020;323(13):1239-1242.
4. *High Proportion of Healthcare Workers with COVID-19 in Italy is a Stark Warning to the world: Protecting Nurses and their Colleagues Must be the Number One Priority.* ICN - International Council of Nurses; 2020.
5. Chew NWS, Lee GKH, Tan BYQ, et al. A multinational, multicentre study on the psychological outcomes and associated physical symptoms amongst healthcare workers during COVID-19 outbreak. *Brain Behavior Immunity.* 2020;88:559-565.
6. Rodriguez RM, Medak AJ, Baumann BM, et al. Academic emergency medicine physicians' anxiety levels, stressors, and potential stress mitigation measures during the acceleration phase of the COVID-19 pandemic. *Acad Emerg Med.* 2020;27(8):700-707.
7. Shechter A, Diaz F, Moise N, et al. Psychological distress, coping behaviors, and preferences for support among New York healthcare workers during the COVID-19 pandemic. *General Hospital Psychiatry.* 2020;66:1-8.
8. Tan BYQ, Chew NWS, Lee GKH, et al. Psychological impact of the COVID-19 pandemic on health care workers in Singapore. *Ann Intern Med.* 2020;173(4):317-320.
9. Sedgwick P. Snowball sampling. *BMJ.* 2013;347.
10. Corbin JM, Strauss A. Grounded theory research: procedures, canons, and evaluative criteria. *Qual Sociol.* 1990;13(1):3-21.
11. Rajaraman A, Ullman JD. *Mining of Massive Datasets.* Cambridge University Press; 2011.
12. Rinker T, Textclean. https://github.com/trinker/textclean
13. Silge J, Robinson D. Tidytext: text mining and analysis using tidy data principles in R. *JOSS.* 2016;1(3):37.
14. Christensen A, SemNetCleaner; 2020. https://github.com/AlexChristensen/SemNetCleaner
15. CDC. *Coronavirus Disease 2019 (COVID-19).* Centers for Disease Control and Prevention; 2020.
16. Rational use of personal protective equipment (PPE) for coronavirus disease (COVID-19). Published February 11, 2020. Accessed September 14, 2020. https://www.cdc.gov/coronavirus/2019-ncov/hcp/infection-controlrecommendations.html
17. Chou R, Dana T, Buckley DI, Selph S, Fu R, Totten AM. Epidemiology of and risk factors for coronavirus infection in health care workers. *Ann Intern Med.* 2020;173(2):120-136.
18. Degesys NF, Wang RC, Kwan E, Fahimi J, Noble JA, Raven MC. Correlation between N95 extended use and reuse and fit failure in an emergency department. *JAMA.* 2020;324(1):94-96.
19. Czubryt MP, Stecy T, Popke E, et al. N95 mask reuse in a major urban hospital: cOVID-19 response process and procedure. *J Hospital Infection.* 2020;106(2):277-282.
20. Maranhao B, Scott AW, Scott AR, et al. Probability of fit failure with reuse of N95 mask respirators. *Br J Anaesth.* 2020;125(3):e322-e324.
21. Lieu A, Mah J, Zanichelli V, Exantus RC, Longtin Y. Impact of extended use and decontamination with vaporized hydrogen peroxide on N95 respirator fit. *Am J Infection Control.* 2020; 48(12): 1457–1461.Published online August 15, 2020.
22. Qaiser S, Ali R. Text Mining: Use of TF-IDF to examine the relevance of words to documents. *International Journal of Computer Applications.* 2018;181 https://doi.org/10.5120/ijca2018917395.
23. Chin AWH, Chu JTS, Perera MRA, et al. Stability of SARS-CoV-2 in different environmental conditions. *Lancet Microbe.* 2020;1(1):e10.

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