

Personal Protective Equipment in COVID-19

Impacts on Health Performance, Work-Related Injuries, and Measures for Prevention

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Objective: To assess impact of personal protective equipment (PPE) on healthcare providers (HCPs) in caring for COVID-19 patients. **Methods:** A cross-sectional survey was conducted over 50 hospitals in China. Descriptive analyses and Chi-square tests were performed on the collected data. **Results:** All 104 frontline HCPs report negative impacts of PPE on their clinical performance, 97% of them experienced discomfort and injuries caused by wearing PPE for long hours. Frontline HCPs provided suggestions to alleviate the negative impacts and to enhance communication between healthcare staff and patients. Two hundred eighty two non-frontline HCPs also revealed similar problems; however, we recorded a few discrepancies between answers given by frontline and non-frontline HCPs. **Conclusions:** Wearing PPE for long hours degrades health performance. Measures were suggested to improve the design of PPE for protecting HCPs and enhancing their services to COVID patients.

Keywords: COVID-19, healthcare providers, occupational medicine, personal protective equipment, safety, work-related injury

The COVID-19 pandemic threatens the lives of millions of people in the world. Healthcare providers (HCPs) embrace the challenges and fight against this vicious virus like soldiers on the frontline. In special hospital units designed for taking care of COVID-19 patients, physicians and nurses spend long shifts on duty dressed in personal protective equipment (PPE) to prevent the virus from invading their own bodies.¹

Generally, the PPE (including a cap, eye-shear, goggles, face mask, scrubs, full-body coverall suit, gloves, and boots) may not be a perfect fit.² While wearing awkward and multi-layered protective gear, HCPs often experience difficulties in delivering a high level of

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Clinical significance: High incidence of injuries and negative impacts to healthcare providers should alert us of ergonomic issues induced by wearing personal protective gear during COVID-19 pandemic. Comments and feedback from frontline workers are tremendously valuable for us to improve the design of protective gear and create new technologies to enhance performance.

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Learning Objectives

- Review previous information on the adverse effects of wearing personal protective equipment (PPE) during the COVID-19 pandemic among healthcare providers (HCPs).
- Summarize the new survey findings on PPE-related negative impacts on clinical performance, discomfort, and mental and physical health issues reported by frontline HCPs treating COVID-19 patients.
- Discuss the implications for PPE design and practices to protect HCPs and improve their ability to care for COVID-19 patients.

care to patients; their performance may be impacted to a significant degree.^{3,4} Each different manufactory and brand requires healthcare providers to follow different procedure in wearing. Non-compliance donning and doffing of PPE may lead to increasing chances of contamination.^{5,6} Besides individual difficulties, HCPs may also experience enormous challenges in team collaborations. They may need more time to recognize and build up team to each other as everyone is dressed in the same uniform.⁷ Some solutions to this problem have been developed in the frontline, including the use of name tags on the back or chest of team members.⁷

Along with obstructing performance, protective gear may hurt HCPs in a more direct manner. We have seen many images posted on social media where physicians and nurses had bruises and even lacerations on their faces due to the pressure of a face mask.⁸ We also read reports that physicians and nurses feel exhausted and weight loss on duty due to dehydration after long shifts spent in protective gear.⁹ There are also many stories in news reports about ICU team members experiencing extensive difficulties in drinking, eating, and taking bathroom breaks once they have put on protective gear.¹⁰ Many HCPs also develop PPE-associated problem or exacerbation of their pre-existing health problems.¹¹

While paying our greatest respects to the healthcare heroes who fight for us on the frontline, we need to systematically assess the severity of problems caused by user-unfriendly protective gear. Unfortunately, there is a limited amount of papers available regarding ergonomic assessments of the work environment and work-related injuries to HCPs who dedicate themselves to the care of patients with COVID-19. Moreover, limited reports can be found on measures to reduce discomfort and injuries associated with protective gear along with suggestions directly taken from frontline HCPs to improve human performance and team collaboration in this demanding and dangerous environment. In this study, we hence investigate problems of HCPs due to wearing PPE during the COVID-19 pandemic. We are carefully collecting those measures suggested by the frontline HCPs in solving these problems.

METHODS

Questionnaire

A cross-sectional survey was completed in August of 2020 in China. The questionnaire (attached in the appendix) includes 16

TABLE 1. General Information of Frontline Healthcare Providers

Age, yrs	Gender (n)		Roles (n)			Duration in Wearing PPE, h/d	Frequency of Putting on PPE (No./d)
	Male	Female	Physician	Nurse	Others		
36.6 ± 6.7	35	69	50	49	5	5.00 ± 1.71	1.35 ± 0.64

PPE, personal protective equipment.

questions on demographics, time, and engagement in caring for COVID-19 patients, negative impact, discomfort, and injuries caused by PPE during patient care. Participants included those personally involved with COVID-19 patients (Frontline HCPs) and those who work in the healthcare facilities but indirectly connect with COVID-19 patient cares (Non-frontline HCPs). Besides negative impact, discomfort, and injury, they were all asked to report measures used in their daily practices to reduce problems from wearing PPE.

Data Collection

The survey was sent to over 120 health institutes in China through the “Questionnaire Star,” a secured online survey App (Ranxing Information Technology Co., Ltd, Changsha, China). Questionnaires and survey methods used in the study were reviewed and approved by the Ethics Review Board of the Second Hospital of Jilin University (No 2020-015). The consent page was displayed to each a participant at the beginning of the on-line survey; survey started when a participant click on the “Agree” button on the consent page.

Statistical Analysis

Descriptive statistics were used for analyzing the incidence of discomfort, injuries, negative impact on performance, and effective measures reported by the HCPs. Chi-square tests were then used for analyzing differences among the data collected from personal experiences of the frontline HCPs, the information heard from frontline HCPs and the information heard from non-frontline HCPs. All data are statistically analyzed and plotted using SPSS17.0 (IBM Corporation, Armonk, New York, NY). Results were reported by

mean ± standard deviation; *P* < 0.05 was considered to be statistically significant.

RESULTS

Within 2 weeks, a total of 386 valid replies were received, representing 52 institutes and hospitals from different geographic locations in China. Among them, 104 participants (27%) were directly involved with care for COVID-19 patients. Frontline HCPs included physicians, surgeons, nurses, respiratory therapists, radiologists, and other allied health professions working in the intensive care units, infectious disease units, and ambulance that dedicated for caring the COVID-19 patients. Frontline HCPs were required to wears double caps, goggles, N95 face mask, multilevel of coverall suit, double gloves, and plastic boots. Their answers to questions were given based on their experience. Non-frontline HCPs included physicians, surgeons, pharmacists, nurses, and those working in the hospital during pandemic but not indirectly connect with COVID-19 patients. Lighter PPE were required for non-frontline HCPs, often not including surgical mask instead of N95. Answers given by non-frontline HCPs might base on what they heard from their colleagues. Answers collected from 104 frontline and 282 non-frontline HCPs were presented and compared.

Demographics

There were 35 men and 69 women frontline HCPs in this survey, including 50 physicians, 49 nurses, and five other medical staff. Mean age was 36.6 ± 6.7 years. They wore PPE for 5.00 ± 1.71 hours per day during anti-COVID-19 service and on average; they needed put one PPE 1.35 ± 0.64 times at the end of their shifts each day (Table 1). Non-frontline HCPs in this study

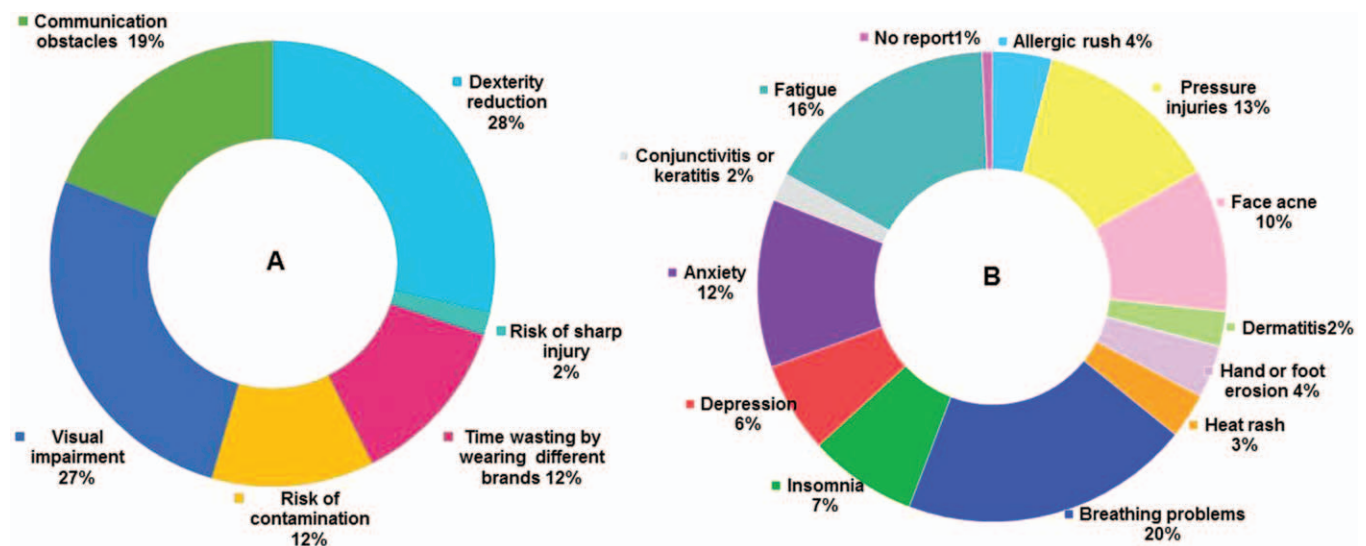


FIGURE 1. Negative impacts on performance (A) and incidence of discomfort (B) related to PPE reported by the frontline HCPs in COVID-19 pandemic. HCP, healthcare providers; PPE, personal protective equipment.

TABLE 2. Measures Suggested by Frontline HCPs

How to Reduce Discomforts and Negative Impacts		How to Enhance Team Works		How to Enhance Service to Patients	
PPE with self-circulating system	34%	Name tag on clothes	37%	Remote system for physician–patient communication	32%
Anti-fogging goggles	29%	Establishing gesture or sign language	24%	Establishing gesture or sign language	20%
Mask with better ventilation and dehumidification	17%	Set up a communication board for physician’s orders	23%	Set up a communication board to display patients’ daily requirement	17%
Protective clothes with elastic properties	8%	Hats of different colors to distinguish team roles	14%	Removing visual barriers to enable eye contact	16%
PPE with hypoallergenic properties	6%			Enhancing voice communication	14%
Gloves that maintain tactile sensation and dexterity	5%				
Other suggestion	1%	Other suggestion	2%	Other suggestion	1%

HCP, healthcare providers; PPE, personal protective equipment.

included 85 men and 197 women, with a mean age of 33.75 ± 9.59 years.

PPE Problems

Negative Impacts on Performance

Frontline HCPs reported many negative impacts of wearing PPE on their performance, including reduction of dexterity due to the thickness of protective clothes and/or gloves (28%), visual impairment due to wearing protective goggles (27%), communication obstacles (19%), increase in time-consuming practice while wearing non-uniform protective clothing (12%), and increasing in risk of contamination while removing protective clothing (12%) and risk of injury due to sharp tools (2%) (Fig. 1A).

Discomfort and Injuries

Among 104 frontline HCPs, 97% reported discomfort, including labored breathing (20%), fatigue (16%), device-related pressure injuries (13%), anxiety (12%), face acne (10%), insomnia (8%), depression (6%), allergic dermatitis (4%), and hand maceration or foot erosion (4%), trunk or limbs heat rash (3%), conjunctivitis or keratitis (2%), and perineal maceration or tinea corporis (2%) (Fig. 1B).

Measures for Reducing Discomfort and Negative Impacts

Frontline HCPs strongly voiced the importance of measures that reduce discomfort and negative impacts of wearing PPE. They considered breathable protective clothing with a self-circulating system (34%) as the most important measure to prevent discomfort

and damage to the HCPs. Alongside this, we should provide anti-fogging goggles (29%), as well as masks with better ventilation and dehumidification functions (17%). Another suggestion was to design protective clothes with elastic properties to fit bodies of different HCPs (8%), design PPE with hypoallergenic properties (6%), and improve gloves that maintain tactile sensation and dexterity (5%). A few of them (1%) suggested using cushion materials to avoid pressure injuries (Table 2).

As individual features are covered by the unified outfits, frontline HCPs suggested name tags and photo for medical staff to be worn on clothing (37%) to improve identification and communication between HCPs; they suggested the names should be displayed on both the chest and the back sides. Approximately a quarter (24%) of frontline HCPs believed that a certain type of gesture or sign language should be developed in the health environment to allow vital communications among HCPs, and another quarter (23%) of frontline HCPs addressed the importance of setting up a communication interface (such as a Whiteboard) inside the special care unit for displaying physician’s medical orders to the entire healthcare team. There are also other suggestions given by the frontline HCPs, including wearing hats of different colors to distinguish roles of individuals in the healthcare team (14%), and designing new electronic devices, such as Bluetooth headsets, paging equipment, and tablet, to support communications among HCPs (2%) (Table 2).

For enhancing communications between HCPs and patient, frontline HCPs suggested the installation of remote physician–patient communication system with up-to-date technology in the isolation ward to enable video conference and consultation (32%), establishing a simple gesture or sign language (20%), using

TABLE 3. Comparisons of Negative Impacts on Performance Based on Personal Experienced or Heard by the Frontline and Non-frontline HCPs

	Reduction of Dexterity	Visual Impairment	Communication Obstacles	Increased Risk of Contamination While Removing PPE	Time Wasting by Wearing Different Brands PPE	Injuries Due to Sharp Tools
Experienced by frontline HCPs	28%	27%	19%	12%	12%	2%##
Heard by frontline HCPs	18%**	33%	23%	9%	9%	8%
Heard by non-frontline HCPs	18%**	36%**	22%	10%	11%	3%##

Compared to “experienced by frontline HCPs.” HCP, healthcare providers; PPE, personal protective equipment.

**P < 0.01; compared with “Experienced by fomtline HCPs.”

##P < 0.01; compared with “Heard by frontline HCPs.”

communication boards or touchless (motion detected) interface for patients to show their daily requirements (17%), removal of visual barriers to enable more eye contacts (16%), and decreasing voice obstructions caused by PPE to restore verbal communication (14%) (Table 2).

Group Comparisons

Here we reported differences among the information collected from three different sources: personal experiences of frontline HCPs, messages heard by the frontline HCPs, and messages heard by the non-frontline HCPs (Table 3).

Chi-square test reveals difference presented in reduction of dexterity ($P < 0.01$), risk of injury due to sharp tools ($P < 0.01$), and visual impairment ($P < 0.01$). Specifically, frontline HCPs personally experienced more negative impacts of dexterity reduction due to the thickness of protective clothes and/or gloves (28%) than heard by others (18%); frontline HCPs personally experienced less risk of injury due to sharp tools (2%) and visual impairment (27%) than heard by other (8% and 36%, respectively). Answers to other survey questions did not show significant difference between the information from personal experience or the information heard by others.

Along with negative physical impacts, 12% of the frontline HCPs reported anxiety, 8% insomnia, and 6% depression during the anti-COVID-19 service (Fig. 1B). Furthermore, 39% of frontline HCPs reported that psychological stresses were more evident than physical stresses experienced during the anti-COVID-19 service, whereas only 7% reported that physical stresses were more evident than psychological ones. The remaining (54%) reported that both physical and psychological stresses were equal.

The survey was conducted in the August of 2020, 4 months after the apex of COVID-19 pandemic in China. At that time, 39% of frontline HCPs reported they have returned to normal life and work schedule after a period of adjusting time. While 51% of frontline HCPs were well adjusted, claiming that the fight against COVID-19 was just an exceptional clinical experience (28%) and they felt proud of themselves and their work (23%), 10% of them were still disturbed by the experience of anti-COVID-19 service and continue to feel anxiety sometimes. However, all 104 frontline HCPs still expressed their willingness to participate in anti-pandemic clinical work in the future. For those who did not directly involve with COVID-19 patients, 270 of 282 of non-frontline HCPs expressed their willingness to participate in anti-pandemic clinical work in future; 12 of them would not.

DISCUSSION

We surveyed a large number of HCPs who were directly involved with COVID-19 patient care in this project. Physical, psychological, and clinical problems to the HCPs during pandemic were systematically reviewed.

In previous studies on HCPs involved in anti-pandemic service, researchers mainly focused on assessment and treatment of psychological problems^{12,13} and device-related injuries.^{14,15} We notice a high percentage of HCPs (97%) reported discomfort and injuries caused by wearing heavy PPE. Majority of the physical discomfort and bodily injuries were resulted from wearing PPE for a long period of time when taking care of COVID-19 patients.^{16,17} In this study, HCPs reported an average of 5 hours per day in wearing heavy PPE during anti-COVID-19 clinical work. Frontline HCPs believed the most important method to reduce discomfort and injuries is to install a self-circulating system in the full PPE, by which body exhaustion and pressure to skin exerted by heavy PPE can be eliminated. In fact, the powered air purifying respirators and the ventilated surgical PPE, such as Stryker Flyte Steri-Shield helmet are commercially available.^{18–20} The improved supplies of self-circulating PPE system should help to reduce discomforts and injuries of frontline HCPs.

Other than discomfort and injuries, all frontline HCPs in this study reported negative impacts of wearing PPE on their daily performance of health procedures, such as in surgery and intubation procedures.^{1,4} The main problems that impair their performance were caused by the reduction of visual and touch sensation while wearing protective eye goggles and multiple layers of gloves.^{21,22} Dexterity and eye-hand coordination are significantly affected in such situations. In addition, wearing heavy PPE that blocks out identifying characteristics of the HCPs creates communication obstacles for team collaboration and physician–patient interaction.

To overcome the previously mentioned problems, the frontline HCPs gave effective solutions in their daily practices. They printed out names on clothes to show their identities, created simple gestures or body language to substitute for the loss of verbal communications, and set up communication boards for displaying physician's medical orders inside the special care units.^{23,24} They made suggestions of wearing hats with different colors to distinguish individuals' roles in the health team, as well as using Bluetooth headsets or paging equipment for better team collaboration.

Frontline HCPs also suggested installing tele-conferencing systems in special care units in order to enhance physician–patient communication. We believe setting up a communication board for patients' daily needs can also be a cost-effective solution. Fang et al²⁵ tried to use free software (eg, video conference platform) for in-hospital communication with patients to provide urgent patient care during the COVID-19 crisis. Alternatively, a more cost-effective solution may include the construction of a "Red Box," which is a specific area set inside the patient rooms and used for patient–physician communication. Maintaining a safe distance, improved communication can be achieved without the need for heavy PPE protection. Evidence showed that the rates of health care-associated infections did not increase with this intervention.²⁶

Besides physical discomfort, we were particularly interested in investigating the psychological impacts of the pandemic on frontline HCPs. In our study, 54% of the frontline HCPs reported both physical stresses and psychological stresses equally bothered them. While 39% of them argued that psychological stresses were more evident than physical ones during the anti-COVID-19 service. Among them, 12% reported anxiety, 8% insomnia, and 6% depression during the anti-COVID-19 service. At the moment when survey was carried out, which was 4 months after anti-COVID-19 service, 10% of frontline HCPs in China still reported experiencing pandemic-related stress and anxiety frequently. Thus, providing long-term mental health care to frontline HCPs should be considered.²⁷

Our last comment is on the discrepancy in survey results between data inputs from personal experience and messages heard from other HCPs. As shown in Table 2, the discrepancy is not massive, presenting only in a few aspects (reduction of dexterity, risk of injury due to sharp tools, and visual impairment). While we value tremendously to feedback received from frontline HCPs, we also acknowledge contribution made by all HCPs who directly or indirectly involving with care to COVID-19 patients; their personal experience is a reliable source of evidence for our investigation. We understand our survey cannot reach every frontline HCP. Alternatively, we asked participants to provide answers to survey questions based on what they heard from their colleagues. Those comments and suggestions are also an importance source for us to know the situations and to hear feedback on how to improve the design of PPE for better patient care during COVID-19 pandemic.

CONCLUSION

High incidence of discomfort, injuries, and negative impacts to health performance should alert us of ergonomic issues induced by wearing PPE to HCPs during the COVID-19 pandemic. Comments and feedback from both frontline and non-frontline HCPs are greatly valuable for us to improve the design of PPE for a better protection, and create new technology to enhance care quality. By

solving ergonomic problems, we will be able to support our HCPs to win the battle against COVID-19.

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