Infect Chemother. 2021 Dec;53(4):705-717
https://doi.org/10.3947/ic.2021.0094
pISSN 2093-2340·eISSN 2092-6448

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Original Article

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The Use of Personal Protective Equipment among Frontline Nurses in a Nationally Designated COVID-19 Hospital during the Pandemic

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OPEN ACCESS

Received: Sep 1, 2021
Accepted: Nov 4, 2021

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ABSTRACT

Background: The appropriate use of personal protective equipment (PPE) can significantly reduce the risk of infection associated with caring for patients. This study aimed to investigate the knowledge, awareness, and behaviors related to the PPE usage among frontline nurses in a nationally designated coronavirus disease 2019 (COVID-19) hospital during the COVID-19 pandemic.
Materials and Methods: The study was performed in two phases: (1) a questionnaire survey to assess the knowledge, awareness, and behaviors related to PPE use, and (2) in-depth personal interviews to elaborate the survey findings. The questionnaires were distributed to all 121 registered nurses in three isolation wards and an intensive care unit which dedicated for patients with COVID-19 and 102 nurses completed survey (84.3% response rate). In-depth interviews were conducted with a total of 7 nurses.
Results: Among the survey participant, 100% stated that they knew how to protect themselves while providing nursing care and 93.1% stated that they knew the recommended PPE by task. Most survey participant mainly wore gloves, face shield, N95 or equivalent respirator, and a long-sleeved gown, but one-third of the participants sometimes used coveralls instead of long-sleeved gown. In-depth interviews, the importance of timely updated and specific guidelines for selecting the appropriate type of PPE was highlighted. The adequate supply of PPE, convenience at work, and the role of responsible leadership mainly determined behaviors related to the PPE.
Conclusion: As new information on COVID-19 continues to emerge, the up-to-date and specific PPE guideline with evidence should be prepared. The spread of accurate information, the role of accountable leadership, and the active communication under positive organizational culture are important for the proper use of PPE.

Keywords: COVID-19; Personal protective equipment; Healthcare personnel; Prevention and control

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Conflict of Interest
No conflicts of interest.

Author Contributions
Conceptualization: HSM, JJ, HKS. Data curation: HSM, HKS. Formal analysis: HSM, HKS. Investigation: YJ, SM, IC. Methodology: HSM, HKS. Writing - original draft: HSM. Writing - review & editing: HSM, JJ, HKS.

INTRODUCTION

With the spread of the coronavirus disease 2019 (COVID-19) pandemic, healthcare workers (HCWs) are at a greater risk of severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) infection due to the nature of their work. In a meta-analysis conducted early in the pandemic, HCWs comprised 10% of all confirmed COVID-19 cases [1]. Although there is limited evidence on the type of personal protective equipment (PPE) that offers the best protection, the appropriate use of PPE can significantly reduce the infection risk associated with caring for patients with COVID-19 [2].

In January 2020, the first case of COVID-19 in Korea was reported [3]. Initially, following the example of the Middle East Respiratory Syndrome (MERS) outbreak, the Korea Disease Control and Prevention Agency (KDCA) guidelines recommended coveralls with foot covering, gloves, goggles or face shield, and N95 or equivalent respirator in any situations involving any contact with suspected or confirmed patients, and powered air purifying respirator (PAPR) for aerosol generating procedures (AGPs) [4]. However, these recommendations differed from those of the World Health Organization (WHO) or other regions and even raised the issue of PPE shortage [4-7]. The subsequently revised guidelines allowed HCWs to choose between coveralls with foot covering and a long-sleeved gown for contact precautions and stated that PAPR was not necessarily required when performing AGPs [8, 9]. Nevertheless, this change may have caused misunderstanding and confusion among HCWs [4].

In the context of the pandemic, HCWs play a critical role in providing care for patients with COVID-19. Frontline HCWs such as nurses and physicians in the intensive care unit or isolation wards should ensure the appropriate use of PPE to protect themselves and prevent nosocomial spread. Simultaneously, there are hurdles in using PPE optimally, including higher patient volumes, unavailability of equipment, increased anxiety and fear, dearth of information, and ambiguity in recommendations. However, few studies have examined the current status of PPE usage and related factors among HCWs during the COVID-19 pandemic [10]. Thus, this study aimed to evaluate the knowledge, awareness, and behaviors related to PPE usage among frontline nurses in a nationally designated COVID-19 hospital in Korea during the COVID-19 pandemic.

MATERIALS AND METHODS

1. Study setting

This study was conducted at the National Medical Center (NMC), a 480-bed public hospital in Seoul, Korea. The hospital was designated by the Korean government as a national center for emerging infectious diseases since the MERS outbreak in 2015 and as the initial receiving center for critical patients with COVID-19 during the first wave of pandemic admissions. During the study period, the NMC operated 3 cohort isolation wards with a total of 44 beds for patients with moderate illness, and an intensive care unit (ICU) with 16 beds for patients with critical illness. According to the KDCA guidelines, the initial NMC PPE recommendation for COVID-19 patient care was coveralls with foot covering for contact precautions, goggles or face shields for eye protection, N95 or equivalent respirators for respiratory protection, and PAPRs for AGPs. From the August 2020, “four-item sets” including gloves, goggles or face shield, N95 or equivalent respirator, and long-sleeved gowns were added to the NMC recommendations. Thereafter, HCWs have been able to choose

https://doi.org/10.3947/ic.2021.0094

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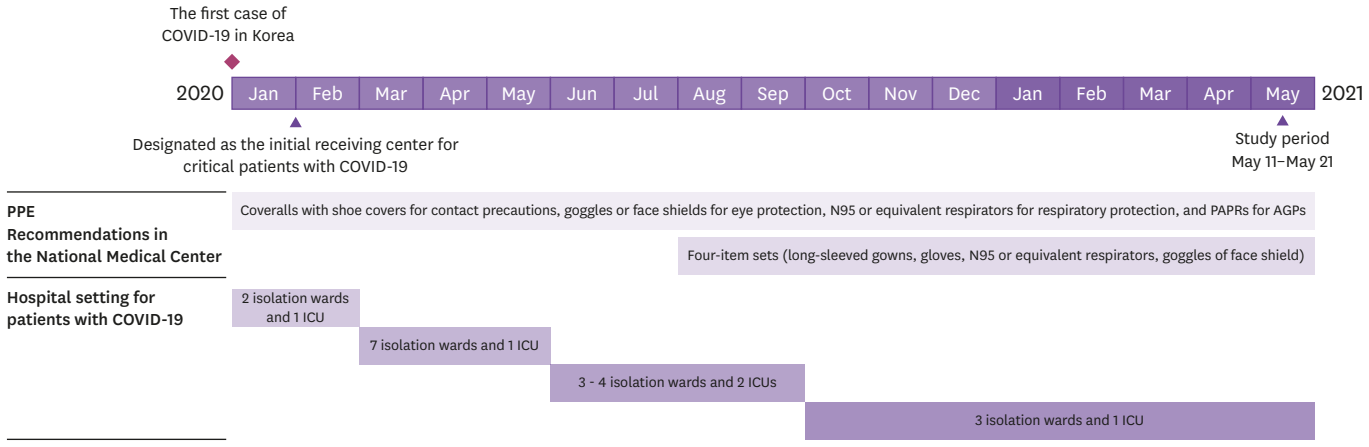

Figure 1. Timeline of PPE recommendations with hospital setting in National Medical Center.
PPE, personal protective equipment; COVID-19, coronavirus disease 2019; PAPR, powered air purifying respirator; AGPs, aerosol generating procedures; ICU, intensive care unit.

between the four-item set and a previously recommended set that included coveralls with foot covering at their own discretion. **Figure 1** presents the timeline for the change of PPE recommendations, the hospital setting, and the study period.

2. Study design, participants, and data collection

We performed the study in two distinct phases: a questionnaire survey and in-depth face-to-face interview between May 11 and May 21, 2021 [11, 12]. The questionnaire survey was conducted to assess the knowledge, awareness, and behaviors related to PPE usage among nurses providing care to patients with COVID-19. The in-depth interview further elaborated the survey findings by exploring participants' views, experiences, and reasons of behavior [13, 14].

For the quantitative phase, we developed a self-administered questionnaire based on previous studies related to the 2009 H1N1 influenza pandemic [15-17]. The survey questionnaire was broadly divided into four sections (**Supplementary Survey File**). The first section comprised questions associated with participants' demographic characteristics. The second section was designed to examine participants' knowledge and information sources regarding PPEs. The third section was designed to investigate participants' awareness of PPE. The participants were asked to report how helpful they thought each PPE item was to prevent COVID-19 infection. The listed PPEs were as follows: N95 or equivalent respirator, gloves, goggles, face shields, long-sleeved gowns, coveralls with foot covering, and PAPRs. The final section was made up of questions to assess the participant's behavior and inconvenience experienced for each listed PPE. A 5-point Likert scale with the options of “strongly agree”, “agree”, “I do not know”, “disagree”, and “strongly disagree” was used to rate questionnaire statements, except the questions concerning sources of information, specific PPE item, and demographic characteristics. The questionnaires, including the informed consent forms, were distributed to all registered nurses working in the isolation wards and ICU designated for patients with COVID-19.

In-depth interviews were conducted with a total of 7 participants, who provided consent. The interview candidates were obtained through purposive sampling and snowball sampling among nurses working in isolation wards or the ICU for patients with COVID-19 during the study period [18]. A semi–structured questionnaire was developed focusing on the

https://doi.org/10.3947/ic.2021.0094

relevant factors of knowledge, awareness, and behaviors to be explored in the interview (**Supplementary Table 1**). As the interview progressed, questions and answers were added freely in order to be able to elucidate the context of wearing PPE during the current COVID-19 pandemic.

3. Data analysis

The quantitative data were analyzed using descriptive statistical methods. All Likert-scale responses were dichotomized as "agree" if the response was "strongly agree" or "agree," and "do not agree" if the response was "I do not know," "disagree," and "strongly disagree." Participants' characteristics were summarized as frequencies and proportions or medians and interquartile ranges (IQRs).

For qualitative analysis, the transcription of the interviews was initially divided into units of a total of 425 semantic paragraphs. Then, divided paragraphs were subsequently coded by a single researcher using a coding framework. The coding framework included themes of influencing knowledge, awareness, and behaviors, and subthemes derived from the content through the framework analysis method [19]. The subthemes and their content items were developed through constant comparison throughout the coding process. Additional three researchers independently coded a random sample of 36 paragraphs (10% of all paragraphs), followed by an iterative process of discussing classification of paragraphs and reaching consensus. Finally, inter-coder agreement calculated by Cohen's Kappa statistic was more than 0.80, which indicated very good agreement [20].

4. Ethics statement

The present study protocol, questionnaires, and consent statement were reviewed and approved by the Institutional Review Board of the National Medical Center (Reference number NMC-2021-03-023). Informed written consent was obtained from all participants in this study.

RESULTS

The questionnaires were distributed to 121 registered nurses, with 84.3% (n = 102) completing the survey. The median age of the participants was 27 years (IQR: 25 - 31), and 52.9% of participants (n = 54) had at least four years of clinical experience. Among the participants, 35.3% (n = 36) worked in the ICU and 64.7% (n = 66) worked in the isolation wards. **Table 1** and **Supplementary Table 2** describes the detailed demographic characteristics of participants. All interview participants were registered nurses working in isolation wards or the ICU for patients with COVID-19, with clinical experience ranging from 4 to 18 years.

1. Knowledge

For the questions on self-assessed level of knowledge, most survey participants stated that they had adequate knowledge (**Table 2**, **Supplementary Table 3**). In particular, 100% (n = 102) stated that they knew how to protect themselves while providing nursing care and 93.1% (n = 95) stated that they knew the recommended PPE by task. On the other hand, there was a difference between the proportion of correct answers to questions based on the KDCA guidelines. Only 14.7% (n = 15) of survey participants correctly identified that PAPR was not necessarily recommended when performing AGPs according to the KDCA guidelines. Most survey participants relied on the hospital education program (78.4%) and informal practical

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Table 1. Demographic characteristics of the survey participants (n = 102)

Characteristics	Number (%)
Age, year[a]	
23 - 25	33 (32.4)
26 - 35	58 (56.9)
36 - 45	9 (8.8)
≥46	2 (2.0)
Sex	
Male	5 (4.9)
Female	97 (95.1)
Marital status	
Unmarried	87 (85.3)
Married	15 (14.7)
Number of housemates	
0	29 (28.4)
1 - 2	33 (32.4)
≥3	40 (39.2)
Education[a]	
Associate degree	9 (8.8)
Bachelor degree	90 (88.2)
Master or doctorate degree	3 (2.9)
Clinical experience, year	
<1	8 (7.8)
1 - 3	40 (39.2)
4 - 6	25 (24.5)
7 - 9	12 (11.8)
≥10	17 (16.7)
Working place	
ICU	36 (35.3)
Isolation ward	66 (64.7)

[a]Percentages may not total 100 because of rounding.
ICU, intensive care unit.

learning in the ward (41.2%) to get information about the recommended PPE and usage. About a quarter of the participants (23.5%) replied that the guideline document issued by a health authority was their source of information.

In qualitative analysis, 5 themes related knowledge were identified (**Table 3**): provision of adequate guideline, leadership, information other than official guidelines, previous experience, and education and communication. The most frequently raised issue was necessity of guidelines to select the appropriate type of PPE, highlighting it as an important relevant factor of knowledge provision (n = 95). In particular, it was very important to present objective and scientific evidence for wearing long-sleeved gowns instead of coveralls. Moreover, the existence of responsible leadership, such as physicians and senior nurses, also played a significant role in providing up-to-date guidance (n = 31) (**Table 3**). The selected remarks are as follows:

> "Because it was the first time that we had experienced (COVID-19). So, we agreed that 'let's go as high level as possible for PPE use'... and after getting used to it, we should start taking them off one by one... It was said that 'yes, it seems to be okay to level down,' but we had no accurate information, actually."

> "What is the most important factor when 'leveling down PPE', the most important thing for members to accept? I think it's just information. I keep thinking that there is not enough information. I had been still wearing a coverall... but as he (the leader of the nursing team) explained so well... so I changed my mind."

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Table 2. Responses to questions about knowledge, sources of information, and awareness

Questions	No. of agreed or correct (%)
Knowledge	
Self-assessed level	
I have knowledge about the clinical characteristics of COVID-19	91 (89.2)
I have knowledge about the transmission characteristics of COVID-19	98 (96.1)
I know how to protect myself while taking care for patients with COVID-19	102 (100.0)
I know the recommended PPE by task	95 (93.1)
Correct knowledge of KDCA guidelines	
The level of PPE should be selected in consideration of task and its expected risk	101 (99.0)
Recommended PPE type for usual nursing care	101 (99.0)
Recommended PPE type for aerosol generating procedures	15 (14.7)
Principles of PPE disinfection and reuse	82 (80.4)
Maintenance of hand hygiene after using PPE	102 (100.0)
Sources of information[a]	
About the clinical characteristics of COVID-19	
Guideline document issued by a health authority (*e.g.* KDCA)	64 (64.7)
Mass media	62 (60.8)
Social networking service	10 (9.8)
Medical or nursing journals	27 (26.5)
Hospital education program	34 (33.3)
Informal learning in the ward (*e.g.* at bedside)	33 (32.4)
Other	6 (5.9)
About the recommended PPE	
Guideline document issued by a health authority (*e.g.* KDCA)	24 (23.5)
Mass media	16 (15.7)
Social networking service	3 (2.9)
Medical or nursing journals	15 (14.7)
Hospital education program	80 (78.4)
Informal learning in the ward (*e.g.* at bedside)	42 (41.2)
Other	3 (2.9)
Awareness	
Use of appropriate PPE will keep me from getting SARS-CoV-2 infection	100 (98.0)
Use of appropriate PPE will keep my family from getting SARS-CoV-2 infection	96 (94.0)
It is inconvenient to use recommended PPE while providing nursing care to patients with COVID-19	88 (86.3)
For my patients, I can withstand the inconvenience from PPE	100 (98.0)
I am proficient in donning and doffing of PPE	102 (100)

[a]Multiple answers were allowed.
COVID-19, coronavirus disease 2019; PPE, personal protective equipment; KDCA, Korea Disease Control and Prevention Agency; SARS-CoV-2, severe acute respiratory syndrome coronavirus-2.

2. Awareness

Most survey participants believed that the use of appropriate PPE could prevent SARS-CoV-2 infection to themselves (98.0%) and their families (94.0%) (**Table 2**, **Supplementary Table 3**). All participants were confident about the donning and doffing of PPE. Regarding individual items of PPE, all participants trusted N95 or equivalent respirators (100.0%) as the best preventive measure to control the transmission of SARS-CoV-2, followed by gloves (96.1%), face shield (92.2%) and long-sleeved gowns (92.2%) when providing nursing care (**Table 4**).

On questions about inconvenience, 86.3% (n = 88) complained of inconvenience from wearing PPE (**Table 4**). At the same time, 98.0% (n = 100) stated that they could withstand the inconvenience for their patients. The most inconvenient PPE item was identified as coveralls with foot covering (77.5%), followed by PAPR (75.5%), goggles (67.7%), and N95 or equivalent respirator (62.8%).

In qualitative analysis, 6 themes related awareness were identified (**Table 3**): acceptability of guideline, previous experience, individual specificity, leadership, communication, and

https://doi.org/10.3947/ic.2021.0094

Table 3. The themes and subthemes extracted from the in-depth interview

Theme	Subtheme	Frequency of mentioned
Knowledge		175
Provision of adequate guideline	Presentation of objective evidence	95
	Clarity of the content	
	Timely update	
	Information about the disease	
	Uniform guidelines	
	Sufficiently specific guideline	
Leadership	Responsible leadership	31
	Competent leadership	
	New leadership	
Information other than official guidelines	From other wards or hospitals	19
	Personally obtained	
	Provided by colleagues	
Previous experience	Experiences from the MERS outbreak response	16
Education and communication	Active communication for the content	14
	Formal educational programs	
Awareness		124
Acceptability of guideline (for each individual)	Accumulation of positive experience after following the latest guidelines	27
	Practical applicability	
	Sufficient level of protection	
	Reliability of the evidence	
Previous experience	Experience during MERS epidemic	25
	Negative experiences (past use of PPE)	
	Experience caring for critically ill patients	
Individual specificity	Psychological barriers or fears	25
	Concerns about spreading to family	
	Difference in sensitivity to risk	
Leadership	Responsible leadership	25
	Authoritative leadership	
	Competent leadership	
	Showing example by leadership	
	New leadership	
Communication	Active communication for guideline	21
	Empathy and persuasion	
	Respect for personal choices	
Others	New facility	1
Behaviors		126
Conditions for use	Adequate supply	57
	Convenience at work	
	Convenience of donning and doffing	
	Provision of suitable facilities	
	Quality of PPE	
Leadership	Responsible leadership	26
	Showing example by leadership	
Communication and cooperation	Active communication for PPE use	14
	Cooperation with administrative service	
Previous experience	Experiences from the MERS outbreak response	12
Others	Respect for personal choices	17
	PPE selection of colleagues	
	Vaccinated or not	
	Excessive waste production	
	New facility	

MERS, Middle East respiratory syndrome; PPE, personal protective equipment.

others. The experience from PPE shortage in the early days of the COVID-19 pandemic, past negative experiences from the MERS outbreak, interaction with leadership, personal psychological barriers, and increased anxiety were mentioned as influencing factors of the current PPE use (n = 25). To reduce the negative awareness of PPE, it was essential for the

Table 4. Responses to questions about each PPE item[a]

PPE	Wearing PPE helps prevent infection	Wearing PPE brings discomfort	Currently wearing PPE
N95 or equivalent respirator	102 (100.0)	64 (62.8)	102 (100.0)
Powered air purifying respirator	83 (81.4)	77 (75.5)	4 (3.9)
Gloves	98 (96.1)	54 (52.9)	102 (100.0)
Goggles	47 (46.1)	69 (67.7)	2 (4.7)
Face shield	94 (92.2)	37 (36.3)	102 (100)
Long-sleeved gown	94 (92.2)	32 (31.4)	100 (98.0)
Coverall with foot covering	82 (80.4)	79 (77.5)	34 (33.3)

[a]Multiple answers were allowed.
PPE, personal protective equipment.

leadership to explain, to communicate with, and persuade nurses based on empathy and trust (n = 25). Through the communication, participants could ask questions, resolve doubts, and reduce their anxiety. The selected remarks are as follows:

"I think there should be a leading person in the hospital who tells me like this… 'Now you reviewed all the references…I trust that you can do it well'. If something went wrong, the leader asked why it happened and listened…When a leader runs away, the people under him (or her) also back off."

3. Behavior

All survey participants responded that they wore N95 or equivalent respirator, gloves, and face shield at work during the study period (**Table 4**, **Supplementary Table 4**). The proportion of participants who chose the long-sleeved gowns (98.0%) was much higher than the coveralls with foot covering (33.3%) in the questions that allowed multiple answers. Only a small proportion of participants used goggles (4.7%) and PAPR (3.9%) while proving nursing care.

In qualitative analysis, 5 themes related awareness were identified (**Table 3**): conditions for use, leadership, communication, previous experience, and others. The adequate supply of PPE, convenience at work, provision of suitable facilities, and quality of PPE were frequently mentioned as influencing factors of the behaviors related to the PPE use (n = 25) (**Table 3**). Some nurses still selected and wore PPE based on their past experience from the MERS outbreak, but behaviors related PPE have changed through the examples of physicians or senior nurses. The selected remarks are as follows:

"After four-item sets were introduced, it was really, really comfortable and easy to work… and we kept watching the leader follow the new recommendations himself (herself)… it led to a change in our PPE use."

DISCUSSION

To our knowledge, this study represents the first effort in Korea to investigate knowledge, awareness, behaviors, and influencing factors related to the usage of PPE during the current COVID-19 pandemic. In our study, most frontline nurses usually wore four-item sets, including gloves, face shield, N95 or equivalent respirator, and a long-sleeved gown, but one-third of the participants sometimes used coveralls with foot covering instead of long-sleeved gown. These results potentially suggest the differences between changes in PPE guidelines and changes in the field behavior.

https://doi.org/10.3947/ic.2021.0094

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With the spread of the pandemic, knowledge about clinical characteristics and transmission modes of COVID-19 progressed rapidly. Therefore, PPE recommendations to protect HCWs providing face-to-face care had to be changed accordingly. In addition, the recommended PPE for HCW protection should be determined to minimize not only the risk of infection, but the adverse effects of wearing PPE, such as exhaustion, irritant dermatitis, heat stress, or dehydration [21, 22]. Overuse of PPE is a form of misuse, and it leads to avoidable PPE shortages and subsequently increases risk of infection to HCW [23]. The WHO guidelines have been consistent with these principles by recommending gowns, gloves, medical masks, or N95 equivalent respirators and eyeglasses for HCWs directly caring for patients with COVID-19 and not recommending double layering of gloves or gowns, shoe protection, and hoods [7]. These recommendations are the same in the United States and Europe [5, 24]. While PPE recommendations from international organizations are largely consistent, PPE use in field was not. In Italy, the first European region heavily affected by COVID-19, 73% (264/360) of HCWs wore hazmat suits, and 6% (24/379) used PAPR in ICU in the early COVID-19 pandemic [25]. However, 17% (352/2,072) of HCWs in hospitals from 89 countries outside Italy wore hazmat suits, and 7% (160/2,300) used PAPR in the same study; meanwhile, no HCW wore full body suits in both community and hospital settings in Canada [10]. Compared to reports from other regions, our findings show a higher utilization of coveralls, as some nurses still used them until May 2021 in Korea.

Nevertheless, it would be challenging to optimize the recommended PPE set to protect all transmission modes in the early stages of the pandemic, as evidence has not been built up for best practices for infection prevention and control. Our in-depth interview results suggested that PPE guidelines can be easily accepted by HCWs when they are specific, clear, consistent, and present objective evidences. Similar results have been reported in studies conducted in other areas; about 75% Italian physicians (n = 516) were unsatisfied with the PPE guideline during the COVID-19 pandemic, and it significantly influenced their risk perception about contracting the infection [26]. As for HCWs in South America, up to 51.4% participants complained of insufficient knowledge about using PPE, which made the participants perceive themselves to be less prepared and trained [27]. As pointed out in prior studies, the inconsistent or outdated policies on PPE use against COVID-19 are common problems among many countries [23, 28]. In addition to the recommendations from the government or the public health authority, some institutional policies and guidelines should be prepared to take into account the hospital facilities and the supply of PPE [27].

Preparing clear PPE guidelines does not guarantee consensus or immediate use among HCWs. In particular, the role of leadership was critical across all domains of knowledge, awareness and behaviors of PPE use for the participants, as highlighted in prior studies [29]. The role of leaders including collaboration, communication, proactivity, and ownership of infection prevention measures have been known as facilitators for the adoption of guidelines among HCWs [30-32]. Our interview results presented that the significance of showing the example of wearing four-item sets by leaders. It is important for leaders to establish close contact with HCWs and build trust in the field, beyond a limited role in providing and managing guidelines.

Our study is limited as it is a self-report voluntary survey in a single institution; the results may show potentially selected responses and over-represent a small proportion of the overall situation. However, since the NMC has treated patients with emerging infectious diseases at the forefront in Korea, these results can provide insight to the effective management of PPE

https://doi.org/10.3947/ic.2021.0094

among HCWs despite some limitations of a single-institution study. Second, it is likely that the results presented biased opinions by considering only nurses in isolation wards and the ICU as study participants among various HCWs. Although these nurses are the representative front-line HCWs in close contact with COVID-19 patients, it is necessary to examine the views for physicians, infection control team, and other medical technicians for the future. In addition, a survey on HCWs working in places with a high risk of exposure to COVID-19 such as emergency rooms and hemodialysis rooms is also needed. Given that the infection control team in hospitals plays a key role in preventing nosocomial infection, how new measures can be incorporated into their existing role should be considered for coping with pandemics brought about by emerging infectious diseases.

In conclusion, while the PPE guidelines for COVID-19 in the field needed to be up-to-date and specific, the adoption of the latest guideline was not straightforward due to various structural and individual factors. Nevertheless, as new information of COVID-19 continues to emerge, the latest specific guidelines for PPE use should be effectively communicated to all HCWs in a more reliable manner. It is highly desirable that HCWs are encouraged to rationalize PPE use based on the latest scientific literature, as well as by being aware of international guidelines and best practices. To use the appropriate PPE in the field, it is important to support the role of accountable leadership who work together and set an example of PPE use among HCWs.

ACKNOWLEDGMENTS

We thank Dr. Myoung-don Oh, Department of Internal Medicine, Seoul National University Hospital, for inspiring this study. We also would like to thank all healthcare workers involved in the diagnosis and treatment of patients with COVID-19 in Korea.

SUPPLEMENTARY MATERIALS

Supplementary Survey File

The use of personal protective equipment among frontline nurses in a nationally designated COVID-19 hospital during the pandemic Survey Questionnaire (English)

Click here to view

Supplementary Table 1

The categories of the semi-structured questionnaire for in-depth interview

Click here to view

Supplementary Table 2

Demographic characteristics of the survey participants according to working place[a]

Click here to view

Supplementary Table 3

Responses to questions about knowledge, sources of information, and awareness according to working place

Click here to view

Supplementary Table 4

Responses to questions about each PPE item according to working place[a]

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