

Impact of personal protective equipment attached powered air-purifying respirator on nursing-skill performance and psychosocial stress of intensive care unit COVID-19 nurses: A cross-sectional study

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Abstract

Aim: To investigate how personal protective equipment with an attached powered air-purifying respirator worn by intensive care unit nurses caring for COVID-19 patients in Korea impacts nursing-skill performance and psychosocial stress.

Design: A cross-sectional descriptive study was designed using purposive sampling.

Review Methods: Online data collection was conducted from 3 March 2021–20 March 2021 on 181 nurses who had worked for more than 1 month in COVID-19 critical care settings wearing personal protective equipment with a powered air-purifying respirator. A structured questionnaire was used to gather data on sociodemographic characteristics, attitude toward personal protective equipment, nursing-skill performance wearing personal protective equipment and psychosocial stress.

Data Sources: Data was sourced from structured questionnaire responses.

Results: Nursing skill performance decreased to 63.4%, compared with normal performance. Subjects' perceptions and attitudes related to PPE scored 3.56 out of 5; 44.7% of subjects reported severe psychosocial stress, which was significantly affected by attitude toward personal protective equipment usage, nursing performance, experience caring for COVID-19 patients and length of personal protective equipment usage per shift.

Conclusion: Greater negative attitude toward usage of personal protective equipment with a powered air-purifying respirator, results in lower nursing-skill performance and higher the psychosocial stress of nurses responding to COVID-19 outbreaks.

Implications for the profession and/or patient care: High negative attitude toward PPE and low nursing-skill performance due to PPE with an attached PAPR results in significant and debilitating psychosocial stress in ICU nurses responding to COVID-19 outbreaks. To respond effectively to future infectious disease outbreaks and improve nursing performance, minimising the inconvenience and restrictions experienced by nurses wearing personal protective equipment is critical.

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Reporting Method: We adhered to relevant EQUATOR guidelines to report.

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KEYWORDS

COVID-19, intensive care unit, nursing-skill performance, personal protective equipment, powered air-purifying respirator, psychosocial stress, South Korea

1 | INTRODUCTION

The World Health Organization (WHO) declared a coronavirus disease (COVID-19) pandemic on 11 March 2020 (WHO, 2020). In South Korea, the number of confirmed cases increased primarily in the Daegu area; the infectious disease crisis alert was raised to the highest level, 'serious,' on 23 February 2020 (Korea Disease Control and Prevention Agency, KCDC, 2020). The COVID-19 response has been ongoing.

Personal protective equipment (PPE) is an infection-control method used to prevent the spread of infectious diseases in and around healthcare workers (Chughtai & Khan, 2020). To ensure the safety of healthcare workers, protect them from infection and maintain adequate levels of staffing to respond to patient needs in infectious disease environments, Level D PPE must be worn, including long-sleeved gowns, gloves, face shields or goggles, N95 masks and waterproof aprons (Zhang et al., 2020).

Among the healthcare workers caring for COVID-19 patients, nurses are at high risk based on their frequent and close patient contact (Shaukat et al., 2020). With the prolonged COVID-19 pandemic and the increasing proportion of critically ill patients among confirmed cases, a powered air-purifying respirator (PAPR) was added to the Level D PPE worn by nurses in South Korea. The PAPR filters out contaminants in the air; it provides purified air using a high-efficiency particulate air (HEPA) filter through a hood or helmet using a battery-operated blower (Licina et al., 2020). Attaching a PAPR to PPE is recommended for various treatments of patients with severe COVID-19, including high-flow oxygenation, ventilation, extracorporeal membrane oxygenation and continuous renal replacement therapy (KCDC, 2020).

However, in using PPE with an attached PAPR, nurses have experienced physical difficulties, including physical exhaustion, fatigue and sleep disturbance. Mental health issues have also been reported, including helplessness, loneliness, anxiety and fear (Licina et al., 2020).

This study aimed to identify the attitudes and physical symptoms of intensive care unit (ICU) nurses who wore PPE with an attached PAPR while caring for COVID-19 patients, and to investigate the impact of those attitudes and symptoms on the nurses' psychosocial stress.

2 | BACKGROUND

COVID-19 was declared a pandemic in 2020. Since then, South Korea has coined a new word, K-Quarantine (Korea Quarantine), and

What does this paper contribute to the wider global clinical community?

The study has illuminated the burdens of South Korean ICU nurses caring for COVID-19 patients, the degree to which those burdens impacted the fulfilment of patient care, and the degree to which the burdens adversely impacted nurses' mental health/stress levels.

With these study findings,

- future research that builds on the findings can be launched to provide more information toward improving nurses' working conditions;
- results may be applied to other geographical settings.

has improved its infectious-disease management throughout the health and medical fields (Ministry of Health & Welfare, 2020). The Korean Center for Disease Control and Prevention (2020) achieved great success in the early stage of the epidemic using the so-called K-quarantine measure, which enforces local quarantine for confirmed patients rather than implementing a global lockdown. Nurses have been acknowledged as the protagonists of the pandemic story, the people most likely to shape the outcome of the pandemic. Globally, nurses are writing a new chapter in the history of nursing in the fight against a novel infectious disease.

As of 2021, 67 hospitals dedicated to COVID-19 were designated as cohort hospitals in South Korea, operating a total of 8680 beds with 1030 medical personnel carrying out treatment, support for testing and classification of the severity of confirmed patient cases (Ministry of Health & Welfare, 2021). Many cohort hospital nurses were assigned to ICUs to care for COVID-19 patients. Problems are often the most serious in the ICU, which can now be directly related to the COVID-19 infection-fatality rate. In the ICU, there are operational difficulties due to shortages of beds and skilled manpower and to unsuitable medical equipment (Shin, 2021). ICU nurses face increased exposure to highly infectious agents due to their frequent and close contact with COVID-19 patients (Shaukat et al., 2020).

In South Korea, each nurse in a COVID-19 cohort hospital was placed in charge of 6–7 patients, as compared to the standard ICU nurse-to-patient ratio of 1:3 (Lee, 2021). The COVID-19 care ratio, a result of a labour shortage, created a burden on ICU

nurses overloaded with work. These ICU nurses treating patients with severe infections also experienced work pressure and psychosocial stress due to the discomfort of wearing PPE (Lee, 2021). Psychosocial stress refers to a state of conflict in which an individual's resources and ability to respond are affected by psychological or situational contexts that arise from external threats (Chang, 2000). ICU nurses responding to COVID-19 are concerned about high-stress levels, depression, anxiety, fear of infecting themselves and family, social isolation and stigmatisation (Barello et al., 2020). If the psychosocial stress of ICU nurses is not relieved in a timely way, it can lead to health problems, loss of interest in work, decreased work performance and lower-quality patient care (Onigbogi & Banerjee, 2019). Therefore, it is important to address the experiences of ICU nurses responding to infectious diseases, and to prepare institutional measures to reduce negative experiences associated with the process of coping with infectious diseases.

PPE use requires periodic training related to donning/doffing the gear, protocol application and monitoring to ensure staff member protection from COVID-19 and to maintain a responsive workforce (Chughtai & Khan, 2020). PPE training positively affects attitudes toward PPE, and a positive attitude toward PPE correlates with nurses' intention to respond to infectious diseases (Kim & Lee, 2016). However, due to the rapid spread of COVID-19, ICU nurses were sent to the frontlines of care immediately after very brief training in PPE usage. This timeline increased the need for timely mental health care to treat nurses' anxiety and stress (Shaukat et al., 2020).

Physical symptoms resulting from PPE usage include heat, thirst, skin pressure, headaches, inability to use the bathroom and extreme exhaustion (Tabah et al., 2020). PPE usage can reduce ICU nurses' dexterity when multiple layers of gloves are required, impair visibility (face shields), cause back pain, make it more difficult to use a stethoscope and limit communication. Moreover, with the increase in the number of critically ill patients and the prolonged spread of the coronavirus disease, PPE with an attached PAPR may increase exposure to infection in case of battery failure (Loibner et al., 2019). ICU nurses wearing PPE with an attached PAPR cannot drink water during their shifts, which may extend for more than 8 h, leading to them feeling dehydrated and fatigued. Some nurses even work while wearing adult diapers, to remove the need for donning and doffing PPE gear repeatedly to use the bathroom. (Sun et al., 2020).

It has been established that nurses experience mental health threats, including anxiety, depression, burnout and psychosocial stress (Sun et al., 2020), and that ICU nurses wearing PPE take longer to perform the nursing skills required for patient care, often feeling insecure about their performance; both consequences that negatively affect patients (Martínez-López et al., 2020). However, few studies have examined the mechanism through which usage of PPE with an attached PAPR affects nursing-skill performance.

3 | THE STUDY

3.1 | Aim and objective

The aim of this study is to identify the factors that affect the psychosocial stress of Korean intensive care unit nurses who wear personal protective equipment with a powered air-purifying respirator and care for COVID-19 patients. The subjects were 181 individuals who worked in ICUs, caring for COVID-19 patients.

4 | METHODS

4.1 | Design

A cross-sectional descriptive study was designed using purposive sampling.

4.2 | Instruments with validity and reliability

The study's structured questionnaire gathered data from nurses on demographic characteristics, attitude toward PPE, nursing-skill performance while wearing PPE and psychosocial stress. Approval for the use of the questionnaire tool was obtained from the original author.

4.2.1 | Sociodemographic characteristics

The general characteristics section of the questionnaire tool consisted of six items that focused on sex, age, educational background, marital status, clinical experience and position. The PPE-related experience section of the questionnaire consisted of five items: PPE-wearing hours per shift, PPE training experience, experience caring for COVID-19 patients, intention to respond to a new infectious disease and physical symptoms experienced due to wearing PPE with an attached PAPR.

4.2.2 | Perception and attitude about PPE

On the basis of a tool created by Daugherty et al. (2009) and a modified tool, Kim and Lee (2016) developed 10 items to measure healthcare providers' perception and attitude toward PPE using a 5-point scale. As perception and attitude have been shown to have a significant positive correlation (Kim & Lee, 2016), this study considered them to be just one variable. The reliability of this tool was measured by Cronbach's α . Cronbach's α results were .79 (perception) and .60 (attitudes) in Kim and Lee's (2016) study and .74 (total) in this study. A higher score indicated a more positive attitude toward PPE.

4.2.3 | Nursing-skill performance

Of the 20 nursing skills detailed in edition 4.1 of the Core Nursing Skill Protocol, (Korea Accreditation Board of Nursing Education, 2017), simple catheterization, enema, pre-operation care, post-operation care and blood transfusion were excluded from the current study's questionnaire that focused on the ICU setting, leaving 15 items. For each item, subjects were asked to report on a 10-point scale their own perceived nursing-skill performance while wearing PPE with an attached PAPR (where 10 points equalled 100%, indicating normal performance without PPE).

4.2.4 | Psychosocial stress

To measure psychosocial stress, the study employed the Psychosocial Well-Being Index-Short Form, based on Goldberg's (1978) General Health Questionnaire, modified for the Korean context by Chang (2000). The tool is comprised of 18 items measured on a 4-point scale (0–3). A higher score indicates higher stress levels. Subjects who scored less than 8 were classified as the 'healthy group,' those with scores between 9 and 26 were the 'potential stress group,' and those with scores of 27 or more as the 'severe stress group' (Chang, 2000). The items' reliability (Cronbach's α) was .90 in Chang's (2000) study and .88 in this study.

4.3 | Sampling and recruitment

The sample size was calculated as 172 using G*power 3.1 software with linear multiple regression, with an effect size of 0.15, a significance level of 0.05, a power of .95 and 10 predictors.

Subjects were 181 individuals who worked in ICUs for COVID-19 patients. The selection criterion was having worked more than 1 month wearing PPE with an attached PAPR in COVID-19 critical care settings. Exclusion criteria were those who wore only Level D PPE without PAPR, and those who cared for suspected patients and patients with other infectious diseases who were not confirmed COVID-19 patients.

4.4 | Data collection

Data collection occurred from 3 March 2021–20 March 2021 using a self-reported online survey on the Google Forms platform. Social networking services (including Facebook and an open chat site for COVID-19 nurses) and recruitment posters, including a URL and QR code directing candidates to the questionnaire, were used to recruit subjects. Subjects understood the purpose and method of the study and gave consent to participate. A total of 181 respondents completed the survey. A complete analysis was performed.

4.5 | Data analysis

Data were analysed statistically using SPSS Statistics 24.0 (IBM, US) software. Residual analysis was performed to confirm normality and there was no violation of normality and equal variance. To test differences, relationships and influences between variables, t-tests, one-way analysis of variance, Pearson's test and linear multiple regression were applied. The level of significance was set at $<.05$.

4.6 | Ethical considerations

The study was approved by the Institutional Review Board (IRB) of University Hospital (IRB No. 2000–002-438). An explanation of the study's purpose and method was made available to all prospective subjects who went on to provide informed consent if they wished to participate. All collected information was coded anonymously; mobile phone numbers that were collected were permanently deleted immediately after a digital gift card was provided to each subject.

5 | RESULTS

5.1 | Subjects' sociodemographic characteristics

The total sample comprised more women (89.5%) than men (Table 1). Subject average age was 28.43 years (standard deviation [SD] = 5.46); subjects in their 20s (74%) were the highest proportion of the sample. Most subjects had a bachelor's degree (80.1%) and were unmarried (80.7%). Most subjects had 1–<3 years (43.6%) of work experience, followed by 3–<5 years (26.5%), 5–<10 years (17.7%) and 10 or more years (12.2%).

The average length time spent wearing PPE with an attached PAPR was 4.35 (SD = 2.01) hours per shift; subjects who wore PPE for 4–6 h accounted for 53% of the total, followed by those who used PPE for 1–3 h (33.1%), 7–9 h (11.6%) and 10 or more hours (2.2%). Most subjects received PPE training (95.6%). The average length of service nursing COVID-19 patients was 5.56 months (SD = 3.94), with 27.6% of nurses reporting service of 1–3 months, 27.6% reporting 4–6 months of service, 22.7% reported 7–9 months and 22.1% reported 10 months or longer. Subject intention of responding to outbreaks averaged 3.73 (SD = 1.03) on a scale of 5.

In terms of physical symptoms related to wearing PPE, subjects frequently experienced thirst (70.7%), skin trouble (70.7%), fatigue (67.4%), ear pain (64.6%), discomfort from being unable to use the bathroom (59.7%) and a headache after taking off PPE (51.9%) (Table 2). In reporting the total number of uncomfortable physical experiences by marking multiple responses, subjects reported an average of 6.50 ± 3.00 experiences out of a possible 14.

TABLE 1 Variable differences according to participant sociodemographic characteristics (N = 181).

Variable	n (%)	Attitude toward PPE		Nursing-skill performance		Psychosocial stress	
		Mean ± SD	t/F (p)	Mean ± SD	t/F (p)	Mean ± SD	t/F (p)
Sex	Male	37.11 ± 4.28	1.56 (.121)	101.89 ± 25.68	1.29 (.200)	22.11 ± 7.99	−1.80 (.073)
	Female	35.48 ± 4.32		94.26 ± 24.32		25.73 ± 8.33	
Age	20–29 ^a	35.51 ± 4.40	2.62 (.076)	96.83 ± 24.25	4.72 (.010)	25.63 ± 8.18	0.35 (.708)
	30–39 ^b	35.45 ± 3.93		93.80 ± 22.91	a, b > c	24.73 ± 8.35	
	≥40 ^c	39.29 ± 4.07		68.43 ± 25.67	Sheffe	23.57 ± 12.21	
Education	Associate ^a	36.78 ± 5.11	2.68 (.072)	95.74 ± 21.78	2.96 (.054)	23.00 ± 8.36	1.80 (.169)
	Bachelor ^b	35.29 ± 4.16		96.37 ± 24.63		25.46 ± 7.74	
Marital status	≥ Master ^c	37.62 ± 4.25		79.31 ± 23.86		28.38 ± 13.39	
	Unmarried	35.51 ± 4.38	−0.84 (.401)	96.82 ± 25.13	1.99 (.048)	25.12 ± 7.80	−0.76 (.450)
Clinical career (years)	Married	36.20 ± 4.13		87.71 ± 20.42		26.31 ± 10.44	
	1–<3 ^a	35.89 ± 4.10	0.94 (.423)	100.44 ± 21.56	3.32 (.021)	24.76 ± 7.91	0.74 (.469)
Position	3–<5 ^b	34.88 ± 4.89		89.38 ± 25.45	a > d	26.44 ± 8.43	
	5–<10 ^c	35.56 ± 4.02		96.59 ± 26.60	Duncan	24.31 ± 8.73	
PPE usage (hours per shift)	≥10 ^d	36.59 ± 4.28		85.91 ± 25.56		26.64 ± 9.32	
	General ^a	35.56 ± 4.36	1.45 (.230)	96.21 ± 24.19	1.89 (.134)	25.63 ± 8.42	0.85 (.467)
Exposure to PPE training	Senior ^b	35.38 ± 4.26		96.75 ± 15.32		23.81 ± 6.30	
	Charge ^c	35.44 ± 3.47		83.67 ± 37.80		26.22 ± 9.68	
Experience caring COVID-19 patients (months)	Head nurse ^d	39.60 ± 4.39		75.40 ± 22.61		20.40 ± 9.97	
	1–3 ^a	35.51 ± 4.38	1.39 (0.249)	97.25 ± 22.70	1.39 (.249)	22.72 ± 7.81	4.12 (.007)
Head nurse ^d	4–6 ^b	36.2 ± 4.13		95.70 ± 25.45		26.68 ± 8.47	b > a
	7–9 ^c	37.11 ± 4.28		89.62 ± 26.06		25.38 ± 7.05	Sheffe
Head nurse ^d	≥10 ^d	35.48 ± 4.32		75.50 ± 6.80		33.00 ± 10.49	
	Yes	35.81 ± 4.17	2.38 (.018)	94.72 ± 24.58	−0.86 (.389)	25.27 ± 8.36	−0.61 (.541)
Head nurse ^d	No	32.13 ± 6.38		102.38 ± 23.15		27.13 ± 8.66	
	1–<3 ^a	35.64 ± 4.08	4.44 (.005)	99.82 ± 26.70	2.29 (.080)	22.40 ± 7.94	5.22 (.002)
Head nurse ^d	3–<6 ^b	36.52 ± 3.92	b, d > c	98.10 ± 23.99		24.22 ± 8.35	c, d > a
	6–<9 ^c	33.66 ± 4.86	Sheffe	87.63 ± 21.44		28.12 ± 8.00	Sheffe
Head nurse ^d	≥9 ^d	36.60 ± 4.01		92.93 ± 24.04		27.63 ± 7.96	

TABLE 1 (Continued)

Variable	n (%)	Attitude toward PPE		Nursing-skill performance		Psychosocial stress	
		Mean $\pm$ SD	t/F (p)	Mean $\pm$ SD	t/F (p)	Mean $\pm$ SD	t/F (p)
Intention to respond to future outbreaks	Strongly agree ^a	38.80 $\pm$ 4.75	16.07 (<.001)	99.84 $\pm$ 26.95	3.60 (.008)	22.34 $\pm$ 9.98	9.02 (<.001)
	Agree ^b	35.57 $\pm$ 3.35	a > c, d Dunnett T3	99.48 $\pm$ 21.79		23.92 $\pm$ 7.11	d > a, b, c Dunnett T3
	Undecided ^c	34.03 $\pm$ 3.59		89.67 $\pm$ 26.04		26.58 $\pm$ 6.62	
	Disagree ^d	33.82 $\pm$ 2.34		81.50 $\pm$ 19.33		33.50 $\pm$ 6.02	
	Strongly disagree ^e	27.00 $\pm$ 5.94		82.75 $\pm$ 25.79		29.50 $\pm$ 5.80	
Degree of physical discomfort	1–3	37.35 $\pm$ 4.46	2.54 (.058)	96.31 $\pm$ 27.46	0.65 (.582)	20.50 $\pm$ 8.40	3.88 (.010)
	4–6	34.77 $\pm$ 3.72		97.22 $\pm$ 21.92		26.47 $\pm$ 8.21	
	7–9	36.02 $\pm$ 4.47		94.15 $\pm$ 27.46		25.35 $\pm$ 8.06	
	≥ 10	35.67 $\pm$ 5.08		89.78 $\pm$ 22.40		26.96 $\pm$ 7.99	

Abbreviations: F, F value; PPE, personal protective equipment; SD, standard deviation; t, t value.

5.2 | Variable descriptive statistics

5.2.1 | Perception and attitude toward PPE

The average subject attitude toward PPE score was 3.56 (SD = 0.43) on a scale of 5 (Table 3). Subjects scored highest on the item 'I know how to use PPE very well' (4.27 $\pm$ 0.64), followed by 'I can wear and remove PPE proficiently' (4.25 $\pm$ 0.67) and 'Wearing PPE in a pandemic outbreak can protect me from infection' (4.17 $\pm$ 0.80).

Gloves (4.39 $\pm$ 0.79) were identified as the item that interfered the most in nursing performance, followed by goggles (4.24 $\pm$ 0.83), N95 or equivalent masks (3.99 $\pm$ 0.95) and PAPR (3.87 $\pm$ 0.84).

5.2.2 | Nursing-skill performance while wearing PPE

Scoring each nursing skill on a 10-point scale (with a score of 10 indicating normal performance without PPE usage), subjects' average score was 95.06 (SD = 24.51) out of a possible score of 150 for all 15 skill items (Table 3).

Differences by nursing skill were analysed via a *t*-test (Table 4). All nursing skills decreased significantly when PPE was worn ($p < .001$). By skill, the largest gap between the with- and without-PPE scores was observed for 'intravenous injection' (4.96 $\pm$ 2.14), followed by 'cardiopulmonary resuscitation and applying defibrillator' (4.94 $\pm$ 2.19), 'Foley catheterization' (4.67 $\pm$ 2.04) and 'tracheostomy care' (4.17 $\pm$ 2.11). The smallest gap was found for 'oral medication' (2.72 $\pm$ 2.07).

5.2.3 | Psychosocial stress

The average psychosocial stress score was 1.41 (SD = 0.46) on a scale of 3 (Table 3). The average total score was 25.35 $\pm$ 8.35, out of 54. In terms of stress severity, both the severe stress group (44.7%) and the potential stress group (53.6%) had significantly higher scores than the healthy group (1.7%).

5.3 | Variable differences according to subject sociodemographics

Scores for attitude toward PPE were significantly higher among subjects who underwent PPE training ($t = 2.38$, $p = .018$), cared for COVID-19 patients for 3–6 months or more than 9 months ($F = 4.44$, $p = .005$) and indicated a strong intention to respond to future outbreaks ($F = 16.07$, $p < .001$) (Table 1).

Scores for nursing-skill performance while wearing PPE were significantly higher among subjects who were 20–39 years old ($F = 4.72$, $p = .010$), unmarried ($t = -1.99$, $p = .048$) and had 1–3 years of clinical experience ($F = 3.32$, $p = .021$).

Items	n (%)	Items	n (%)
Symptoms			
1. Thirst	128 (70.7)	8. Dyspnoea	79 (43.6)
2. Skin trouble (rash, itching, dry)	128 (70.7)	9. Heat	77 (42.5)
3. Fatigue	122 (67.4)	10. Headache from wearing a hood	65 (35.9)
4. Ear pain from wearing a N95 mask	117 (64.6)	11. Extreme exhaustion	55 (30.4)
5. Discomfort from being unable to use the bathroom	108 (59.7)	12. Back pain	50 (27.6)
6. Headache after removing PPE	94 (51.9)	13. Nausea & vomiting	41 (22.7)
7. Dizziness	87 (48.1)	14. Insomnia	20 (11.0)
Number of individual experiences of physical symptom			
		Mean $\pm$ SD	Range
1–3	26 (14.4)	6.50 $\pm$ 3.00	1–14
3–6	74 (40.9)		
7–9	54 (29.8)		
≥ 10	27 (14.9)		

TABLE 2 Physical symptoms wearing PPE with an attached PAPR (N = 181).

Abbreviations: PAPR, powered air-purifying respirator; PPE, personal protective equipment.

Variables	n (%)	Mean $\pm$ SD	Range
Perception and attitude toward PPE			
Total average per item	181 (100.0)	3.56 $\pm$ 0.43	
Average score of individuals		38.19 $\pm$ 4.34	22–47
Nursing-skill performance			
Average score of individuals	181 (100.0)	95.06 $\pm$ 24.51	25–148
Psychosocial stress			
Average score per item		1.41 $\pm$ 0.46	
Total average individual score	181 (100.0)	25.35 $\pm$ 8.35	2–47
Severity by group			
Healthy (≤ 8)	3 (1.7)	5.33 $\pm$ 3.06	2–8
Potential stress (9–26)	97 (53.6)	9.77 $\pm$ 4.66	9–26
Severe stress (≥ 27)	81 (44.7)	32.78 $\pm$ 4.70	27–47

TABLE 3 Descriptive statistics of variables.

Abbreviations: PPE, personal protective equipment; SD, standard deviation.

Psychosocial stress scores were significantly higher among subjects who cared for COVID-19 patients for 6–9 months ($F = 5.22$, $p = .002$), wore PPE for 4–6 h per shift ($F = 4.12$, $p = .007$) and were unwilling to respond to future outbreaks ($F = 9.02$, $p < .001$).

5.4 | Correlations between variables

Psychosocial stress showed a significant correlation with attitude toward PPE ($r = -.31$, $p < .001$) and nursing-skill performance ($r = -.35$, $p < .001$) (Table 5).

5.5 | Factors influencing psychosocial stress

Multiple regression analysis was performed to identify the factors affecting psychosocial stress (Table 6). Residual analysis showed that the variance expansion factors were between 1.08 and 1.16, all below 10. The Durbin-Watson statistic was 1.67, close to 2, confirming that the regression model was suitable. Factors influencing psychosocial stress included experience caring for COVID-19 patients ($\beta = .254$, $p < .001$), attitude toward PPE ($\beta = -.227$, $p = .001$), nursing-skill performance while wearing PPE ($\beta = -.219$, $p = .002$) and PPE usage time ($\beta = .176$, $p = .012$); the explanatory power was 22.7%.

TABLE 4 Nursing-skill performance differences with and without PPE.

Items	Difference	
	Mean $\pm$ SD	t (p)
1. Intravenous infusion	4.96 $\pm$ 2.14	31.13 (<.001)
2. CPR & defibrillator application	4.94 $\pm$ 2.19	30.41 (<.001)
3. Foley catheterization	4.67 $\pm$ 2.04	30.77 (<.001)
4. Tracheostomy care	4.17 $\pm$ 2.11	26.66 (<.001)
5. Endotracheal suction	3.92 $\pm$ 2.17	24.30 (<.001)
6. Intradermal injection	3.82 $\pm$ 1.96	26.30 (<.001)
7. Admission care	3.59 $\pm$ 2.09	23.11 (<.001)
8. Subcutaneous injection	3.41 $\pm$ 2.00	22.97 (<.001)
9. Gavage feeding	3.40 $\pm$ 2.13	21.46 (<.001)
10. Intramuscular injection	3.36 $\pm$ 2.02	22.39 (<.001)
11. Medical-waste management	3.17 $\pm$ 2.07	20.66 (<.001)
12. Checking vital signs	2.96 $\pm$ 1.98	20.14 (<.001)
13. Oxygen therapy	2.93 $\pm$ 1.96	20.06 (<.001)
14. Applying and monitoring pulse oximetry & EKG	2.91 $\pm$ 2.02	19.32 (<.001)
15. Oral medication	2.72 $\pm$ 2.07	17.69 (<.001)

Abbreviations: CPR, cardiopulmonary resuscitation; EKG, electrocardiogram; PPE, personal protective equipment; SD, standard deviation.

TABLE 5 Correlations between variables.

Variable	1	2	3
1. Perception and attitude toward PPE	1		
2. Perceived nursing-skill performance level while wearing PPE with an attached PAPR	.29 (<.001)	1	
3. Psychosocial stress	-.31 (<.001)	-.35 (<.001)	1

Abbreviations: PAPR, powered air-purifying respirator; PPE, personal protective equipment.

TABLE 6 Factors influencing psychosocial stress.

Variable	B	β	t	p	VIF
(Constant)	41.86		8.00	<.001	
Perceived nursing-skill performance level with PPE and an attached PAPR	-0.08	-0.22	-3.11	.002	1.16
Perception and attitudes toward PPE	-0.44	-0.23	-3.27	.001	1.12
Working hours with PPE and an attached PAPR	0.73	0.18	2.55	.012	1.10
Experience caring for COVID-19 patients	0.54	0.25	3.73	<.001	1.08
$R^2 = 0.244$; $Adj R^2 = 0.227$; $F = 14.20$					

Abbreviations: PAPR, powered air-purifying respirator; PPE, personal protective equipment.

6 | DISCUSSION

When infectious diseases such as severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS) were spread in the past, ICU nurses experienced excessive psychosocial stress due to workloads associated with the care of infected patients. This study investigated the factors influencing the psychosocial stress of ICU nurses wearing PPE with an attached PAPR while caring for COVID-19 patients.

As the COVID-19 pandemic has been prolonged, ICU nurses have experienced a workforce shortage, accumulation of fatigue due to long working hours, the necessity of wearing protective equipment and increased safety risks (Shin, 2021).

Most subjects (95.6%) in this study underwent training focused on wearing and removing PPE with an attached PAPR, a slightly higher percentage than the 86% reported by Tabah et al. (2020). As training affects confidence in using PPE (Tabah et al., 2020), it is important to emphasise the availability of sufficient supplies and periodic training on wearing and removing PPE (Chughtai & Khan, 2020).

The subjects in the current study used 3 M's Jupiter Powered Air Turbo Unit, provided by the Korean government to all cohort hospitals. The unit is a PAPR that consists of a decontamination belt, breathing tube, battery and filter. Ong et al. (2020) reported that

81% of their study's subjects complained of headaches from wearing N95 masks and goggles, but that using a PAPR reduced discomfort from the goggles. Future studies should explicitly compare the complaints related to each PPE with an attached PAPR component.

The current study found that the physical symptoms related to wearing PPE with an attached PAPR reported most frequently were, in order: thirst, skin symptoms, general fatigue, ear pain due to wearing N95 masks and physiological problems (inability to use the bathroom). Reports of thirst after wearing PPE were higher in this study than the reported 47% in the Tabah et al. (2020) study. Results of previous studies were supported by this study's findings, suggesting that wearing PAPR reduces visibility, and may cause fatigue and back pain (Loibner et al., 2019). As some ICU nurses have been compelled to wear adult diapers for long shifts due to the difficulty of donning and doffing PPE, adjustments to the amount of time PPE must be worn are required (Sun et al., 2020).

PPE impedes nurses' movement. Wearing two or more layers of gloves reduces dexterity, while using a PAPR hood narrows the field of view, each making it difficult to perform nursing tasks (Loibner et al., 2019). In this study, overall nursing performance decreased to 63.4% while wearing PPE with an attached PAPR, when all 15 nursing skills assessed were considered together. Subjects reported that wearing PPE with an attached PAPR caused stress or discomfort, which also interfered with nursing skills. These results were consistent with previous studies, including the Kim and Lee (2016) study that reported that wearing PPE was uncomfortable and led to decreased concentration and inefficient nursing-skill experiences. Wearing PPE with an attached PAPR interferes with nursing skills; associated problems include the inability to use a stethoscope, limitations in verbal communication and exposure to infection in cases of battery failure (Kim & Lee, 2016).

Subject experience caring for COVID-19 patients, attitude toward PPE and nursing-skill performance while wearing PPE with an attached PAPR significantly influenced psychosocial stress in the current study. The longer the COVID-19 pandemic time period, the higher the risk of exposure to infection and the higher the psychosocial stress experienced by medical personnel (Zhang et al., 2020). Compared to other occupational groups, ICU nurses have higher psychosocial stress and more negative attitudes toward PPE due to cumulative physical discomfort (Kambhampati et al., 2020). Excessive workloads and inadequate support also increase psychosocial stress (Onigbogi & Banerjee, 2019). Social support measures are needed to improve the work environment for ICU nurses (Shaukat et al., 2020).

In the study, attitude toward PPE demonstrated differences based on subject intention to respond to future outbreaks of infectious diseases, results that were similar to those of previous studies (Kim & Lee, 2016). PPE usage affected nursing-skill performance less among younger, unmarried individuals and those with shorter clinical careers. However, psychosocial stress did not significantly differ by age or clinical experience. Repeated studies will be necessary to confirm individual differences.

Comparisons to the full spectrum of results of this study are limited, as few studies have examined the relationship

between nursing-skill performance and the use of PPE with an attached PAPR. In this study, nursing-skill performance showed a significant positive correlation with attitude toward PPE. Subjects' positive attitudes toward PPE with an attached PAPR were perceived as less uncomfortable with nursing skill performance.

In terms of psychosocial stress severity, the severe stress group included 44.7% of the current study's subjects. At the beginning of the COVID-19 outbreak, healthcare workers who treated patients directly experienced higher post-traumatic stress disorder symptoms, depression and anxiety, compared with healthcare workers who did not treat those patients (Johnson et al., 2020). Dubey et al. (2020) argued that a lack of PPE and training related to infection control, stigma and isolation affected psychosocial stress. While it may have seemed that healthcare workers were adjusting, wearing PPE increased their psychosocial stress (Martínez-López et al., 2020). In this study, psychosocial stress increased as the attitude toward PPE with an attached PAPR and nursing-skill performance decreased. The quality and functionality of PPE should be improved to interfere less with nursing-skill performance.

6.1 | Strengths and limitations of the work

The significance of this study's results stems from identifying factors affecting the psychosocial stress of ICU nurses wearing PPE with an attached PAPR in response to pandemic conditions. However, as data were collected from ICU nurses nationwide, data on the specific hospitals at which the nurses worked and PPE worn were not collected, limiting the generalisation of the results. Also limiting the generalisation of this study's results is the potential for PAPR to have varying standards and materials in different countries and work environments.

6.2 | Recommendations for further research

Based on this study's findings, future research should continue to investigate various factors affecting the psychosocial stress of nurses responding to COVID-19. Improved PPE training programs are also recommended, as is research focused on the correlation between individual physical symptoms and specific components of PPE coverage.

7 | CONCLUSION

Nurses, who account for the largest proportion of healthcare workers responding to the COVID-19 pandemic, have faced physical burdens and work stress from wearing PPE with an attached PAPR. This study examined the psychosocial stress of ICU nurses who care for the most critically ill COVID-19 patients.

ICU nurses' dexterity performing the necessary nursing skills was reduced remarkably owing to the limitations of PPE with an attached PAPR. Significant difficulty was reported performing intravenous injections, cardiopulmonary resuscitation, Foley catheterization and tracheostomy care. The more negative the attitude toward PPE with an attached PAPR, the more the physical discomfort in performing nursing care and the higher the psychosocial stress were reported to be. High negative attitude toward PPE and low nursing-skill performance due to PPE with an attached PAPR resulted in significant and debilitating psychosocial stress in nurses responding to COVID-19 outbreaks.

8 | RELEVANCE TO CLINICAL PRACTICE

To respond effectively to future infectious-disease outbreaks and improve nursing performance, minimising the inconvenience and restrictions experienced by nurses wearing personal protective equipment is essential. Identifying the factors that impact the psychosocial stress of nurses responding to COVID-19 and identifying solutions to alleviate that stress is critical.

AUTHOR CONTRIBUTIONS

Study concepts and design: YJ, OL, SK. Data collection: YJ. Data analysis: YJ, OL. Manuscript writing: YJ, OL, SK.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

ETHICS STATEMENT

The study was approved by the Institutional Review Board (IRB NO: 2000-002-438) of Chung-Ang University Medical Center.

STATISTICS

The authors have checked to make sure that our submission conforms as applicable to the Journal's statistical guidelines described here. There is a statistician on the author team: Lee, Ogcheol (Co-author). The authors affirm that the methods used in the data analyses are suitably applied to their data within their study design and context, and the statistical findings have been implemented and interpreted correctly. The authors agree to take responsibility for ensuring that the choice of statistical approach is appropriate and is conducted and interpreted correctly as a condition to submit to the Journal.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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