Biomedical Sciences and Clinical Medicine 2025;64(4):269-276.
doi: 10.12982/BSCM.2025.29
https://he01.tci-thaijo.org/index.php/CMMJ-MedCMJ/index

BSCM
Biomedical Sciences and Clinical Medicine

Original Article

Open Access

COVID-19 Risk Control and PPE use: Thai Personnel Safety

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Received: January 23, 2024;
Revised: May 15, 2025;
Accepted: July 9, 2025

ABSTRACT

OBJECTIVE The study evaluated the COVID-19 risk control measures in hospitals and assessed the knowledge, attitudes, and practices of healthcare personnel regarding those measures with emphasis on promoting awareness and ensuring utilization of proper use of personal protective equipment (PPE) as urgent measures to safeguard healthcare personnel.

METHODS This cross-sectional study assessed the perception of COVID-19 risk control measures based on the hierarchy of controls and examined the knowledge, attitudes, and adherence to safety measures among healthcare personnel using a structured questionnaire. Participants were selected based on their roles in patient care and occupational health management during the COVID-19 pandemic from 30 different Thai hospitals. Data analysis involved mean score comparison and examination of the magnitude of relationships using the Generalized Linear Model (GLMs).

RESULTS A total of 3,086 healthcare personnel responded to this study, with 51.90% employed in regional and general hospitals. Among those personnel, 95.80% held a bachelor's degree or lower and 44.50% were nurses, with 88.00% being responsible for patient care. The study found a high level of awareness regarding the health risk control measures implemented by the hospitals. Participants demonstrated high scores in knowledge, attitudes, and practices (KAP) related to the safety measures. Younger age, prior infection experience, higher knowledge scores, and positive perceptions of organizational PPE management were identified as factors associated with increased PPE adherence scores.

CONCLUSION PPE is an indispensable tool for protecting healthcare personnel from infectious hazards, particularly in environments where exposure to infectious patients is unavoidable. The effectiveness of PPE relies on comprehensive training, proper use and an adequate supply of PPE within the healthcare setting.

KEYWORDS health risk control measure, personal protective equipment, personnel health safety, COVID-19

INTRODUCTION

During the start of the initial wave of the COVID-19 outbreak in Thailand, which began in January 2020, many healthcare personnel had limited knowledge of infection control, patient care protocols, and personal protection measures. By April 2020, a significant number of healthcare personnel world-wide had succumbed to the infection, with 708 recorded deaths (accounting for 0.35% of global COVID-19 mortality at that

time). Of these fatalities, 365 (51.50%) were physicians and 126 (17.80%) (1) were nurses. This alarming situation necessitated urgent measures to protect and control the spread of COVID-19 among healthcare personnel (2).

COVID-19 is caused by a novel strain of the coronavirus which is primarily transmitted through respiratory droplets (3). Consequently, healthcare personnel who regularly interact with infected individuals face a higher risk of infection compared to the general population (2). During the outbreak, implementing hospital-based COVID-19 risk control measures became a top priority for healthcare personnel (4). One of the most structured approaches for controlling health risks, including infectious diseases, is the Hierarchy of Controls.

The hierarchy of controls is a fundamental framework for managing occupational health risks, including infectious disease exposure, and includes four primary levels of intervention: (5-7) (1) Hazard Elimination: modifying work processes to eliminate or reduce hazardous exposure, e.g., remote work policies for healthcare personnel to minimize unnecessary exposure (5), (2) Risk Reduction: implementing substitution or engineering controls and isolating individuals from exposure sources, potentially involving workspace and ventilation modifications and barrier use (5-7), (3) Administrative Controls: managing risk through practice guidelines, reducing the duration or frequency of exposure, training, job rotation, and limiting the number of individuals exposed (7), and (4) personal protective equipment (PPE) management: the last line of defense to protect individuals from hazards, including appropriate training and sourcing of suitable PPE (5-7). The first three levels of control involve elimination or control of risk at its source. Hospital environmental management, including ventilation adjustment, control of temperature and humidity control, the use of ultraviolet light, and frequent cleaning of contact surfaces can help reduce infectious exposure and the risk of infection (8). Occupational health and safety is a critical aspect of workplace management, particularly in healthcare settings where personnel are exposed to numerous risks. Healthcare personnel who care for patients must use PPE, especially during droplet-producing procedures (8, 9) which are a significant cause of virus transmission. Promoting the use of PPE among healthcare personnel requires both formal education on its appropriate use and practical, experience-based learning. These efforts are crucial for enhancing infectious disease awareness, fostering positive attitudes, and developing effective communication skills to encourage PPE adoption by colleagues (10). Ultimately, this approach builds confidence among hospital staff, reinforcing the belief that using PPE effectively reduces the risk of COVID-19 infection and allows them to work safely (11).

Notably, PPE played a crucial role in the early stages of the outbreak when the transmission source and infection routes were not yet well understood. Proper use of PPE, such as respiratory masks and goggles, effectively reduced respiratory and mucous membrane exposure. Nonetheless, PPE use is the last risk reduction method in the hierarchy of controls principles (12). The increased use of PPE led to supply shortages during the initial outbreak due to heightened demand and panic (13). Misunderstanding and neglect of other hierarchy of controls measures were observed as well (14, 15), such as sharing meals and engaging in conversations without proper protective gear. Finally, PPE cannot be used continuously all day because it causes difficulty with breathing and speaking. There was also some misunderstanding that after vaccination for COVID PPE use was not necessary. On the contrary, adherence to the full hierarchy of controls remains essential regardless of vaccination status

The COVID-19 pandemic posed significant challenges to healthcare systems worldwide, necessitating the implementation of comprehensive health risk control measures to prevent infectious spread in hospitals, to protect healthcare personnel, and to ensure the safety and well-being of patients. Controlling health risk became an urgent priority for hospitals seeking to continue their business as they responded to the rapid increase in patient numbers. Consideration of the utilization of risk control measures following the hierarchy of controls is a practice that urgently needs to be established among healthcare personnel before the country can secure a sufficient supply of vaccines for the entire population (16). This study was conducted during the later stages of the initial COVID-19 outbreak to evaluate in-

fection risk control measures within hospitals. It also assessed the knowledge, attitudes and practices of healthcare personnel regarding the care of COVID-19 patients and the proper use of PPE. By focusing on these aspects, the study aimed to ensure that healthcare personnel are well-prepared and confident in their ability to manage infection risks. This preparation is crucial for maintaining high standards of patient care and ensuring operational continuity within hospitals, even during challenging times.

METHODS

Study method

1. A cross-sectional study was conducted in 30 government, community, and private hospitals in the Bangkok metropolitan area as well as the central and eastern regions of Thailand. The study was reviewed and approved by the ethics committees of Nopparat Rajathanee Hospital and the hospitals providing data.

2. For this study, a purposive sample of 3,000 healthcare personnel responsible for patient care and those on the occupational health team was selected. Informed consent was obtained from all participants. Data collection was conducted between April and May 2021, during the post-initial outbreak period.

3. An assessment tool was used to evaluate healthcare personnel perceptions of COVID-19 infection risk control measures within the hospitals. This was done using a structured questionnaire developed based on the Guidance on Preparing Workplaces for COVID-19 (OSHA) (17) and the hierarchy of controls. The questionnaire covered aspects such as policy, risk reduction, administration, and PPE management. It was reviewed for accuracy by three experts, and its reliability was tested, resulting in a Cronbach's alpha coefficient of 0.75.

4. Knowledge, attitudes, and practices related to the care of COVID-19 patients, as well as PPE adherence, were assessed using a questionnaire developed based on the COVID-19 risk contact assessment by the World Health Organization (WHO) (18) and the U.S. Department of Health and Human Services (HHS) COVID-19 Healthcare Planning Checklist (19). The questionnaire was reviewed for accuracy by three experts, and its reliability was tested, resulting in a Cronbach's alpha coefficient of 0.82. Participants received detailed explanations and provided informed consent before completing the online assessment via a Google Form and submitted their data.

Data analysis

After the data collection, the information gathered was analyzed using existing software. Qualitative data was analyzed in terms of frequency and percentage. Quantitative data was analyzed using mean and 95% confidence intervals (CI). To compare mean scores and examine the magnitude of relationships between variables, statistical analysis utilized Generalized Linear Models (GLMs).

RESULTS

The majority of the healthcare personnel in the study were from regional/general hospitals (51.90%.), with average age of 35.5 years (Table 1). The healthcare personnel were predominantly female (85.50%) and most had education levels at or below a bachelor's degree (95.80%). Most were nurses (44.50%) and worked in patient care (88.0%). Regarding the perceptions of the implementation of exposure risk control measures, organizational management for PPE usage and administrative measures received high scores (4.7 out of 5 and 16.9 out of 19, respectively), as shown in Tables 2. Conversely, risk reduction measures had the lowest score at 7.7 out of 9. The mean scores for knowledge, attitude, and practices assessment by the healthcare personnel were high. Notably, the mean score for the practice of COVID-19 patient care (6.8 out of 7) was higher than the mean score for the PPE adherence (6.4 out of 7).

The study found that the private hospitals tended to have higher scores for knowledge and practice with the highest score for PPE adherence ($p \leq 0.05$). Males and younger personnel were also associated with higher scores for knowledge, practice and PPE adherence ($p \leq 0.05$). Additionally, personnel with patient care responsibilities had higher scores for attitude, practices and PPE adherence ($p \leq 0.05$). Finally, perception scores of the hierarchy of controls measures showed statistically significant positive correlations. The strongest correlation was with practice (r = 0.40), followed by PPE adherence (r = 0.37), knowledge (r = 0.33), and care of COVID-19 patients (r = 0.22) ($p \leq 0.05$) as detailed in Table 3

Table 1. Demographic characteristics of surveyed healthcare personnel

Variable	N (%)	Variable	N (%)
Hospital type		Position	
Regional	1,601 (51.88)	Doctor	34 (1.10)
Community	818 (26.50)	Nurse	1,373 (44.49)
Private	667 (21.61)	PN/NA	511 (16.56)
		Other	1,168 (37.85)
Gender		Age	
Male	449 (14.55)	≤ 40	2,263 (73.47)
Female	2,637 (85.45)	> 40	823 (26.53)
Education		Mean=34.16 max=63 min=18	
≤ Bachelor	2,957 (95.82)	Patient care	
> Bachelor	129 (4.18)	Yes	2,717 (88.04)
		No	369 (11.96)

PN/NA = practical nurse/nursing assistant

Table 2. Scores for hierarchy of control and knowledge, attitudes and practices

Hierarchy of control	N	Full score	Mean (SD)	KAP	N	Full score	Mean (SD)
Policy	3,086	3	2.90 (0.369)	Knowledge	3,086	7	6.30 (1.140)
Reduce risk	3,086	9	7.65 (1.494)	Attitude	3,086	4	3.80 (0.555)
Administrative	3,086	19	16.94 (2.885)	Practice	3,086	14	13.20 (1.084)
PPE management	3,086	5	4.69 (0.741)	Patient care		7	6.83 (0.520)
				PPE adherence		7	6.40 (0.824)

KAP, knowledge, attitude, practice; PPE, personal protective equipment

The Generalized Linear Model analysis revealed that healthcare personnel aged 40 years or younger, and those with a history of COVID-19 infection had higher PPE adherence scores by 1.12 and 1.3 points, respectively (95%CI: 1.04-1.21 and 1.23-1.45). Furthermore, each 1-point increase in knowledge scores and PPE management scores was associated with a 1.3 point and 1.5 point increase in PPE adherence scores, respectively (95%CI: 1.26-1.34 and 1.43-1.57), with a statistical significance level of $p < 0.01$, as shown in Table 4.

DISCUSSION

The perception scores of infection risk control measures by hierarchy of controls

The study found that perception scores regarding the implementation of infection risk control measures based on the hierarchy of controls were generally high, ranging from 85.00% to 90.00%. The hierarchy of controls ranks occupational health control measures by effectiveness, with elimination of the infection source being the most effective strategy. However, eliminating the presence of infectious patients in hospitals is not feasible. Instead, measures to reduce pathogen presence in the hospital environment such as establishing acute respiratory infection (ARI) clinics, using negative-pressure rooms, implementing physical isolation, and improving ventilation systems are widely recommended (20). Additionally, technology-based patient management and strategies to reduce hospital crowding have been proposed to minimize environmental contamination (21). These structural measures may require extensive preparation, which is challenging during urgent outbreaks. In line with our study's findings, infection elimination and pathogen reduction strategies received the lowest scores (85.00%), while administrative and exposure risk control measures were rated higher (89.20%). These control measures include policy enforcement, hospital facility management, hygiene protocols, staff and patient screening systems, and exposure reduction strategies such as contact investigation, quarantine, surveillance, and treatment (5-7).

The role of PPE in infection prevention

PPE is considered the least effective risk control measure in the hierarchy of controls (5). However, in clinical settings, higher-level controls such

Table 3. Comparison of mean knowledge, attitude and practice scores among healthcare personnel by other factors

Variable	N (%)	Mean score				
		Knowledge	Attitude	Practice	Subgroup of practice	
					COVID Patient care	PPE adherence
Hospital*						
Regional	1,601 (51.90)	6.25	3.75	13.24	6.86	6.38
Community	818 (26.50)	6.13	3.83	13.11	6.76	6.34
Private	667 (21.60)	6.47	3.72	13.37	6.84	6.52
p-value		≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01
Gender**						
Male	449 (14.50)	6.38	3.80	13.36	6.83	6.51
Female	2,637 (85.50)	6.24	3.76	13.22	6.83	6.38
p-value		0.02	0.09	≤ 0.01	0.85	≤ 0.01
Age**						
≤ 40	2,263 (73.47)	6.29	3.75	13.28	6.84	6.43
> 40	823 (26.53)	6.20	3.79	13.13	6.80	6.32
Mean=34.16, max=63, min=18						
p-value		0.05	0.11	≤ 0.01	0.09	≤ 0.01
Education**						
≤ Bachelor	2,957 (95.82)	6.28	3.77	13.24	6.83	6.40
> Bachelor	129 (4.18)	5.86	3.72	13.06	6.79	6.27
p-value		≤ 0.01	0.37	0.06	0.34	0.06
Position**						
Doctor	34 (1.10)	6.35	3.68	13.03	6.70	6.32
Nurse/practical nurse/ nurses' aide	1,884 (61.10)	6.22	3.76	13.25	6.83	6.41
Other	1,168 (37.80)	6.33	3.77	13.22	6.83	6.38
p-value		0.05	0.63	0.40	0.33	0.41
Patient care*						
Yes	2,717 (88.00)	6.25	3.79	13.25	6.83	6.41
No	369 (12.00)	6.40	3.58	13.12	6.83	6.28
p-value		0.02	≤ 0.01	0.03	0.96	≤ 0.01
Hierarchy of control scores***	3,086 (100.00)	r = 0.33	r = -0.004	r = 0.40	r = 0.22	r = 0.37
p-value		< 0.01	0.82	< 0.01	< 0.01	< 0.01

*One-way ANOVA, **Independent t-Test, ***Spearman correlation
PPE, personal protective equipment

Table 4. Odds ratio of PPE adherence scores and associated variables analyzed using Generalized Linear Models

Variable	N (%)	SE	COR	AOR	95%CI		P-value
					Lower	Upper	
Age ≤ 40	2,263 (73.3)	0.040	1.157	1.123	1.039	1.213	< 0.01
History of COVID-19 infection	553 (17.9)	0.046	1.561	1.328	1.213	1.454	< 0.01
Increased Knowledge score	3,086 (100.0)	0.016	1.369	1.297	1.258	1.338	< 0.01
Increased PPE management score	3,086 (100.0)	0.024	1.588	1.497	1.429	1.569	< 0.01

Adjusted for hospital type, gender, age, education, position, patient care, contact high risk, History of COVID-19 infection, Knowledge Score, Attitude Score, PPE management score (hierarchy of controls), Reduce risk and Administrative Score (hierarchy of controls)
SE, Standard Error; COR: crude odds ratio, AOR: adjusted odds ratio

as elimination are often impractical. This makes PPE essential for protecting healthcare workers with direct patient contact. Our study found that hospitals prioritized PPE allocation for personnel as a primary protective strategy, recognizing its role in both rapid implementation and routine

infection prevention. PPE is a fundamental part of universal precautions against infections transmitted via respiratory droplets, such as COVID-19 (22). That virus is known to be highly prevalent in respiratory tissues, including the upper respiratory tract, nasal passages, throat (23), tears, and feces (24). Therefore, most hospitals emphasized standard precautions and appropriate PPE usage to protect healthcare workers (22, 25). Despite these measures, our study found critical challenges in PPE implementation. During the early COVID-19 outbreak, PPE shortages were a significant issue, exacerbated by increased demand from both healthcare personnel and the public (26). Larger hospitals, such as central and general government hospitals, scored higher in PPE implementation, while community hospitals faced challenges due to limited resources. Our findings support recommendations to strengthen community hospital capacity and encourage private hospitals to expand isolation rooms for infected patients (27). Additionally, private hospitals demonstrated higher PPE efficiency and workforce management compared to government hospitals, primarily due to the necessity of maintaining continuous business operations.

Factors influencing healthcare personnel practices

The study also examined how demographics and prior infection experience influenced PPE adherence and safety behaviors. Healthcare personnel in direct patient care roles, particularly nurses, received higher levels of PPE support than other groups. However, lack of proper training and inconsistent PPE use limited overall effectiveness. Early in the pandemic, limited knowledge about COVID-19 transmission led to increased anxiety and fear among healthcare personnel, affecting their adherence to PPE protocols (28). Age was identified as a significant factor. Previous studies have reported that individuals over 40 years of age who work in direct patient care roles had higher knowledge, attitudes, and practice (KAP) scores, likely due to their greater experience (29). This contrasts with the findings of the present study, which indicated that while healthcare personnel over 40 had better attitudes, they demonstrated lower knowledge of and adherence to PPE guidelines. A possible explanation for this discrepancy is that most participants in this study were in a younger age group (mean = 34.2). Furthermore, they were part of patient care teams where they received training and had ready access to PPE, and they could readily use technology for better access to information (30). Additionally, our study found that male healthcare personnel had higher KAP scores than female personnel, which may be attributed to their higher representation in frontline patient care roles (99.10%).

Impact of knowledge and hospital management on PPE adherence and usage

Using a generalized linear model to analyze factors related to safe behaviors regarding COVID-19 infection, it was observed that individuals aged 40 years or younger and those with prior infection experience had higher scores for PPE adherence, with scores of 1.1 and 1.3, respectively (95%CI: 1.04-1.21 and 1.21-1.45). Further analysis of personnel with prior infection experience found significantly higher KAP scores (6.7, 3.9, 13.6) compared to non-infected personnel (6.2, 3.7, 13.2), ($p < 0.01$). Additionally, an increase of 1 point in knowledge and hospital support for PPE usage scores was associated with a 1.3-point and 1.5-point increase in PPE adherence scores (95%CI: 1.26-1.34 and 1.43-1.57). These findings suggest that increased knowledge of COVID-19 and first-hand infection experience enhance PPE adherence through improved awareness, understanding of risks, and practical application of safety protocols. Additionally, our study identified hospital management support for PPE, including training programs, appropriate equipment selection, and adequate stockpiling, as the most influential factor in PPE adherence (26). Given the critical PPE shortages experienced early in the pandemic, establishing systematic inventory management and distribution protocols is crucial for future preparedness (9, 31).

Study limitations and recommendations for future research

This study was conducted as a rapid response project to support pandemic preparedness. The study's strengths include a sufficiently large sample size to detect score differences. However, certain limitations should be acknowledged:

- The sample was limited to frontline health-

care personnel, which may have introduced selection bias, making the findings less representative of the entire healthcare workforce.

- Self-reported survey data may not fully capture real-world adherence to infection control measures, as social desirability bias could influence responses.
- The reliance on online survey methods may have excluded healthcare personnel with limited digital access, affecting sample diversity.

Future studies should incorporate direct observations and interviews to gain a more comprehensive understanding of healthcare personnel safety behaviors and greater adherence to infection control measures. Additionally, exploring the long-term impact of infection prevention training and evaluating systemic improvements in PPE policies would be beneficial for strengthening hospital preparedness.

CONCLUSION

This study highlights the critical role of PPE, administrative controls, and infection risk awareness in mitigating COVID-19 risks in healthcare settings. While PPE serves as an essential protective measure, its effectiveness is dependent on proper training, consistent availability of PPE, and strong institutional support. Despite PPE being the least effective measure in the hierarchy of controls, it remains vital for healthcare personnel, particularly in high-risk environments where exposure to infectious patients is unavoidable. This study found that increased knowledge, infection experience, and strong hospital support significantly enhanced PPE adherence and safe practices among healthcare workers.

The study also highlights the importance of organizational strategies, such as comprehensive infection control policies, ongoing training programs, and efficient PPE supply chain management, which are crucial for ensuring sustained PPE effectiveness. Additionally, administrative and environmental interventions, including improved ventilation systems, structured hospital workflows, and digital infection tracking, should be prioritized to reduce healthcare-associated infections beyond reliance on PPE alone. Future pandemic preparedness efforts should focus on strengthening multi-level risk control measures, ensuring adequate PPE reserves, and integrating evidence-based training programs to enhance healthcare worker compliance and safety. Strengthening hospital infrastructure and response systems will be key to improving resilience against future outbreaks, safeguarding both healthcare personnel and patient populations.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the Thailand Science Research and Innovation (TSRI) for their financial support of this study. We would also like to extend our thanks to the project coordinator and the healthcare personnel for their cooperation and assistance with the data collection in the study.

FUNDING

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

CONFLICT OF INTEREST

The authors have no conflicts of interest to report.

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