




**ORIGINAL RESEARCH:
EMPIRICAL RESEARCH - QUANTITATIVE**

Health care workers' experience of personal protective equipment use and associated adverse effects during the COVID-19 pandemic response in Singapore

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Abstract

Aim: One of the greatest challenges in responding to the COVID-19 pandemic is preventing staff exposure and infection by ensuring consistent and effective use of personal protective equipment (PPE). This study explored health care workers' experience of prolonged PPE use in clinical practice settings and their concerns regarding PPE supply, effectiveness and training needs.

Design: A descriptive cross-sectional design was adopted in this study.

Methods: Health care workers ($N = 592$) from an acute care hospital completed an online survey from July to September 2020 assessing: (i) usage frequencies, side effects and interference with patient care; and (ii) perceptions of access to PPE, likelihood of exposure to infection and adequacy of PPE training.

Results: PPE-related side effects were reported by 319 (53.8%) participants, the majority being nurses (88.4%) and those working in high-risk areas such as the emergency department (39.5%), respiratory wards (acute 22.3% and non-acute 23.8%) and COVID-19 isolation ward (13.8%). The average time wearing PPE per shift was 6.8 h (SD 0.39). The most commonly reported symptoms were from donning N95 masks and included: pressure injuries (45.5%), mask-induced acne (40.4%) and burning/pain (24.5%). Some 31.3% expressed that PPE-related side effects had negatively affected their work. The odds of having PPE-associated side effects was higher in women (OR 2.10, 95% CI [1.29–03.42], $p = .003$) and those working in high-risk wards (OR 3.12, 95% CI [2.17–4.60], $p < .001$). Most (90.1%) agreed that PPE supplies were readily available, sufficient for all (86.1%) and there was sufficient training in correct PPE use (93.6%). Only 13.7% of participants reported being 'highly confident' of overall PPE protection.

Conclusions: Prevention and management of PPE-related adverse effects is vital to: preserve the integrity of PPE, improve adherence and minimize viral transmission.

Impact: The high incidence of PPE-associated pressure injuries and perception that PPE use can interfere with clinical care should inform future development of PPE

products, and strategies to better equip health care workers to prevent and manage PPE-related side effects.

KEYWORDS

acute care, health care workers, nurse, pressure injuries, protective personal equipment, side effect, skin tear

1 | INTRODUCTION

Coronavirus disease 2019 (COVID-19) caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was first reported in December 2019. To date, there are more than 207 million confirmed cases and more than 4.3 million deaths reported worldwide (World Health Organization, 2020). Given the high transmissibility and modes of transmission of SARS-CoV-2, health care workers (HCWs) are required to continue using maximum barrier precautions with personal protective equipment (PPE) (Centers for Disease Control and Prevention, 2020). The World Health Organization recommends N95 masks or surgical masks, goggles or face visors, gloves, aprons and gowns as the necessary PPE and alcohol-based disinfectants and soap are recommended for hand hygiene (World Health Organization, 2020). The extended time that HCWs need to use PPE when providing care during the COVID-19 pandemic has raised concerns about the increasing incidence of occupationally induced adverse effects (Gheisari et al., 2020; Lan et al., 2020; Navarro-Triviño & Ruiz-Villaverde, 2020).

2 | BACKGROUND

Prolonged PPE use increases the risk of skin irritation and some commonly reported symptoms include: burning, pain, pressure injuries, skin tears, blisters, acne, abrasions, eczema/atopic dermatitis and allergic reactions (Daye et al., 2020; Lan et al., 2020). As some HCWs initiate self-care measures without seeking medical review, the incidence of PPE-associated adverse skin reactions is likely to be under-reported (Foo et al., 2006). It may also be challenging for HCWs to seek dermatology consultation during peak periods of the COVID-19 pandemic.

Besides skin problems, HCWs have also reported experiencing PPE-associated headaches that include pain and discomfort in the facial and earlobe region that affected their work performance (Ong et al., 2020; Radonovich et al., 2009; Shenal et al., 2012). PPE-associated headaches occur due to extended periods of compression of pericranial soft tissues associated with using N95 face masks and protective eyewear. Poorly fitting N95 masks may be one factor contributing to the increased incidence of headaches and may also influence adherence to PPE guidelines (Rebmann et al., 2013).

Other reported PPE-related side effects include breathing difficulties, heat stress and dehydration from increased sweating (Khoo et al., 2005; Loibner et al., 2019). Others have reported that wearing

IMPACT STATEMENT

- It is vital to establish the prevalence of PPE-related pressure injuries (PI) and side effects experienced by health care workers (HCWs) working in humid, subtropical climates such as South-East Asia.
- This study explored HCWs' perceptions of supply and access to PPE and their concerns regarding the potential for exposure to COVID-19 infection and the adequacy of PPE training provided.
- Nurses working in the emergency department reported the most side effects, with the most commonly reported symptoms relating to N95 mask use, including pressure injuries, mask-induced acne and burning/pain.
- HCWs reported that experiencing PPE-related side effects negatively affected their work.
- Most agreed that PPE was readily available, sufficient for all and there were adequate PPE training, however only a low percentage of the HCWs were highly confident of overall PPE protection.
- Findings will inform the development of targeted interventions to improve infection control practices and better support HCWs providing care and treatment during the COVID-19 pandemic.
- Improvements in PPE design are needed to increase HCWs' adherence to PPE usage and minimize the potential for exposure to COVID-19 infection.

PPE led to poor dexterity due to multiple glove layers, poor visibility when wearing face shields and some individuals suffered back pain when using powered air-purifying respirators (PAPR) (Loibner et al., 2019).

Effective and consistent use of PPE is one of the greatest challenges in managing the COVID-19 pandemic, as its use has substantial physical and psychological impacts on both HCWs and patients (Hignett et al., 2020; Sorbello et al., 2020). Physical challenges include the constant donning and doffing of PPE during a shift and the requirement to use uncomfortable masks and goggles for prolonged periods. During the initial phases of the COVID-19 pandemic some clinicians experienced increased levels of stress and anxiety associated with the need to operate under changing practice standards, and concerns about the likelihood of COVID-19 exposure when performing different medical procedures (Adams &

Walls, 2020; De Kock et al., 2021; Newman, 2020). With the need for rapid response to the COVID-19 outbreak, it was critical for HCWs to rapidly develop their skills in donning and doffing PPE to ensure personal protection from exposure to COVID-19 (Savoia et al., 2020). Initial reports of a widespread, international lack of PPE supply and reports of difficulties in international supply chains also raised HCWs' concerns that critical PPE might not be available to protect them when providing essential care to patients with known or suspected COVID-19 infection (Newman, 2020). As the pandemic evolved and a better understanding of viral transmission mechanisms emerged, there was a need for ongoing changes in PPE policies and procedures. This dynamic policy environment also made consistent training of HCWs in optimal PPE use challenging (Savoia et al., 2020).

Although there have been many reported problems arising from prolonged PPE use, most of the literature originates from Europe and China. European countries are generally characterized by their temperate climate with cooler temperature and dryer environment during the summer months, while China has a more pronounced winter season (Daye et al., 2020; Hignett et al., 2020; Lan et al., 2020; Navarro-Triviño & Ruiz-Villaverde, 2020). No studies have reported data from tropical countries such as Singapore, where more humid conditions and warm temperatures are the norm all year round (Encyclopaedia Britannica, 2016). There is also evidence suggesting that in hot and humid climates the prevalence of atopic dermatitis is higher (Deckers et al., 2012; Tsai et al., 2019). One explanation for this phenomena, is that the increased perspiration that occurs under humid conditions, also affects the skin's barrier function increasing cellular turnover which in turn increases the incidence and severity of atopic dermatitis in susceptible individuals.

As of August 2021, 76% of the Singaporean population had received two doses of COVID-19 vaccine, however, the likelihood of viral mutation and the risk of widespread transmission remained high (Ministry of Health, 2021). Facing this ongoing challenge, HCWs in Singapore have continued using PPE for prolonged periods in hot and humid environments potentially increasing their risk of experiencing PPE-related side effects (Lan et al., 2020; O'Neill et al., 2020). Furthermore, a substantial number of Singapore's health services are not equipped with air conditioning in all clinical areas, which may increase the risk of developing PPE-related side effects (Deckers et al., 2012; Tsai et al., 2019). For example, HCWs working in Singapore needed to work prolonged shifts (up to 12 hours) in a variety of locations without air conditioning, such as: the emergency department influenza and respiratory infection screening areas, community care facilities (CCF)/community recovery facilities (CRF), dormitories or involved in dormitory outbreak control operations and isolation/quarantine facilities.

This study explored health care workers' experience of prolonged PPE use in clinical practice settings and their concerns regarding PPE supply, effectiveness and training needs in Singapore. The study findings will be used to inform targeted interventions to improve adherence to PPE guidelines, and infection control practices to better

support HCWs providing essential care and treatment during the COVID-19 pandemic in Singapore.

3 | THE STUDY

3.1 | Aim

The aims of this study were: to examine the prevalence and impact of PPE-related side effects among HCWs providing care during the COVID-19 pandemic in Singapore and to explore their perceptions of PPE effectiveness, supply, access and training.

3.2 | Research questions

- (i) What is the prevalence of HCW self-reported PPE-related pressure injuries (PI) and side effects including: (a) Frequency, duration and type of PPE used, (b) Type and characteristics of PPE-related side effects and, (c) Perceptions that PPE use interfered with patient care provision.
- (ii) What are HCW's perceptions of access to PPE supplies, their potential risk of COVID-19 exposure and infection and, the adequacy of the guidance and training they received in appropriate PPE use.

3.3 | Design

A cross-sectional descriptive survey study design was used.

3.4 | Participants

A convenience sampling approach was employed. All HCWs, including doctors, nurses, allied health professionals, pharmacists, health care and administrative staff working in the hospital during the COVID-19 pandemic, were eligible and invited to participate in this study. Their work locations included: the isolation ward for COVID-19 patients, acute respiratory infection (ARI) ward, non-ARI ward, emergency department influenza and respiratory infection screening areas, operating theatre, outpatient facilities, CCF/CRF, dormitories or involved in dormitory outbreak control operations and isolation/quarantine facilities. Exclusion criteria were student HCWs.

Based on the population of health care workers reported in the latest SingHealth statistics report, the total number of staff eligible to participate (nurses, medical doctors, pharmacists, allied health and patient care associates) was 9201 (SingHealth Duke NUS Medical Centre, 2021). To generate a representative sample from this population with an error margin of 5% around the 95% confidence interval a minimum sample size of 370 responses was required (The Research Advisors, 2006).

3.5 | Data collection

Data were collected via an online survey distributed to HCWs working in an acute care tertiary public hospital in Singapore from July 2020 to September 2020. Participation in the survey was voluntary and confidential. The online survey was disseminated hospital-wide via email with a cover letter explaining the study and inviting participants to complete the survey. To improve the response rate, weekly emails were sent out during the data collection period to encourage HCWs to participate in the study. At the same time, posters explaining the study were also posted on the organization's online platform and put up on notice boards in all work locations across the organization.

3.5.1 | Survey development

As there is no validated survey in the literature, a survey tool was developed based on a systematic literature review and input from an expert panel that included: international researchers, credentialed infection control practitioners and nurse consultants who were in charge of infection control procedures and PPE training activities across the organization. Survey content was informed by the research literature that identified HCWs' experiences of common PPE-related side effects, and the impact of these on their daily work (Daye et al., 2020; Gheisari et al., 2020; Lan et al., 2020; Navarro-Triviño & Ruiz-Villaverde, 2020). The survey also explored HCWs' perceptions of their risk of exposure to COVID-19 at work, PPE supply and accessibility and the adequacy of PPE training provided in their workplace (Hignett et al., 2020; Newman, 2020; Sorbello et al., 2020).

The survey tool was then refined through a series of meetings with the expert panel who provided feedback on the relevance and appropriateness of the survey structure and evaluated the need for rewording, reordering or adaptation of individual questions. Panel members ranked individual questions as: 'appropriate', 'revision required' or 'should be removed'. Where more than two of the five experts evaluated questions as 'revision required' or 'should be removed', the item was revised until consensus was reached. Finally, the survey was evaluated for interpretability, redundancy and ease of administration and based on their suggestions, minor modifications were made.

The final survey contains three sections that comprise questions answered with a Likert scale, ranging from '1' (strongly disagree) to '5' (strongly agree), some yes or no questions, and some open-ended questions. Participants had to provide complete responses for each question before they could submit the survey online. Demographic data such as gender and age, occupational information including occupation title, current employment status (full/part-time), work location and history of pre-existing skin conditions (eczema, atopic dermatitis, heat rash dermatosis, psoriasis, dry skin, others including acne, hives and keloid) were collected. The second section of the questionnaire comprised questions on PPE usage, the frequency of PPE-related side effects (burning/pain, pressure injuries, skin tear, blister, eye protection-induced acne,

mask-induced acne, abrasion, eczema and allergic reaction), and impact of PPE-associated side effects on daily work and patient care. In addition, participants were asked to elaborate whether PPE-related side effects had affected their work and resulted in them experiencing discomfort when providing care wearing full PPE. The third section focused on HCWs' perceptions of PPE supply and accessibility, their likelihood of exposure to infection, and the PPE training provided in their workplace. Participants were also asked to elaborate on which clinical procedures they perceived might increase their risk of exposure to COVID-19 infection, and the influence of 'PPE spotters', (observing donning and doffing procedures) on practices in their workplace.

3.6 | Ethical considerations

The study was approved by the institutional human research ethics committee. Consent was implied by voluntary and anonymous completion of the survey.

3.7 | Data analysis

Data were exported using SPSS version 25.0 (SPSS Inc.) for analysis. An independent study team member carried out cross-checks to ensure data accuracy before analysis (Gerrish & Lacey, 2010). Descriptive statistics, including frequencies and percentages, were used to summarize: demographic characteristics, occupation, work location, existence of pre-existing skin conditions, hours of PPE use, PPE-related side effects and self-care measures used. Descriptive analyses were also used to summarize participants' perceptions of the impact of side effects on their daily work and patient care, the accessibility of PPE supplies, the likelihood of exposure to infection, and the training provided.

Logistic regression and odds ratio estimates were computed to demonstrate the relationship between sociodemographic characteristics (age, gender, occupation, pre-existing conditions and level of COVID-19 risk in the work area (high or low) and PPE-associated side effects. The level of significance was set at $p < .05$.

The free-text survey responses were analysed using qualitative thematic analysis as per Braun and Clarke (2006).

4 | RESULTS

A total of 592 HCWs completed the survey. The majority of respondents were female (81.9%) and below 40 years old (75.7%) (Table 1). Most were nurses (87.3%), followed by doctors (4.2%) and allied health (2%). Out of 592 participants a pre-existing skin condition was reported by 269 (45.4%). Among them, dry skin ($n = 156$, 58.0%) and eczema ($n = 92$, 34.2%) were the most commonly reported conditions. The mean hours of PPE usage were 6.14 h (SD 5.85) per day. Eighty-eight percent of participants reported using N95, and 70.3%

TABLE 1 Comparison of demographic, clinical characteristics and hours of PPE use between participants with and without PPE-related side effects (N = 592)

Gender	Experience of PPE-related side effects, n = 319 (53.8%)	No experience of PPE-related side effects, n = 273 (46.2%)	Total (N = 592)	χ^2 ^a	p value
Male	42 (13.1%)	59 (21.6%)	101 (17.1%)	7.29	.03*
Female	273 (85.6%)	212 (77.7%)	485 (81.9%)		
Prefer not to say	4 (1.3%)	2 (0.7%)	6 (1.0%)		
Age					
<21	3 (0.9%)	3 (1.5%)	6 (1%)	16.06	.07
21–30	130 (40.8%)	91 (33.3%)	222 (37.5%)		
31–40	126 (39.5%)	94 (34.4%)	220 (37.2%)		
41–50	32 (10.0%)	35 (12.8%)	67 (11.3%)		
51–60	20 (6.3%)	30 (11.0%)	50 (8.4%)		
≥61	8 (2.5%)	19 (7.0%)	27 (4.6%)		
Occupation					
Doctor	14 (4.4%)	11 (4.0%)	25 (4.2%)	5.84	.21
Nurse	282 (88.4%)	235 (86.1%)	517 (87.3%)		
Allied health	8 (2.5%)	6 (2.2%)	14 (2.4%)		
Others	15 (4.7%)	21 (7.7%)	36 (6.1%)		
Work Location ^c					
COVID-19 isolation ward	44 (13.8%)	19 (7.0%)	63	8.47	<.001*
Acute respiratory infection ward	71 (22.3%)	26 (9.5%)	97	17.93	<.001*
Non-acute respiratory ward	76 (23.8%)	134 (49.1%)	210	21.31	<.001*
Emergency Department	126 (39.5%)	84 (30.8%)	210	5.07	.02*
Operating theatre	9 (2.8%)	6 (2.2%)	15	0.34	.56
Community isolation facilities	22 (6.8%)	19 (7.0%)	41	0.001	.98
Others (including outpatient clinics)	45 (14.1%)	10 (3.7%)	55	0.07	.97
Skin conditions ^b (pre-existing) ^c					
None	185 (58.0%)	138 (50.5%)	323	36.77	<.001*
Yes	134 (42.0%)	135 (49.5%)	269		
Eczema	64 (47.8%)	28 (10.3%)	92		
Atopic dermatitis	52 (38.8%)	11 (4.0%)	63		
Heat Rash	46 (34.3%)	6 (2.2%)	52		
Dermatosis	4 (3.0%)	3 (1.1%)	7		
Psoriasis	7 (5.2%)	1 (0.4%)	8		
Dry skin	104 (77.6%)	52 (19.0%)	156		
Others (Acne, Hives and Keloid)	21 (15.7%)	7 (2.6%)	28		
Hours of PPE use (hours)/shift, mean (SD)	6.80 (0.39)	5.37 (4.21)	6.14 (5.85)	-2.99 ^b	<.003*

*Significant value $p < .05$.

^aChi-square test.

^bIndependent two-sample t-test.

^cData expressed denotes multiple responses.

wore surgical masks, and for eye protection face shields were worn by (67.4%) and goggles (52.7%).

4.1 | PPE-related side effects

PPE-related side effects were reported by 319 (53.8%) participants, the majority being nurses (88.4%) and those working in high-risk areas such as the emergency department (39.5%), respiratory wards (acute 22.3% and non-acute 23.8%) and COVID-19 isolation ward

(13.8%), (Table 1). Some HCWs were deployed to work between low- and high-risk locations, thus 50 (15.7%) participants who reported PPE-related side effects had worked in multiple work locations.

4.2 | Factors associated with experiencing PPE-related side effects

The odds of experiencing PPE-associated side effects was higher in women (OR 2.10, 95% CI [1.29–3.42], $p = .003$), and those working in COVID-19 high-risk wards (OR 3.12, 95% CI [2.17–4.60], $p < .001$). In contrast the odds were lower in those aged ≥ 51 years (OR 0.40, 95% CI [0.22–0.72], $p = .002$) and those with pre-existing skin conditions (OR 0.33, 95% CI [0.23–0.47], $p < .001$) (Table 2). Being aged between 31 and 50 years old and occupational status were not significantly associated with the likelihood of developing PPE-related side effects.

4.3 | Commonly reported symptoms from the PPE

Overall, the most commonly reported symptoms associated with PPE use were related to using N95 masks, including mask-related pressure injuries (PIs) (45.6%), mask-induced acne (40.4%) and burning/pain (24.5%) (Table 3). Others reported PIs from donning goggles (32.3%) and acne (25.4%) from using surgical/reusable mask.

TABLE 2 Factors associated with the development of PPE-related side effects

Gender	Adjusted OR (95% CI) ^a	<i>p</i> value
Male	Ref	.003*
Female	2.10 (1.29–3.42)	
Age		
≤ 30	Ref	
31 to 50	0.76 (0.51–1.12)	.16
≥ 51	0.40 (0.22–0.72)	.002*
Occupation		
Doctor	Ref	
Nurse	0.98 (0.39–2.49)	.97
Allied health	0.96 (0.20–4.50)	.95
Others	0.70 (0.23–2.20)	.55
Work location		
Low risk ^b	Ref	
High risk ^c	3.12 (2.17–4.60)	<.001*
Skin conditions* (pre-existing)		
No	Ref	
Yes	0.33 (0.23–0.47)	<.001*

*Significant value $p < .05$.

^aNo PPE and other medical device related side effects is the reference group.

^bNon-acute respiratory wards, outpatient clinics, operating theatre and others.

^cIsolation wards and community isolation facilities, acute respiratory wards and DEM.

HCWs using N95 masks experienced adverse effects mainly on the nose bridge (55.2%) and cheeks (53.3%). Those using goggles reported skin injuries on the nose bridge (27.6%), forehead (28.2%) and cheeks (19.7%). The measures commonly taken to treat or prevent these adverse effects were using plaster bandages, acne cream, steroid cream and oral medications (18.8%), hydrocolloid dressings (10%) as well as using silicone or transparent film (9.4%).

4.4 | Impact of PPE adverse effects

A total of 31.3% ($n = 100$) of participants expressed that experiencing PPE-related side effects had adversely impacted their daily work, mainly due to an inability to concentrate because of pain, discomfort, itch, headache and the need for frequent adjustment of PPE (Table 3). Some participants 'strongly agreed'/'agreed' (19.6%) that PPE had interfered with their ability to provide patient treatment and/or general nursing care (Table 4). Some participants 27.5% ($n = 163$) reported experiencing discomfort donning full PPE to provide patient treatment and/or general nursing care. The most commonly reported reasons for discomfort were due to poor visibility from the fogging of goggles/glasses, body heat and perspiration. This affected their ability to perform procedures such as cannulation (as it was difficult to visualize the vein), and to perform dressings. As a consequence it took longer to complete care and there were delays in attending to patients.

4.5 | Perceptions of PPE supply, accessibility and training provided

The majority (90.1%) of participants 'agreed'/'strongly agreed' that PPE was readily available in their department and 86.1% agreed that there were sufficient PPE supplies for all staff (Table 5). Most respondents (93.6%) 'agreed'/'strongly agreed' that: (i) they had received sufficient training in correct PPE use and, (ii) that they had a clear understanding of how to use different types of PPE. Overall, most HCWs agreed that there were sufficient visual reminders on the correct PPE donning (90.2%) and doffing (87.5%) procedures and that these reminders were useful (donning (86.2%) and doffing (83.7%)). However, only 45.9% of participants felt that the sequence of donning and doffing PPE was 'very important' (Table 5).

4.6 | Perceptions PPE effectiveness and COVID-19 exposure risk

A total of 25.7% of HCWs reported that they had to perform clinical procedures daily that increased their exposure to airborne or droplet transmitted microorganisms during the COVID-19 pandemic (Table 4). A total of 138 (23.3%) of respondents felt that performing some clinical procedures could increase their risk of exposure to COVID-19. The most common clinical procedures reported were: airway procedures (intubation, suctioning, bronchoscopy, oropharyngeal examination,

TABLE 3 Impact of PPE-related side effects on daily work (N = 319)

Types of PPE (N = 319)	Goggles	Face shield	N95 mask	Surgical/reusable mask	χ^2 ^b	p value
Side effects^a (n (%))						
Burning/pain	51 (16.0%)	12 (3.8%)	78 (24.5%)	8 (2.5%)	184.58	<.001 [*]
Pressure injuries	103 (32.3%)	16 (5%)	146 (45.8%)	12 (3.8%)		
Skin tear	14 (4.4%)	2 (0.6%)	45 (14.1%)	5 (1.6%)		
Blister	15 (4.7%)	3 (0.9%)	28 (8.8%)	2 (0.6%)		
Eye protection induced acne	36 (11.3%)	10 (3.1%)	—	—		
Mask induced acne	1 (0.3%)	1 (0.3%)	129 (40.4%)	81 (25.4%)		
Abrasion	25 (7.8%)	10 (3.1%)	51 (16%)	6 (1.9%)		
Eczema	8 (2.5%)	5 (1.6%)	20 (6.3%)	12 (4%)		
Allergic reaction	3 (0.9%)	2 (0.6%)	24 (7.5%)	18 (5.6%)		
Others	24 (7.5%)	13 (4.1%)	22 (6.9%)	9 (2.8%)		
Headache	18 (5.6%)	8 (2.5%)	4 (1.3%)	—		
Blurred vision	6 (1.9%)	4 (1.3%)	—	—		
Giddy	4 (1.3%)	—	1 (0.3%)	—		
Itchy	—	1 (0.3%)	10 (3.1%)	4 (1.2%)		
Eye pain	1 (0.3%)	—	1	—		
Difficulty in breathing	—	—	3 (0.9%)	2 (0.6%)		
Throat irritation	—	—	1 (0.3%)	—		
Dry skin	—	—	2 (0.6%)	3 (0.9%)		
Location^a						
Nose bridge	88 (27.6%)	10 (3.1%)	176 (55.2%)	30 (9.4%)	257.22	<.001 [*]
Cheeks	63 (19.7%)	8 (2.5%)	170 (53.3%)	70 (21.9%)		
Forehead	90 (28.2%)	36 (11.3%)	19 (6%)	7 (2.2%)		
Top of the ear	35 (11.0%)	14 (4.4%)	76 (23.8%)	16 (5.0%)		
Behind the ear	30 (9.4%)	9 (2.8%)	42 (13.2%)	17 (5.3%)		
Eyebrow arch (from wearing goggles)	35 (11%)	—	—	—		
Others	8 (2.5%)	7 (2.2%)	38 (11.9%)	35 (11.0%)		
Impact of PPE side effects			Yes	No		
Did PPE side effects experienced influence your daily work?			100 (31.3%)	219 (68.7%)		
Examples of how PPE side effects affected daily work (most commonly reported – qualitative data)			<ul style="list-style-type: none"> • Cannot concentrate/focus due to pain • Discomfort • Itch • Frequent adjustment • Headache • Mask pressure on acne causing pain 			

*Significant value $p < .05$.

^aData expressed denotes multiple responses.

^bChi-square test.

use of Bilevel Positive Airway Pressure [BIPAP] machine or obtaining COVID-19 swab tests), attending to suspected COVID-19 patients and cardiopulmonary resuscitation (Table 6).

Survey responses revealed that only 13.7% of respondents were 'highly confident' that their PPE provided sufficient protection from COVID-19 exposure, and only 17.9% were 'highly confident' that their N95 mask fitted correctly (Table 6).

4.7 | Presence of 'spotters' influences practice

Among the respondents, 45.4% ($n = 269$) reported having spotters in their clinical area to monitor PPE donning and doffing (Table 7). Only 35% ($n = 95$) of this group felt that the presence of spotters raised their awareness and influenced their compliance to recommended PPE donning and doffing procedures.

TABLE 4 PPE interference with patient treatment/nursing care (N = 592)

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
PPE interferes with my ability to provide patient treatment and/or general nursing care	22 (3.7%)	95 (16%)	246 (41.6%)	168 (28.4%)	61 (10.3%)
Long-sleeved gowns interfere with my ability to provide patient treatment and/or general nursing care	18 (3.0%)	66 (11.1%)	232 (39.2%)	205 (34.6%)	71 (12%)
Discomfort during nursing care	Yes	No			
Do you experience discomfort wearing full PPE when providing patient treatment and/or general nursing care?	163 (27.5%)	429 (72.5%)			
Types of discomfort experienced	<ul style="list-style-type: none"> • Glasses/goggles fogging causes poor vision • Hot/warm, & sweaty/perspire • Interferes with procedures (palpating veins, performing dressings, auscultation, delay in attending to patients, increases time to complete work) • Difficulty in breathing • Itch • Pain from wearing PPE • Heat rash • Restricted movement 				

5 | DISCUSSION

We sought to examine the prevalence of PPE-related adverse effects experienced by HCWs in Singapore during the COVID-19 pandemic. A total of 53.8% of survey respondents reported experiencing PPE-related side effects, confirming previous reports that prolonged localized pressure on the skin and the hot and humid microclimate created in the covered region of the mask increases the likelihood of developing pressure injuries (Bambi et al., 2021) and acne flare-ups (Abiakam et al., 2021; Chiriac et al., 2020; Han et al., 2020; Yaqoob et al., 2021). The warm tropical climate in Singapore may also have contributed to the development of adverse effects after prolonged wearing of PPE as previously reported by Narang et al. (2019). HCWs in other countries have also reported a high incidence of PPE-related adverse effects during the COVID-19 pandemic, with up to 97% of the HCWs in China reporting skin reactions from prolonged PPE use (Daye et al., 2020; Jiang et al., 2020; Lan et al., 2020; Lin et al., 2020; O'Neill et al., 2020; Yan et al., 2020). The finding that HCWs with pre-existing skin conditions were already using preventative treatment and receiving dermatology consultation (Desai et al., 2020) may explain the lower self-reported prevalence of PPE-related side effects in that subgroup in the current study.

Similar to the studies by Daye et al. (2020) and Xia et al. (2020), the occurrence of PPE-associated side effects was most commonly reported by female HCWs. This could be related to women using cosmetics more frequently than the males, which may have contributed to the development of PPE-associated skin reactions (British Columbia Ministry of Health, 2021). Alternatively this may reflect differences in work patterns, such that women are more likely to be employed in roles where they are required to use PPE for prolonged periods without a break (Chua et al., 2020; Llop-Gironés et al., 2021). Older adults (aged ≥ 51 years) were less likely to report PPE-associated side effects, possibly reflecting age-related differences in the risk of developing skin conditions such as acne vulgaris.

This supports findings from a previous Singapore study performed during the Severe Acute Respiratory Syndrome outbreak, where younger HCWs (<29 years) were more likely to report PPE-related side effects including acne, dry skin and itch (Foo et al., 2006).

Participants working in the COVID-19 high-risk wards commonly worked 12-h shifts and were more likely to report PPE-associated side effects. This finding supports previous reports of an association between longer shift duration and higher incidence of PPE-related side effects (Unoki et al., 2021). The recommended preventative measures for mask-related skin injuries are to put on a properly fitted N-95 mask and applying skin barrier protectant (including moisturizer or gel) and a dressing pad or silicon tape before mask application. These measures can help minimize pressure and friction (Coyer et al., 2020). It is also essential to take frequent breaks of at least 10–15 min and to remove the masks every 2–3 h (Chua et al., 2020; Llop-Gironés et al., 2021), although this may be difficult to achieve in busy clinical environments. PPE-related side effects not only result in user fatigue and compliance with PPE usage guidelines (Agarwal et al., 2020; Fan et al., 2020) skin injuries also create a potential portal for COVID-19 viral infection (Liu et al., 2020). It is therefore essential to prevent and manage skin injuries that may increase HCWs risk of contracting COVID-19 infection in the workplace.

Consistent with reports from Jose et al. (2021), HCWs highlighted that fogging of glasses or goggles resulting in poor vision was the top factor affecting comfort levels when providing patient treatment. The lack of air conditioning in some clinical areas, and the heat and humidity in Singapore may also have compounded this issue. While applying cleaning or anti-mist agents on the goggles or glasses may be useful temporary measures, it would be beneficial to investigate strategies to improve the anti-fogging properties of goggles and face shields. Other reasons for discomfort included overheating and perspiration while wearing PPE, which interfered with HCWs ability to carry out patient care procedures such as cannulation and dressing changes (Hignett et al., 2020). Experiencing these discomforts

TABLE 5 Participants' perceptions of PPE supply, training and reminders (N = 592)

PPE supply	Strongly Agree	Agree	Neutral	Disagree	Strongly disagree
Recommended PPE is readily available in the department?	268 (45.3%)	265 (44.8%)	51 (8.6%)	7 (1.2%)	1 (0.2%)
Enough PPE supplies for all healthcare staff in the department?	243 (41%)	267 (45.1%)	65 (11%)	16 (2.7%)	1 (0.2%)
Reminders and training	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Sufficient training in correct PPE use	218 (36.8%)	336 (56.8%)	32 (5.4%)	2 (0.3%)	4 (0.7%)
Clear understanding of the indications for different types of PPE	221 (37.3%)	333 (56.3%)	32 (5.4%)	1 (0.2%)	5 (0.8%)
Sufficient visual reminders about correct PPE Donning procedures	203 (34.3%)	331 (55.9%)	46 (7.8%)	6 (1.0%)	6 (1.0%)
Sufficient visual reminders about correct PPE Doffing procedures	197 (33.3%)	321 (54.2%)	60 (10.1%)	7 (1.2%)	7 (1.2%)
Visual reminders on Donning PPE are useful	197 (33.3%)	313 (52.9%)	71 (12%)	5 (0.8%)	6 (1.0%)
Visual reminders on Doffing PPE are useful	195 (32.9%)	301 (50.8%)	82 (13.9%)	8 (1.4%)	6 (1.0%)
Importance of the sequence of Donning and Doffing PPE (N = 592)				Donning	Doffing
0 Not important				8 (1.4%)	3 (0.5%)
1				3 (0.5%)	3 (0.5%)
2 Slightly important				32 (5.4%)	24 (4.1%)
3				59 (10%)	52 (8.8%)
4				12 (1.9%)	10 (1.7%)
5 Not sure				15 (2.5%)	13 (2.2%)
6				26 (4.4%)	18 (3.0%)
7				28 (4.7%)	26 (4.4%)
8 Moderately important				91 (15.4%)	79 (13.3%)
9				46 (7.8%)	60 (10%)
10 Very important				272 (45.9%)	304 (51.4%)

may also contribute to HCW stress and exhaustion after prolonged periods of PPE use. These findings highlight potential opportunities to conduct human factors and ergonomic research to enhance the functional design of PPE so that HCWs are better supported to provide patient care in future pandemics.

Our HCWs perceived that PPE supplies were readily available and there was a sufficient stock for all in their work areas. This is reassuring as the adequacy of PPE supply has been shown to be one of the top concerns impacting on HCWs' overall mental health and well-being, (Moorthy & Sankar, 2020; Savoia et al., 2020). Interestingly, it was highlighted that HCWs reporting PPE availability issues may be overestimating the level of PPE required in low-risk areas. This may reflect gaps in their knowledge of infection control and concerns about personal exposure and potential infection (Savoia et al., 2020). Therefore, to prevent PPE supply chain disruptions there needs to be both accurate forecasting of PPE demand and HCW education regarding infection risks and choice of appropriate PPE in different clinical contexts (Sanford & Holdsworth, 2021; Tian et al., 2020).

Effective use of PPE includes the proper donning and removal and proper disposal of contaminated PPE to prevent either the wearer or people around them being accidentally exposed to the COVID-19 virus (Pottier et al., 2021). Most HCWs in this study reported that they had received sufficient training in PPE selection and use, despite

this, less than half felt that the donning and doffing sequence was very important. This highlights a key knowledge gap that should be the focus of further education (Christensen et al., 2020). Delivering training using simulation scenarios, video-based training and strategies to provide HCWs with visual cues to enhance adherence to correct donning and doffing procedures needs further evaluation. One simple but effective measure, with demonstrable effectiveness, is to provide HCWs with a full-length dressing mirror so they can observe their actions when donning and doffing PPE (Xia et al., 2020). Only a minority of respondents were highly confident of the protection provided from PPE and simulation-based training might also alleviate HCWs' fear of being contaminated and instil them with more confidence that PPE use provides them with sufficient protection from airborne pathogens such as the COVID-19 virus (Kang et al., 2021).

Behavioural change strategies, including monitoring and feedback, are effective strategies in infection prevention and control practice to reduce health care-associated infections and the use of spotters has been shown to minimize PPE misuse (Lee et al., 2019; Patel et al., 2021). From April 2020, 'Spotters' were stationed in high-risk work areas to observe and supervise appropriate PPE use and, that HCWs used the correct technique when donning and doffing PPE. Only a small number of participants however, felt that the spotters presence influenced the way they used PPE.

TABLE 6 Perception of mask fitting and PPE protection, likelihood of exposure to COVID-19 (N = 592)

	0 not confident	1	2 slight confident	3	4	5 not sure	6	7	8 very confident	9	10 highly confident
PPE protection	4 (0.7%)	14 (2.4%)	58 (9.8%)	52 (8.8%)	13 (2.2%)	29 (4.9%)	47 (7.9%)	90 (15.2%)	180 (30.4%)	23 (3.9%)	81 (13.7%)
Confidence in N95 mask fit	13 (2.0%)	14 (2.4%)	48 (8.1%)	39 (6.6%)	10 (1.7%)	52 (8.8%)	45 (7.6%)	79 (13.3%)	158 (26.7%)	28 (4.7%)	106 (17.9%)
Are there any specific clinical procedures that increase your risk of exposure to COVID-19 infection?			138 (23.3%)	Yes	No	Not applicable					
Procedures identified as associated with increased risk of COVID-19 exposure			138 (23.3%)	<ul style="list-style-type: none"> Airway procedures (intubation, suctioning, bronchoscopy, oropharyngeal examination, administering BiLevel Positive Airway Pressure ventilation and Performing COVID-19 swab tests) Attending to suspected COVID-19 patients Resuscitation Feeding (general) /Nasogastric feeding Performing venipuncture Violent/agitated patients (unable to put on full PPE on time) Unable to maintain safe distancing measures in clinics. 	272 (45.9%)	182 (30.7%)					
How often do you perform clinical procedures that increase your exposure risk?	Daily	152 (25.7%)	86 (14.5%)	2 to 3 times a week	87 (14.7%)	Once a week	231 (39%)	Not applicable			

In the context of the COVID-19 pandemic, HCWs' behaviour may also have been influenced by other contextual cues that heightened their awareness of the importance of using PPE correctly, and this may have reduced the impact of the spotters' presence (Bouchoucha & Moore, 2019). Only a minority of HCWs in this study reported high confidence in the protection provided by using PPE, and it may be natural that they were more inclined to vigilantly observe their own techniques in donning and doffing of PPE.

Wearing masks played a pivotal role in protecting HCWs from infection during the COVID-19 pandemic, as a good mask fit can effectively filtrate the airborne viral particles, minimize the risk of transmission, and provide HCWs with confidence that they have the level of protection they need (Adams & Walls, 2020). Despite this, only a minority of HCWs in our study reported a high level of confidence in their N95 mask fitting correctly. Current practice at the study site is to use the qualitative fit testing approach recommended by international guidelines and, the accepted test agents recommended by the Occupational Safety and Health Administration are used (3M Safety, 2020). Introducing quantitative fit testing would however remove the subjectivity of the test results and may improve HCWs' confidence that their N95 masks fits correctly and provides optimal protection from airborne pathogens (Regli et al., 2021).

5.1 | Limitations

Although this is, to our knowledge, the only study reporting side effects of PPE use in a tropical setting, there are some limitations. The main limitation is the opportunity of self-reported response bias among the HCWs. We were unable to verify and determine the severity of the side effects through the self-administered questionnaires and this study is unable to establish a cause-and-effect relationship between PPE use and the self-reported side effects experienced by HCWs. Also, there is a lack of direct observation of the use of PPE in the clinical setting. However, the use of online surveys in this study was the most ideal approach to reach out to participants working in different work locations including those in the isolation wards and facilities. An effective way to reduce the social desirability bias was through the assurance of anonymity and confidentiality assured to the participants when completing the online survey (Fisher & Katz, 2000; Larson, 2019). As the study sample was recruited from a tertiary institution, it may not be possible to generalize the findings to all health care settings.

5.2 | Implications for practice

A better understanding of the side effects associated with prolonged use of different types of PPE will inform the development of strategies to improve PPE design, and prevention in the workplace. Raising

TABLE 7 Influence of PPE spotters on adherence to guidelines (N = 592)

	Yes	No	Not applicable	Not sure
Are spotters used in clinical area to monitor donning and doffing PPE?	269 (45.4%)	63 (10.6%)	52 (8.8%)	208 (35.1%)
If Yes, Does the presence of 'Spotters' influence the way you use your PPE?	95 (35.3%)	153 (56.8%)	21 (7.8%)	–
Examples of how PPE 'Spotters' influenced PPE practices	<ul style="list-style-type: none"> • Be more mindful • Frequent remind staff proper donning and doffing PPE • Increase awareness • Prompt on doing hand rub • Spotters are auditors • Compliant to donning and doffing PPE 			

HCWs' awareness of the importance of prevention and the need for regular breaks when using PPE may help reduce the incidence of side effects associated with prolonged use. Visual reminders may be useful to encourage HCWs to take frequent breaks with the removal of masks during long periods of donning PPE. HCWs should also be encouraged to seek medical attention if PPE-related side effects become severe, as a breakdown in skin integrity may increase the risk of viral exposure and infection.

At the same time, improving PPE education and training should increase adherence to correct PPE use and minimize the potential for COVID-19 exposure. Printed step-by-step illustrated instructions in the correct sequence for PPE donning and doffing, displayed in designated clinical areas, is essential to raise awareness of the need to protect themselves and others from accidental contamination and viral exposure. Adequate training and greater knowledge of infection prevention and control may also improve HCWs' confidence in the protection provided by their PPE.

6 | CONCLUSION

The impact of PPE-related adverse effects on our HCWs must not be underestimated, even during times of pandemic. Prevention and management of these adverse effects is vital to preserve the integrity of PPE and minimize the risk of COVID-19 transmission. Even though climate factors, including temperature and humidity, cannot be controlled, other approaches can be undertaken to improve the experience of HCWs particularly those using full PPE in high-risk work areas.

Improvements to enhance the functional design of PPE and objective measurement of mask fitting will improve HCWs' experience and their confidence in the level of protection provided by the PPE they are using. During a pandemic, early preparation and forecasting of PPE demand may prevent supply chain disruptions and ensure that appropriate PPE is readily available when required. Adequate education and training of all HCWs in infection prevention and control and appropriate PPE use is essential. PPE training should also be integrated into future preregistration clinical curriculum to increase all HCWs' knowledge and skills in PPE selection and use, especially correct PPE donning and doffing procedures and the prevention of PPE-related side effects.

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CONFLICT OF INTEREST

The authors have no conflict of interest to disclose.

AUTHOR CONTRIBUTIONS

All authors have agreed on the final version and meet at least one of the following criteria (recommended by the ICMJE [<http://www.icmje.org/recommendations/>]):

- substantial contributions to conception and design, acquisition of data or analysis and interpretation of data;
- drafting the article or revising it critically for important intellectual content.

PEER REVIEW

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DATA AVAILABILITY STATEMENT

Due to the sensitive nature of the questions asked in this study, survey respondents were assured raw data would remain confidential and would not be shared. Data not available / The data that has been used is confidential.

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