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Infection, Disease & Health 27 (2022) 38–48

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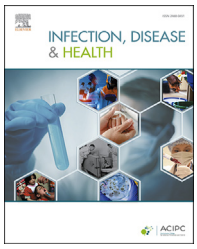

Research paper

Personal protective equipment training for non-healthcare workers in the Covid-19 pandemic: Effectiveness of an evidence-based skills training framework

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Received 7 July 2021; received in revised form 25 September 2021; accepted 27 September 2021
Available online 7 October 2021

KEYWORDS
Personal protective equipment compliance;
Training;
Non-healthcare workers;
Skill based training framework;
Pandemic

Abstract *Background:* Large-scale quarantine facilities staffed with non-healthcare workers (NHCW) were instrumental in preventing community spread of COVID-19 (coronavirus disease of 2019). The objective of this study was to determine the effectiveness of a newly developed procedural skills training framework in ensuring personal protective equipment (PPE) compliance of PPE-naïve NHCWs.
Methods: We developed a PPE procedural skills training framework for NHCWs using the Learn, See, Practice, Prove, Do, and Maintain (LSPPDM) framework and international guidelines on PPE for healthcare workers. The NHCWs underwent PPE training using this framework, conducted by a team of Infection Prevention nurses, prior to being stationed within the CCF. Effectiveness of the LSPPDM PPE training framework was assessed using: 1) competency assessment scores for NHCWs, 2) PPE compliance rates from daily audit findings, and, 3) healthcare-associated COVID-19 infection rates of NHCWs.

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https://doi.org/10.1016/j.idh.2021.09.040
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Results: A total of 883 NHCWs had completed the PPE training and demonstrated competency in PPE compliance, fulfilling 100% of the checklist requirements. Mean PPE compliance of all NHCWs during the 11-week study period was noted to be >96%. The post-implementation improvement was statistically significant when the compliance was expressed in 3-days blocks) and in bed management staff ($P = < 0.05$). None of the 883 NHCWs who underwent PPE training via the LSPPDM framework were diagnosed with healthcare-associated COVID-19 infection.
Conclusion: An evidence-based skills training framework is effective in PPE training of large numbers of NHCWs, resulting in high compliance of appropriate PPE use and prevention of healthcare-associated COVID-19 infection.
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Highlights

- Effectiveness of PPE training in non-healthcare workers who are PPE-naïve is unknown.
- Non-healthcare workers (NHCWs) attained >95% PPE compliance rates after training.
- An evidence-based training framework is effective PPE training of NHCWs.
- The training framework prevented healthcare-associated COVID-19 infection in NHCWs.
- A scalable and reproducible PPE training framework is useful for future pandemics.

Introduction

The coronavirus disease of 2019 (COVID-19) pandemic has presented unprecedented challenges to global healthcare systems. Novel, large-scale, rapidly deployable community isolation quarantine facilities termed Community Care Facilities (CCFs) were instrumental in preventing community spread of COVID-19 in Singapore [1,2]. Appropriate use of personal protective equipment (PPE) remains the most important factor in protecting CCF healthcare workers (HCWs) against COVID-19 [3]. In addition to HCWs, large numbers of non-healthcare workers (NHCWs) such as bed management staff, housekeeping staff, and security officers had to be trained quickly, as their services were needed in the CCFs. However, there is limited guidance on the training and usage of PPE for NHCWs who are in close contact with COVID-19 positive patients [4].

Inadequate training, improper use of PPE, protocol deviations and errors in doffing PPE have been shown to result in self-contamination and transmission of infectious diseases such as COVID-19 in trained HCWs [5—8]. Despite this, only 13% of HCWs in an academic health centre removed their PPE in the correct order whilst under direct observation, demonstrating significant inconsistency in real-world PPE doffing practices [9,10]. In addition, personal beliefs, perceptions and experiences can also affect adherence to PPE usage, resulting in additional variability [11,12]. This undesirable variability in PPE skills may arise from suboptimal PPE training [13], and from the lack of an evidence-based framework for PPE training [14].

Several authors have described PPE training methods to improve adherence in HCWs, including simulation training, however these have not been consistently underpinned by evidence-based skills training frameworks [13,15—19]. One group demonstrated that a mastery learning methodology, coupled with deliberate practice, was effective in training HCWs, but highlighted that studies with translational outcomes were required [20]. Most notably, there are no studies examining the effectiveness of PPE training in NHCWs, who are PPE-naïve. The Learn, See, Practice, Prove, Do, and Maintain (LSPPDM) framework is a procedural skills training framework that has demonstrated success in critical care and surgical settings, which could enhance effectiveness of PPE training in PPE-naive NHCWs [21,22].

For CCF operations, large numbers of NHCWs had to be rapidly trained during the COVID-19 pandemic. Facing this challenge, we designed a multi-faceted, evidence-based PPE training framework using the LSPPDM model to train all personnel who were deployed at the CCFs. The aim of this study was to determine the effectiveness of this newly developed training framework in ensuring PPE compliance of NHCWs. We hypothesized that this framework would lead to high rates of PPE compliance, and minimize healthcare-associated COVID-19 infection amongst NHCWs at the CCFs.

Methods

Study setting and participants

This IRB-approved study (CIRB 2020/2914) was undertaken at CCF@EXPO. Singapore EXPO is a purpose-built conference facility with 10 halls, spanning 100,000 square meters. It was converted into a large-scale community isolation quarantine facility with a capacity of 8000 beds [1]. Our parent healthcare organization, Singapore Health Services (SingHealth) managed 4 halls at CCF@EXPO, housing up to 800 patients per hall. During the study period from 10 May to 30 Jul 2020, up to 3200 COVID-19 patients were quarantined within the facility. This facility was designed to isolate ambulatory, generally asymptomatic, COVID-19 positive patients who were at low risk of developing complications from the disease. Each hall was retrofitted with

400 twin-sharing cubicles with 2 patient beds, medical consultation rooms, pharmacy, vital signs monitoring stations, toilets, bathrooms, food collection stations, water dispensers, recreational amenities and laundry facilities.

SingHealth CCF@EXPO was operated by 26 doctors and 72 "angels", i.e., a group of nursing and allied health staff who performed the same tasks of screening and monitoring the patients [1]. The team was supported by pharmacists and administrative support staff. The facility was managed by a managing agent and security agency which provided NHCWs who managed ground operations including admissions and discharges, logistics support, food and water supplies, environmental decontamination, and security. The NHCWs had no prior working experience in healthcare settings, were PPE-naïve and had longer "dwell" times as compared to HCWs as their duties required them to be stationed within the CCF for up to 8 h. In addition, larger numbers of NHCWs had to be rapidly trained in PPE to discharge their duties safely and effectively within a COVID-19 environment.

Study design

The LSPPDM procedural skills training framework was selected after a critical review of extant literature. The framework is founded on adult learning theory, undergirded by evidence-based best practices, and has been shown to improve outcomes [21,22]. We then developed a PPE training framework for NHCW based on international guidelines and local health ministry recommendations for HCWs [4], guided by the steps and principles of the LSPPDM framework. The NHCWs underwent PPE training using this framework, conducted by a team of Infection Prevention nurses, prior to being stationed within the CCF.

Our training framework included multiple steps, mapped to the 6 components of the LSPPDM framework (Fig. 1). Orientation training consisted of didactic instruction, practice and competency assessments (Learn, See, Practice, Prove). NHCWs were also educated on the epidemiology, transmission and prevention of COVID-19 infections i.e., enhanced infection prevention measures recommended for management of COVID-19 patients. This included: 1) steps of hand hygiene, 2) appropriate use of PPE including storage of their personal N95 mask, surgical mask and face-shield while taking meals or rest, 3) steps of donning and doffing PPE, 4) equipment cleaning including face-shield and mobile phones, 5) environmental hygiene and 6) safe management measures whilst working at CCF@EXPO (safe distancing when taking meals and rest, taking shower before going home, monitor temperature twice a day). Competency checks were conducted at one-to-one basis, where trainers reiterated the key points emphasized during the didactic teaching, demonstrated the steps and conducted competency assessment. This included appropriate use of PPE, the correct sequence of donning and doffing using an assessment checklist (Table 1). The checklist was presented in poster format which was displayed next to all skill set stations. This was to ensure consistency among the trainers during practical session and competency assessment. Participants had to demonstrate competencies in all assessed aspects before they were considered 'competent' and allowed to work in "hot zones" within CCF@EXPO.

Following the initial training, there was on-site supervision by the Infection Prevention nurses, use of signages, posters, mirrors for self-check and buddy checks for PPE donning/doffing prior to entry/exit from CCF, unannounced PPE audits daily, refresher training for non-compliance in PPE and reinforcement of infection prevention and control measures through regular walkabouts and inspections by the leadership team. Details of the LSPPDM framework are included in Fig. 1.

Outcomes

Effectiveness of the LSPPDM PPE training framework was assessed using the following: 1) Competency assessment scores for NHCWs, 2) PPE compliance rates from daily audit findings and 3) healthcare-associated COVID-19 infection rates of NHCWs at the end of their operation at CCF@EXPO.

Competency assessment was conducted and scored individually using a standardized checklist for donning and doffing PPE (Table 1). This checklist was developed by the Infection Prevention team which adapted best practice guidelines on PPE use for HCWs from local and international recommendations. Authors (LCL and GLEW) with domain knowledge in PPE use and training in infection prevention reviewed the checklist and provided necessary modifications. The checklist was approved by Author LML, the Infection Prevention Advisor to all CCFs to ensure completeness and consistency with hospital practices. Individuals were assessed to be competent once they demonstrated the competence in the sequence and techniques of all steps successfully.

Compliance rates were recorded using an audit checklist (Fig. 2). The audit team would enter the "hot zones" within CCF@EXPO to observe the infection prevention and control practices and compliance of individual NHCWs. Random sampling of up to 38 times per day was conducted from 10 May 2020 to 30 July 2020 (11 weeks), with 1767 observations made. This included the appropriate use of PPE according to Infection Prevention recommendations, correct techniques and sequence in donning and removal of PPE, and correct techniques in disinfecting and storing reusable PPE (Fig. 2). NHCWs were given immediate feedback when non-compliance was observed. Immediate supervisors were also informed of the non-compliance. Web-messaging platform groups were created to share non-compliances in a timely fashion to prevent repeat errors. Major non-compliances

Learn	See	Practice	Prove	Do	Maintain
Didactic teaching with the use of slides and videos: Trainees were grouped according to their department and profession. This was to provide the trainees an environment that they would feel comfortable and encouraged to interact with trainers and bring up their doubts for clarification. Trainers asked questions and invited trainees to respond to the questions and stimulated critical thinking process esp. the rationales of IP recommendations on appropriate use of PPE. Commonly observed mistakes and lapses in practices were highlighted Trainees were allowed to ask questions and make clarifications. Assumptions, myths and misperceptions were clarified	**Demonstration of steps (donning and doffing of personal protective equipment) by 2 trainers:** One trainer demonstrated the steps while the other trainer (narrator) provided the rationales for each of the steps Emphasis was on the dos and don'ts, the correct sequence and techniques, dos and don'ts, and performing self-check and buddy check	**4 to 5 skill set stations are set up for practical session and each station was overseen by one trainer:** Trainees were given one set of personal protective equipment to practice. They were allowed to clarify doubts and steps that they were unclear Posters with emphasis on dos and don'ts were displayed next to the stations to enhance learning process Trainer repeated demonstration of all the steps if trainees could not remember the sequence or had missed out some of the steps or did not perform the steps correctly	**At the same skill set station, the trainees performed return demonstration to the trainers:** They were considered competent if they were able to perform the steps correctly and in correct sequence If not, they had to repeat the demonstration until they were competent When they passed the assessment, their supervisors were informed that they were safe to work in hot zones	**At hot zones, two IP auditors provided on-site supervisions:** Trained staff performed the steps of donning and doffing at the designated stations At the donning station, when IP auditors noticed staff did not perform steps correctly, the auditors immediately corrected the steps and requested the staff to repeat the steps to achieve competence. Mirrors were provided next to the stations to facilitate staff in performing self-checks At the doffing station, when IP auditors noticed staff showed lack of confidence in the sequence, the auditors provided step-by-step guidance. Posters were made available at all stations serving as constant reminders to staff	**IP auditing team conducted daily audits and provided immediate feedback to staff:** An audit checklist was used to assess the performance of staff. The checklist aligned with the emphasis given during training (LSPP phases) Immediate feedback was given to the audited staff to reinforce the correct practice Daily feedback was given to the staff' supervisors. When persistent gaps in practice were observed, root cause analysis was conducted with the supervisors and actions were carried out to address the gaps. The actions included refresher training and enhanced visual reminders at strategic locations Regular reporting to Operational Huddles on significant gaps in PPE practice and communication at staff roll calls; regular walkabouts and meetings with key stakeholders to identify practical strategies to enhance the practice

Figure 1 Application of LSPPDM (Learn, See, Practice, Prove, Do, Maintain) framework to PPE training at CCF@EXPO.

Table 1 PPE donning and doffing checklist used at CCF@EXPO,

Donning of PPE		
Check that the trainee:		
1	Perform **hand hygiene before** donning on PPE	
2	**N95 mask** is donned on in correct sequence and safe manner	
	2.1	Top strap is 45 degrees rested on the crown of the head
	2.2	Bottom strap is to rest firmly on the neck
	2.3	Straps are to be straightened without twisting
	2.4	Metal piece are moulded to the shape of the top of nose and cheeks
	2.5	Seal check is performed correctly
	2.6	No fogging is seen on glasses (if applicable) or movement of the fringe hair
3	**Eye protection** is donned on in correct sequence and safe manner	
	3.1	If goggles are used, the strap is securely fastened on the crown of the head and does not fall off during use
	3.2	If face shield is used, it is securely fastened on the crown of the head despite movement and does not fall off during use
	3.3	Eye protection provides full coverage for eyes
	3.4	No fogging is seen on glasses (if applicable) or movement of the fringe hair
4	**Gown** is donned on in correct sequence and safe manner	
	4.1	Gown is straightened
	4.2	The back of the gown is interlaced and overlapped before typing
	4.3	Ribbon knot is tied only at the back and NOT on the side or front
	4.4	Ribbon knot is tied securely
5	**Gloves** are donned on in correct sequence and safe manner	
	5.1	Gloves are intact, fingers are snugly fitted and smoothened
	5.2	Cotton cuffs are fully covered by gloves
6	Verify all PPEs are properly donned on, either self-check with a mirror or verification by buddy	
Doffing of PPE		
Check that the trainee:		
1	Perform **hand hygiene after removal of EACH** piece of PPE	
2	**Gloves** are removed in correct sequence and safe manner	
	2.1	Gloves to gloves, skin to skin' removal technique is used
	2.2	One of the gloves is grasped with fingers of the other hand
	2.3	The glove is then peeled off, turned inside out and removed
	2.4	The removed gloved is held in the palm of the other gloved hand
	2.5	Un-gloved fingers are slid under the remaining glove and the remaining glove is turned inside out and removed
3	**Gown** is removed in correct sequence and safe manner	
	3.1	The bottom ties are unfastened followed by the top ties
	3.2	Ribbon knots are NOT snapped
	3.3	Hands and the sleeves do not make contact with other surfaces of the body
	3.4	Gown is pulled away from the neck and shoulders, touching the inside only
	3.5	Gown is turned inside out
	3.6	Both elbows are straightened, gown is then rolled downwards and away from the body
	3.7	Gown is not torn forcefully
4	**Eye protection** is removed in correct sequence and safe manner	
	4.1	Head is leaned forward slightly and chin is lifted up
	4.2	Goggles strap or face shield headband is removed gently
5	**N95 mask** is removed in correct sequence and safe manner	
	5.1	Bottom strap of the mask is grasped firmly and then the top strap is grasped using another hand
	5.2	Mask is removed by pulling it away from face without touching any part of the face
6	Hand hygiene is performed and **surgical mask** is donned on appropriately	

Category *	No	Items	Yes	No	NA
1. Hand Hygiene	1.1	Before touching a patient			
	1.2	Before clean/aseptic procedure			
	1.3	After potential exposure to blood fluids			
	1.4	After touching a patient			
	1.5	After touching patient's immediate environment			
2. Respiratory protection	2.1	Appropriate mask is donned on as indicated			
	2.2	Mask is donned on in correct sequence and safe manner			
	2.3	N95 mask is kept in a clean re-sealable plastic bag in safe manner when not in use			
	2.4	Mask is removed in correct sequence and safe manner			
	2.5	Mask is disposed in safe manner			
3. Gown	3.1	Appropriate gown is donned on as indicated			
	3.2	Gown is donned on in correct sequence and safe manner			
	3.3	Gown is removed in correct sequence and safe manner			
	3.4	Gown is disposed in safe manner			
4. Gloves	4.1	Gloves are donned on as indicated			
	4.2	Gloves are donned on in correct sequence and safe manner			
	4.3	Gloves are removed in correct sequence and safe manner			
	4.4	Gloves are changed as indicated			
	4.5	Gloves are disposed in safe manner			
5. Eyes protection	5.1	Eyes protection is donned on as indicated			
	5.2	Eye protection is donned on in correct sequence and safe manner			
	5.3	Eye protection is removed in correct sequence and safe manner			
	5.4	Eye protection is disinfected properly after use			
	5.5	Eye protection is kept in a clean re-sealable plastic bag in safe manner when not in use			
	5.6	Disposable eye protection is disposed in safe manner			
6. Head cover **	6.1	Head cover is donned on as indicated			
	6.2	Head cover is donned on in correct sequence and safe manner			
	6.3	Head cover is removed in correct sequence and safe manner			
	6.4	Head cover is disposed in safe manner			

Note *
This checklist focuses on staff' compliance in appropriate use of PPE. The audit on the compliance of other IP measures including accessibilities of hand hygiene agents and PPE is outlined in another checklist.

Note **
Head cover is NOT part of PPE standards. The only indication is for staff with long hair to contain their hair while carrying out duties in the hot zone. Care must be taken to prevent self-contamination during removal and thus the item has been included in the audit.

Figure 2 Audit checklist on compliance with PPE protocol. Infection Prevention Team used the checklist to audit staff compliance with hand hygiene and PPE (personal protective equipment) protocols. "Yes" = compliance; "No" = non-compliance; "NA" = non-applicable.

were also brought up in the daily operational huddles which were disseminated to the NHCWs.

As most of the NHCWs were recruited from external agencies to work at CCF@EXPO, they had to undergo mandatory COVID-19 reverse transcription polymerase chain reaction (RT-PCR) tests prior to returning to their original workplace. The number of healthcare-associated COVID-19 infections was recorded to determine the effectiveness of the PPE training framework.

Statistical analysis

The daily PPE compliance levels were recorded and charted using 3-day block and weekly block averages. Statistical process control (SPC) charts for NHCW subgroup populations (bed management staff, housekeeping staff and security officers) were analyzed using Healthcare Rules recommended by the Institute for Healthcare Improvement. For statistical analysis, Chi Square test has been used to test the significance of the difference before the intervention of the training framework (i.e., the first two weeks of deployment to CCF) and after the implementation. P value of <0.05 is considered statistically significant.

Results

i *Competency assessment scores of NHCWs*

A total of 883 NHCWs (568 bed management staff, 160 housekeeping staff, and 155 security officers) had completed

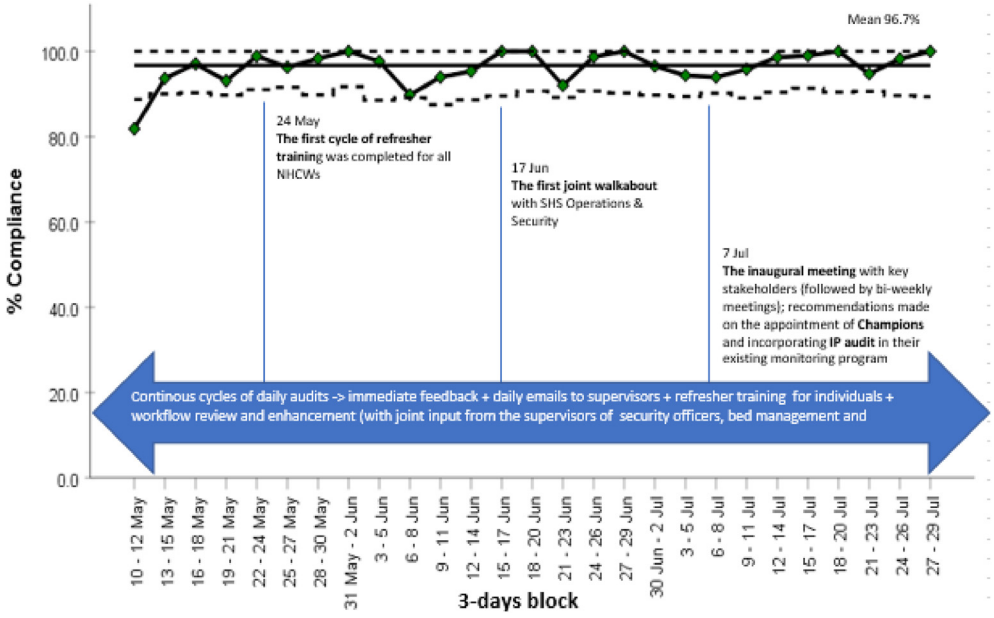


Figure 3 NHCWs' compliance with PPE protocol (3-days blocks). NHCWs refer to non-healthcare workers. PPE refers to personal protective equipment. SHS refers to the Singapore Health Services. Key stakeholders refer to the supervisors of security officers, bed management and housekeeping staff. The daily audit was started on 10 May; mean = 96.7% (N = 1767 observations).

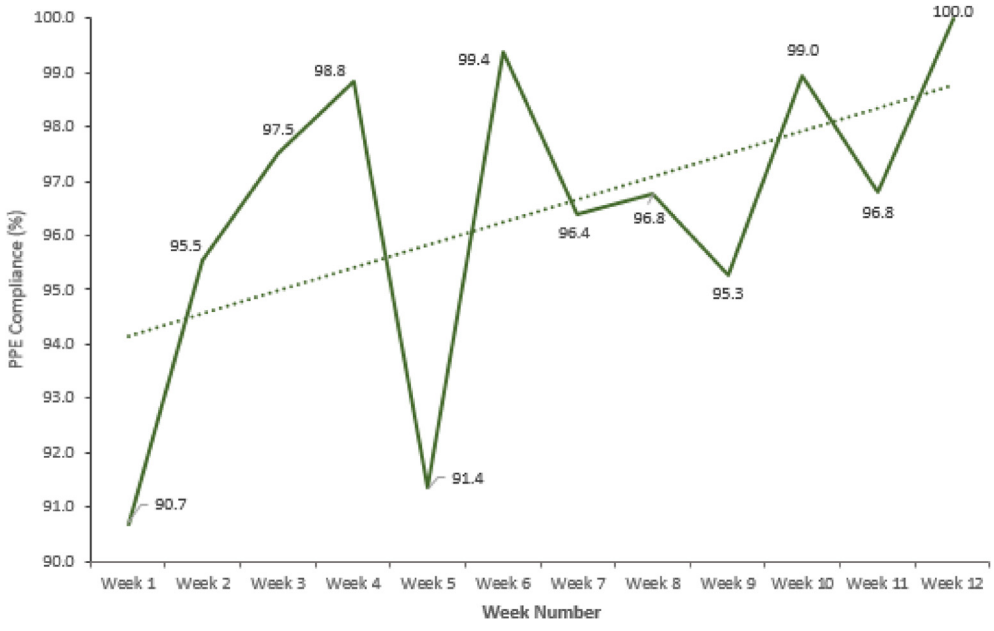


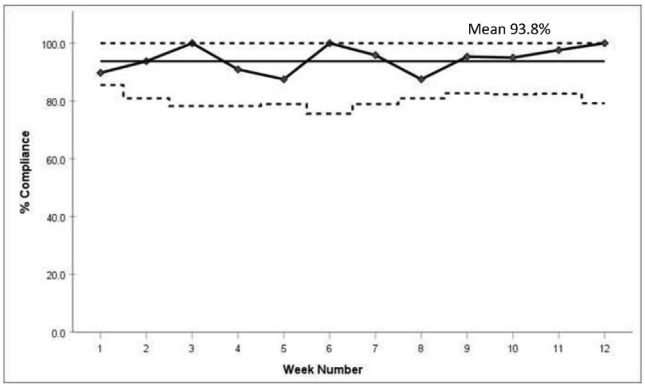
Figure 4 NHCWs' compliance with PPE protocol (weekly blocks). NHCWs refer to non-healthcare workers. PPE refers to personal protective equipment. The audit results were plotted weekly; mean = 96.5% (N = 1767 observations).

the PPE training from 6 May to 24 May 2020 and demonstrated competency in PPE compliance, fulfilling 100% of the checklist requirements (Prove). One NHCW did not pass the assessment and was not allowed to work in the CCF@EXPO "hot zone".

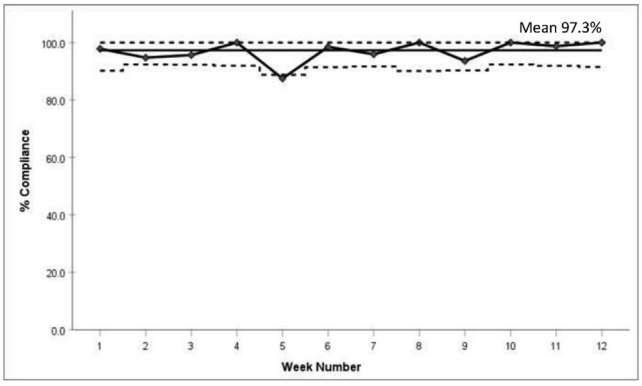
ii *PPE compliance rates from daily audit findings*

The mean PPE compliance of all NHCWs during the 11-week study period (Do, Maintain) was noted to be 96.7% (3-day block sampling method, Fig. 3) and 96.5% (weekly block sampling method, Fig. 4). There was an initial drop in compliance (<95%) as shown in Figs. 2 and 3 but the compliance quickly improved and gradually stabilized with the daily audits and immediate feedback given to the NHCWs. Before and after analysis showed statistically significant improvement in 3-day block sampling (P = 0.03; OR = 0.435; 95% CI = 0.248—0.766) but not in weekly block sampling (P = 0.326; OR = 0.326; 95% CI = 0.346—1.428).

a) Security officers' compliance with PPE protocol (weekly plots)



b) Housekeeping staff' compliance with PPE protocol (weekly plots)



c) Bed management staff' compliance with PPE protocol (weekly plots)

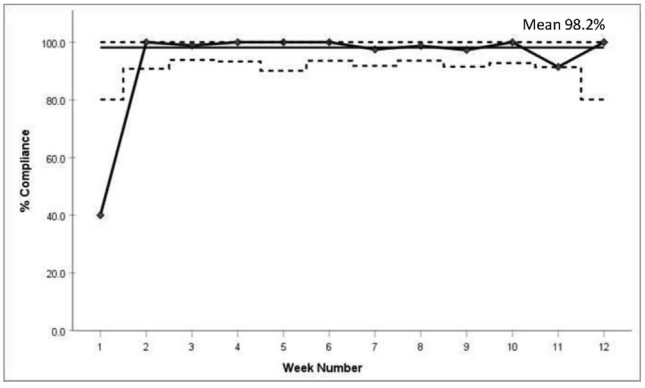


Figure 5 Statistical Process Control charts of NHCWs' compliance with PPE protocol. The control charts were plotted weekly for three subgroups: a) security officers, b) housekeeping staff and c) bed management staff. The aggregated mean for the security officers, housekeeping and bed management staff was 93.8% (N = 400 observations), 97.3% (N = 823 observations) and 98.2% (N = 544 observations) respectively.

When divided by subgroups, the bed management staff, housekeeping staff and security officers achieved mean compliance rates of 98.2%, 97.3% and 93.8% respectively (Fig. 5). Before and after analysis showed statistically significant difference in bed management staff (P = 0.021; OR = 0.149; 95% CI = 0.087–0.603) but not in security

officers (P = 0.148; OR = 0.545; 95% CI = 0.237—1.254) and housekeeping staff (P = 0.201; OR = 0.541; 95% CI = 0.208—1.407).

iii *Healthcare-associated COVID-19 infection rates of NHCWs*

Mandatory COVID-19 PCR tests were performed for all NHCW at the end of their tour of duty at CCF@EXPO. None of the 883 NHCWs who underwent PPE training via the LSPPDM framework were diagnosed with healthcare-associated COVID-19. One NHCW was found to be positive for COVID-19, however, this was determined by an independent assessment body to be a community-acquired infection and not healthcare-associated.

Discussion

We found that use of LSPPDM, an evidence-based procedural skills training framework for PPE training, was effective in ensuring high rates of PPE compliance (>96%) and prevention of healthcare-associated COVID-19 infection in PPE-naïve NHCWs. The before and after analysis showed statistically significant difference in 3-days blocks and bed management staff. This is probably due to the short study period and small sample size when the data was further divided to three subgroups. These results were notable, as many NHCWs had to be rapidly trained to expeditiously operate in the community isolation facilities during the COVID-19 pandemic. The high rate of PPE compliance, the established consistency in PPE practice and the familiarity with infection prevention protocols would have led to the building up of confidence to work in the high-risk zones and this in turn had likely contributed to the prevention of healthcare-associated COVID-19 infections among the NHCWs deployed to CCF@EXPO. This is despite the long dwell times that each NHCWs spent in the "hot zones" within the CCF. This is the first study providing evidence regarding the effectiveness of an evidence-based education framework for training and usage of PPE for NHCWs in close contact with COVID-19 positive patients.

The LSPPDM framework is a procedural skills training framework that has previously demonstrated success in healthcare professionals. Using the above framework, Zante et al. noted increased competency of intensive care unit (ICU) fellows and reduced levels of senior supervision required for chest tube insertion, pericardiocentesis, and cricothyroidotomy [21]. Similarly, a study at the Mayo Clinic highlighted the usefulness of the LSPPDM framework in conjunction with simulation training for intertrochanteric fracture fixation [22]. However, PPE training for HCWs has been largely conducted without reference to contemporary medical skills training frameworks, often omitting the "Do" and "Maintain" aspects. Al-Tawfiq et al. described an educational program to screen and triage patients with MERS-CoV infection, emphasizing the Learn, See, Practice and Prove (LSPP) aspects in PPE donning/doffing and performing a nasopharyngeal swab [19]. However, the authors did not report the outcomes of the Do and Maintain aspects, and it is unclear if the initial training translated to subsequent PPE compliance. Tan et al. described a three-stage PPE training program for HCWs during the COVID-19 pandemic with pre- and post-tests which focused on LSPP, demonstrating significant improvements in post-test scores, even in a large-scale setting [23]. However, the subsequent PPE compliance rate of the HCWs was not reported; the Do and Maintain components of the LSPPDM framework were also not utilized.

In our study, we have addressed an unanswered question regarding PPE training in NHCWs during the COVID-19 pandemic; our study is the first to provide evidence that an evidence-based skills training framework is effective not only in sustaining high rates of PPE compliance but also preventing healthcare-associated COVID-19 infections in this population. Our study demonstrated an initial drop in PPE compliance despite NHCWs passing the initial competency assessment. This non-compliance rate quickly improved and gradually stabilized with the daily audits which helped to reinforce PPE compliance amongst the NHCWs, emphasizing the importance of the Maintain component of the LSPPDM framework. Pandemics require strict PPE compliance in both HCWs and NHCWs to prevent disease transmission. Our study is relevant as it demonstrates the effectiveness of the LSPPDM framework in NHCWs, a population which has not been examined in the past.

The high rate of PPE compliance amongst the NHCWs may have been related to the education on the COVID-19 infection and competency assessment performed by the Infection Prevention Team. Harrod et al. highlighted that training and education should not only focus on the "how" of PPE usage, but should also include the "why" or the necessity of PPE [11]. Katanami reported a low PPE adherence rates amongst cleaners as opposed to doctors through a video monitoring study, suggesting that the knowledge of PPE necessity could play a part [10]. Katanami also postulated that frequent care visits by cleaners may have resulted in a lower adherence rates as they had to enter and leave the room. In contrast, the NHCWs would don on PPE once, enter and stay in the community isolation facility for at least 4 h before they went for meal breaks and before they went off duty. This may have reduced the opportunities for non-adherence to PPE.

Another factor that may have contributed to the high PPE compliance rates was the psyche of the NHCWs who had to spend long hours (up to 8 h) in the community isolation facility. The knowledge that 100% of the population within the community isolation facility was COVID-19 positive and that all surfaces were potentially contaminated may have played an important role in maintaining PPE adherence. Doll et al. found that HCWs tend to adjust their PPE behaviors based on their perceived level of risk and these perceptions vary between HCWs [24]. The study also highlighted that if direct patient contact was not anticipated, PPE was not necessary. Therefore, it is plausible that the HCWs maintained a high level of vigilance and

compliance to PPE, especially since COVID-19 was highly infectious and could result in death or serious illness.

The experience at CCF@EXPO has demonstrated that the institution-based isolation can probably be performed safely outside hospital setting without the need for a large team of HCWs [1]. This will help in easing the demand for essential resources including HCWs and hospital beds in battling with the pandemic and in efforts to sustain the healthcare system during the pandemic. In our study, stable patients with COVID-19 infections were admitted to the facility where the logistics of admission and discharges, food provision, and environmental services was supported by the NHCWs. However, this approach would not have been possible without a team of staff who are compliant with PPE protocol, confident in working in an environment surrounded by COVID-19 patients and are readily to be deployed to other CCFs with similar settings. Our study has demonstrated the plausibility of implementing an evidence-based skill training framework in mastering PPE competencies and developing confidence in staff without prior working experience in healthcare settings.

Our study has several limitations. Firstly, the Do and Maintain aspects of the model were carried out by trained infection prevention auditors. Direct observations by the auditors may result in the Hawthorne effect for the NHCWs being observed, leading to a higher compliance rate [11]. The Hawthorne effect was mitigated in our study as auditors were dressed in full PPE and undistinguishable from HCWs within the community isolation facility; auditors also spent a significant amount of time within the community isolation facility to acclimatize NHCWs to their presence. The auditors also reassured NHCWs that non-compliance incidents would not result in punitive action. Secondly, multiple auditors collected data with possible inter-observer variability; we sought to minimize this via auditor training and competency assessment by Author GLEW, and the use of an audit checklist which was standardized across all external operation facilities operated by SingHealth. Thirdly, we would ideally have liked to observe and audit every single PPE usage episode in NHCWs as part of the Maintain component of LSPPDM, but this was not feasible. Instead, we used consistent daily random sampling over a period of 11 weeks, allowing us to obtain a representative sample of PPE compliance rates of the NHCWs. Fourthly; the study period might be too short to examine the sustainability of the use of the framework. Fatigue in PPE and in other infection prevention protocols might set in and have a negative impact on the behavior and practices in NHCWs. However, with the use of the framework, the team would be able to identify this group of staff during Maintenance Phase and carry out prompt actions to rectify the problem.

In conclusion, our results suggest that in pandemics, using an evidence-based skills training framework is effective in rapid PPE training of large numbers of NHCWs, whilst ensuring a high PPE compliance rate and prevention of healthcare-associated COVID-19 infection in NHCWs. Having a scalable, reproducible and easily implementable PPE training methodology will allow healthcare institutions to rapidly train NHCWs to care for low-risk COVID-19 patients. This will allow redeployment of precious healthcare resources from similar community isolation facilities as healthcare systems transit back to normalcy. This is especially important as we can potentially leverage on non-healthcare resources to care for low-risk COVID-19 patients or future pandemics.

Ethics

IRB approval was obtained for the study (CIRB 2020/2194).

Authorship statement

MHLL, NCKT, KT, LML and LCL contributed in the conceptualization and design of the study; SHW and JP assisted in data collection; GLEW conducted data validation; MHLL, NCKT, KT, LML and LCL conducted analysis and interpretation of the findings; MHLL and LCL drafted, edited and revised the article; NCKT, KT, LML, HKT and WC gave final approval of the article to be published.

Conflict of interest

The authors have no conflict of interest to declare.

Funding

No funding had been received during or after this study.

Provenance and peer review

Not commissioned; externally peer reviewed.

Acknowledgements

We wish to thank and acknowledge the contribution of all staff in the 3-months operation of CCF@EXPO, and SingHealth Infection Prevention Team for their roles in executing the Infection prevention training and audit programmes.

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