PPE-Based Strategies For COVID-19 Prevention Amongst Healthcare Workers

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Abstract. When the novel coronavirus began to spread, there was a general lack of understanding of COVID-19, which makes healthcare workers face an extremely high risk of infection when treating patients. In the early stage of the outbreak, the global supply of PPE (personal protective equipment) was tight, and HCW (healthcare workers) generally suffered the problem of insufficient protective equipment. Therefore, it is necessary to provide more effective protection for HCW. This article studies and discusses the effectiveness and strategies of using PPE to prevent COVID-19 among HCW. This article uses CNKI and PubMed as search platforms. And it analyzes the literature on the use of PPE, the spread of COVID-19 and the prevention and control of hospital senses to understand the current research progress and existing problems. This study includes a total of 8 articles. The more parts of the body covered by PPE , the better the protection effect it provides. This is also accompanied by an increase in difficulty and comfort when wearing and taking off PPE. Strict adherence to officially standardized PPE wearing and removal procedures can effectively reduce the infection rate of HCWs in response to the COVID-19 virus, while overprotection of HCWs may prolong unloading time and potentially increase the risk of contamination. The findings revealed that proper wearing of masks like N95 significantly reduces the infection rate of SARS-CoV-2, while the combo of full-body PPE, respirator, and coat offers enhanced protection to HCWs, minimizing pollution risks.

Keywords: Personal protection equipment (PPE); COVID-19; Healthcare workers.

1. Introduction

1.1. The global spread and impact of COVID-19

Since the outbreak of COVID-19 at the end of 2019, it has spread rapidly around the world, posing a serious threat to global public health security. The COVID-19 pandemic has been a relentless challenge to societies and healthcare systems across the globe for over two years. This pandemic is caused by the SARS-CoV-2 virus, a tiny microorganism ranging from 80 to 200 nanometers in size and estimated to have a half-life of just one hour in the air. When individuals are infected, the highest concentration of the virus is found in their saliva. However, interestingly, viral RNA can still be detected in stool samples up to the third and fourth weeks following the emergence of symptoms [2]. And it has been labeled as one of the most significant health disasters in modern history. Its reach extends beyond the realm of healthcare, triggering profound social and economic crises that experts are still scrambling to assess and manage. As of January 1st, 2022, according to the latest global statistics, the pandemic has resulted in a staggering 288,598,994 confirmed cases and a heartbreaking toll of 5,454,996 deaths [3]. Over half a billion confirmed cases of the COVID-19, have led to approximately 6.3 million fatalities globally.

1.2. The risk of infection in HCW and the importance of protective measures

Medical professionals, known as healthcare workers (HCW), who are on the frontlines treating these patients face a significant risk of contracting the infection. Early in the COVID-19 pandemic, a survey conducted across 130 countries revealed a significant number of HCW deaths. Approximately 18 months later, the World Health Organization (WHO) estimated that out of 135 million HCW worldwide, at least 115,000 (ranging from 80,000 to 180,000) had succumbed to the SARS-CoV-2 infection [1]. The proportion of COVID-19 cases is significantly high among HCW working in patient

wards, making them more vulnerable to the virus than the general population. Logical evidence is crucial for establishing safety SOPs, PPE inspection, and HCW practice reviews in healthcare settings. This evidence is essential to prevent negligence in caring for infectious COVID-19 patients. Compared to those not working in hospitals, HCW who lack sufficient PPE or are unfamiliar with its proper usage face a considerably increased risk of contracting COVID-19. Various factors, including the working environment, occupation type, duration of contact with COVID-19 patients, and access to testing, have been identified as being linked to SARS-CoV-2 infection among HCW [1].

1.3. The importance and challenges of personal protective equipment

Personal protective equipment (PPE) is equipment worn to minimize exposure to hazards that can lead to severe workplace injuries and illnesses. PPE is a crucial tool in preventing infections among HCWs who are directly or indirectly exposed to the virus. However, no country has been able to demonstrate adequate preparedness for this pandemic or possess sufficient PPE for their HCWs. Therefore, apart from the challenges of procuring PPE, there is also a need to rationalize its use in the face of a global shortage [4]. If personal protective equipment (PPE) is used reasonably, the risk of infection faced by HCWs can be reduced. Not everyone requires a full set of PPES. HCWs exposed to aerosol-generating procedures require a full set of PPES compared to those transferring patients. Furthermore, as shown in a simulation-based study, most HCWs have not received training on putting on and removing PPE, and 79.2% of HCWs demonstrated contamination. There is a need for simpler PPE protocols and PPE education tools to ensure consistency among HCWs [4]. In addition, different types of PEE also have different degrees of protection for HCW. Covering a larger portion of the body indeed offers better protection, yet it often entails a trade-off. This is primarily because increased coverage typically correlates with greater difficulties in both putting on and removing the PPE. Such extensive coverage often results in PPE that is less comfortable to wear. Unfortunately, these factors may lead to increased contamination risks, as users may struggle with the PPE's functionality or find it uncomfortable to wear for extended periods. Among various types of PPE, coveralls are generally recognized as the most challenging to remove while offering potentially the highest level of protection. This is particularly important as studies have shown that despite advancements in PPE design and usage, contamination remains a common occurrence in approximately half of the studied scenarios. Therefore, it is crucial to strike a balance between protection, ease of use, and comfort when selecting appropriate PPE for specific tasks and environments [5].

2. Method

2.1. Search Strategy

This article approximately 234 research papers were extracted from China National Knowledge Infrastructure (CNKI) and PubMed. These publications contain at least one of the terms: Personal Protective Equipment (PPE), COVID-19, Healthcare Workers, Infection Control. These papers were then thoroughly considered by scanning the abstract for relevant information about PPE Use & Protection Strategies and safety of Frontline Healthcare Workers. A second round of elimination occurred by reading the publications in detail and keeping the papers that provided helpful information for this review.

2.2. Inclusion & Exclusion Criteria

The inclusion criteria: (1) Articles published during and after 2020, (2) articles written about PPE Use & Protection Strategies and Safety of Frontline Healthcare Workers, (3) Research must focus on the role of personal protective equipment (PPE) in the prevention of COVID-19 for medical staff, including the effectiveness, usage rate, compliance and improvement policies of PPE. And the research should target medical personnel, especially those who are directly involved in the care of COVID-19 patients, such as doctors, nurses, technicians, etc.

The exclusion criteria were as follows: (1) all publications in non-English or non-Chinese languages, (2) papers without any relevant data about PPE Use & Protection Strategies and Safety of Frontline Healthcare Workers, (3) papers with repeating information.

2.3. Information Sources

The primary platforms used were CNKI and PubMed. From those two platforms, papers about COVID-19 infection among HCW and PEE were extracted. Most of these studies occurred in hospitals during the peak of the COVID-19 spread. These studies considered healthcare worker PPE compliance and effectiveness during COVID-19. Several the studies conducted a statistical analysis of the findings, utilizing various graphs and tables to condense and offer profound insights.

2.4. Data Extraction

This review encompassed information garnered from a comprehensive collection of eight studies. And this study employed a standardized approach for data extraction, meticulously collecting crucial information from all eligible studies. This encompassed details such as the year of publication, the research site, the criteria for inclusion, the research objectives, the sample size and the type of PPE.

3. Result

3.1. Study Selection and characteristics

PubMed and CNKI jointly searched for 234 articles. After preliminary title and summary screening, we identified 28 documents that may be suitable for our research. However, in the final full-text screening stage, after careful review, the author removed 20 studies that did not meet the requirements, and finally selected 8 papers (Figure 1) that met our research standards. These papers will serve as an important reference for our research.

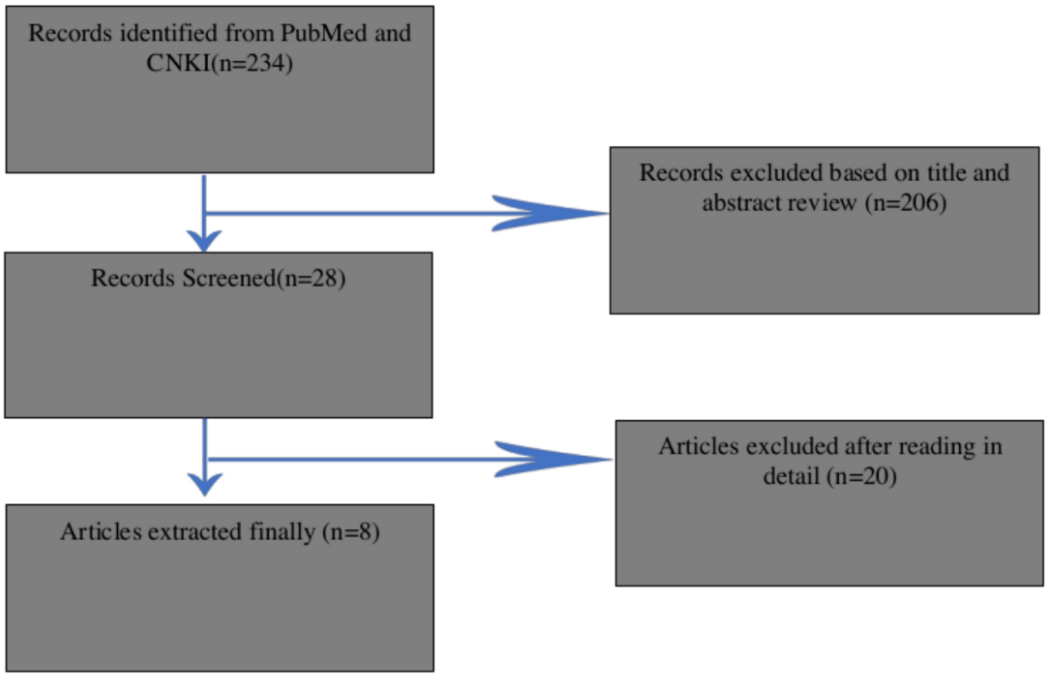


Fig. 1 Study selection process

Table 1. Characteristics of the included studies.

Authors /year	Country	Sample Size	Intervention	Main findings & suggestions
Lenny L. EkawatiI, et al., 2022	**Indonesia**	HCW in Indonesia for 18 months	The healthcare workers' mortality rates were alarmingly five times higher compared to the general population in Indonesia.	The COVID-19 event in Indonesia resulted in the loss of many hundreds of HCW, most of them being senior physicians, nurses, and midwives.
Daniela Schoberer, et al., 2022	**Austria**	The study encompassed participant counts ranging from 37 to 5442 individuals, collectively encompassing a total of 9503 participants across various studies.	The comprehensive analysis revealed that wearing face masks could effectively safeguard healthcare workers from infection, exhibiting a significant protective effect (OR = 0.16; 95% CI: 0.05–0.55, I2 = 83%). When compared to not utilizing proper PPE, the utilization of suitable PPE appeared to safeguard healthcare workers from COVID-19 infection; however, the observed effect lacked statistical significance (OR = 0.52; 95% CI: 0.13–2.12).	HCW's use of PPE can reduce the risk of COVID-19 infection. The analysis results confirm the effectiveness of using PPE, especially masks, to prevent COVID-19 infection. Using N95 masks can significantly reduce the risk of contracting COVID-19.
Sidra Abid Syed, et al. ,2022	**Pakistan**	The study comprised a total of 25 participants, all falling within the age range of 20 to 40 years. The participant pool consisted of 15 males and 10 females.	/	The proposed study introduces the innovative design and utilization of a face shield specifically tailored for HCWs to safeguard them against COVID-19. This shield not only ensures protection but also continuously monitors crucial physiological parameters, such as body temperature,

				heart rate, and SpO2. Furthermore, our face shield can be utilized by individuals to monitor post-COVID symptoms and maintain regular health checks.
Gopal Chawla, et al., 2020	**India**	/	/	The procurement challenges of standardized PPE, combined with its unsatisfactory user experience, necessitate HCWs to explore alternative strategies. These strategies aim to minimize contact with patients while maintaining optimal patient care. Nevertheless, HCWs who must necessarily interact with patients must be equipped with adequate PPE, as there is no viable substitute for it.
Verbeek JH, et al., 2020	**UK**	The study encompassed a total of 24 research works, involving 2278 participants. Out of these, 14 were randomised controlled trials (RCTs), one was a quasi-RCT, and nine exhibited a non-randomised design.	Increasing the coverage of body parts indeed enhances protection, but it often entails greater challenges in donning (putting on) or doffing (taking off) the equipment, as well as compromising user comfort. Consequently, this may paradoxically result in increased contamination risks. While a powered, air-purifying respirator (PAPR) with a hood offers superior protection compared to an N95 mask with a	Increasing body coverage enhances protection but often sacrifices donning ease and user comfort, potentially increasing contamination risk. PAPRs with hoods offer superior protection but are harder to put on, while long gowns strike a balance between safety and donning/doffing simplicity.

			gown, its donning process is more intricate. Therefore, a long gown may represent the optimal balance between ensuring adequate protection and facilitating easy doffing.	
Shalika Hegde, 2020	**UK**	Health care workers	Although coveralls can be the most challenging PPE to remove, they potentially offer the highest level of protection. Long gowns rank slightly behind in terms of protection, followed by regular gowns and aprons.	Increasing the body parts covered by PPE enhances its protective capacity. Nevertheless, this augmentation is accompanied by a surge in the challenges of putting on and removing the PPE, along with reduced comfort levels.
YOU Jianping, et al., 2020	**China**	56 clinical front-line medical staff participated in the study, nursing 37 people, clinical medical treatment 19 people; 11 men and 45 women; average age 29.86±4.96 years old; average working years 6.95±4.75 years	Referring to the PPE process proposed by China's CDC, it is found that the main fluorescent agent pollution includes: the left hand and wrist, and the left calf are the most susceptible parts. After removing PPE by referring to the PPE process issued by the WHO, it was found that the main key contamination parts of fluorescent reagents are: left hand and wrist, right hand and wrist are high-risk parts that are easy to be contaminated.	Relying solely on PPE cannot completely prevent or avoid viral infection. Previous reports have shown that unfamiliarity with PPE operation essentials, incorrect use of PPE, and substandard training can actually increase the risk of infection for medical staff during clinical care. Studying and exploring the main risk points in the PPE operation process is crucial for scientifically mastering PPE skills, enhancing the effectiveness of emergency protection training in the short term, strengthening HCWs' protective awareness, and reducing and avoiding

				the risk of occupational exposure.
JIANG Shan, et al., 2023	**China**	A total of 70 medical staff were included. The basic characteristics of medical personnel are shown in Table 1. Among them, intensive care unit (ICU) accounts for 54.29%, non-ICU accounts for 45.71%; doctors account for 12.86%, and nurses account for 87.14%.	/	HCWs strictly abide by the infection control process in their daily medical activities, and the risk of COVID-19 pollution is low. Excessive protection will increase the time and difficulty of unloading protective equipment, resulting in the inability to leave the potential contaminated area quickly and prolonging the environmental time of unprotected contact pollution.

3.2. Synthesis of the results

This paper from Indonesia focuses on the mortality rate of health care workers in Indonesia during the 18-month COVID-19 epidemic. During the initial 18 months of the COVID-19 pandemic, Pusara Digital recorded the tragic passing of 1,545 HCWs. Notably, there was a slight variance in the gender breakdown of these deaths, with males accounting for 51% and females for 49% [1]. This paper studies the effect of protective equipment in the COVID-19 epidemic, and also mentions some shortcomings in the use of these equipment and puts forward the importance of personal protective equipment in reducing the risk of infection of medical workers [2]. During the COVID-19 epidemic, a scheme was proposed to use smart masks to monitor the vital signs of patients. The aim of this study was to devise and demonstrate the utilization of a PPE capable of monitoring crucial physiological indicators during the ongoing COVID-19 pandemic. These indicators encompassed body temperature, heart rate, and SpO2. Additionally, the proposed face shield incorporates the ThingSpeak mobile application, enabling seamless and continuous communication and monitoring of the measured physiological variables [3]. The study from India puts forward the shortage of personal protective equipment and the importance of rational use of PPE. How to PPE correctly to prevent highly communicable diseases caused by exposure to contaminated body fluids, so as to protect medical personnel from those terrible diseases. Beyond implementing other infection control measures, the consistent utilization of comprehensive PPE serves to mitigate the risk of infection among HCWs. EN (European) and ISO (international) standards pertaining to protective clothing and fabric permeability for viruses are instrumental in identifying PPE that technically offers sufficient protection against highly infectious diseases [5]. PPE is critical in the fight against COVID-19. The provision of protection is enhanced as a greater number of body parts are encompassed by the utilization of PPE [6]. The study from China compares the key polluting parts in the process of PPE unloading under the guidance of different PPE guidelines. Learn from the advantages of different protective equipment wear and take-off processes, actively carry out evidence-based practice exploration, improve the wear and take-off process steps in a targeted manner, and improve the scientific use of PPE [7]. The last study discusses the protection willingness of PPE of HCW in designated hospitals for the treatment of novel coronavirus infection and the pollution of the novel coronavirus and provide a theoretical basis for HCWs to reasonably choose PPE [8].

4. Discussion

4.1. Analysis of the effect of PPE on SARS-CoV-2 infection protection for HCW

This study is based on eight studies to provide evidence for reducing the rate of COVID-19 infection in medical staff through PPE-related measures. Our findings demonstrate that PPE and masks, worn appropriately, serve as crucial protective measures against COVID-19. A subgroup analysis exploring the efficacy of various mask types revealed that the utilization of N95 masks significantly diminishes the likelihood of contracting SARS-CoV-2 with a high degree of certainty [2]. The more parts of the body covered by PPE, the better the protection effect it provides, including wearing protective clothing or wearing disposable isolation clothing inside or outside, folding goggles and protective screens, and wearing shoe covers/boot covers. The key contaminated parts are all over the body and even in unexpected places, which is enough to prove the importance of wearing full-body PPE [6]. And an air-purifying respirator paired with a coverall may offer superior protection against contamination risks compared to an N95 mask and gown [6].

4.2. The impact of the type of masks used by HCW during the COVID-19 on reducing their infection rate

During the epidemic, the types of masks used by medical staff played a crucial role in reducing their infection rate. Different types of masks have different protective effects on medical staff due to their different protective performance. Medical surgical masks are the most commonly used masks, which are suitable for the basic protection of medical personnel and related personnel. This kind of mask can filter out some bacteria and viruses, thus reducing the risk of infection of medical staff in an environment with body fluids and blood splashes. However, due to its limited filtration efficiency of particulate matter, it may not be possible to completely prevent high-risk infections. The subgroup analysis encompassed solely one study that evaluated the effectiveness of wearing surgical masks. Despite demonstrating a statistically significant impact, the confidence in the evidence remains low due to the limited sample size [2].

Medical protective masks, such as N95 masks, have a more significant protective effect on medical personnel. This kind of mask can filter out more than 95% of bacteria and viruses in the air, providing a higher level of protection for medical staff. During the epidemic, especially in the face of airborne respiratory diseases, medical protective masks can effectively reduce the infection rate of medical staff. In addition to the above two masks, KN95 masks are also one of the types of masks commonly used by medical staff during the epidemic. The protective performance of KN95 masks is comparable to that of N95 masks, which can also provide a high level of protection. The filtration efficiency of such masks is more than 95%, which can effectively reduce the risk of medical staff being infected with respiratory diseases such as COVID-19. However, it should be noted that the protective effect of masks is not absolute. Even if they wear high-performance masks, medical staff still need to strictly abide by other protective measures, such as washing hands frequently and social distancing, to minimize the risk of infection.

4.3. Strength and limitation

The challenges associated with acquiring standardized PPE, coupled with the unpleasant user experience, necessitate HCWs to explore alternative strategies. Such strategies aim to minimize contact between HCWs and patients without compromising patient care. Nevertheless, for HCWs who must maintain contact with patients, the utilization of adequate PPE remains imperative, and there is no viable alternative to this requirement. And wearing a full set of PPE still has a potential negative impact. This is also accompanied by an increase in difficulty and comfort when wearing and taking off PPE [6]. Excessive protective measures can increase the time and difficulty required to remove protective equipment, potentially delaying the prompt exit from potentially contaminated areas and prolonging unprotected exposure to the contaminated environment [8]. Therefore, HCW

should avoid excessive protection, which will prolong the unloading time and increase the risk of pollution.

5. Conclusion

The significance of PPE in safeguarding medical workers against COVID-19 cannot be overstated. This study delves deep into the crucial role PPE plays in protecting healthcare professionals at the forefront of the pandemic. The correct utilization of PPE, particularly the wearing of N95 masks and other types of respirators, has been shown to significantly reduce the infection rate of SARS-CoV-2. This reduction is vital in minimizing the spread of the virus and keeping medical workers safe while they carry out their duties. Moreover, the combination of full-body PPE, including respirators, coats, and hoodies, provides an enhanced level of protection. This ensemble creates a barrier that effectively shields medical workers from potential exposure to the virus. The comprehensive approach ensures that every aspect of a HCW's attire contributes to their overall safety. The results of this study provide compelling evidence supporting the crucial role of PPE in the fight against COVID-19. They not only confirm the importance of wearing PPE correctly but also highlight the need for continued research and innovation in this field. As the pandemic evolves, so must our understanding of how best to protect those who are most vulnerable to its ravages. This study also offers valuable insights for medical workers in their practical work. It emphasizes the need for strict adherence to PPE protocols and highlights the importance of training and education in ensuring proper usage. By equipping HCWs with the knowledge and tools they need to stay safe, we can help mitigate the risk of infection and keep our healthcare system functioning effectively. In conclusion, the role of PPE in protecting HCW against COVID-19 is paramount. This study underscores the need for continued research, innovation, and education in this crucial area. As we move forward in the fight against this pandemic, it is essential that we prioritize the safety and well-being of those who are bravely standing on the front lines.

References

[1] Ekawati LL, Arif A, Hidayana I, et al. Mortality among healthcare workers in Indonesia during 18 months of COVID-19. PLOS Glob Public Health, 2022, 2(12): e0000893.

[2] Schoberer D, Osmancevic S, Reiter L, Thonhofer N, Hoedl M. Rapid review and meta-analysis of the effectiveness of personal protective equipment for healthcare workers during the COVID-19 pandemic. Public Health Pract (Oxf), 2022, 4:100280.

[3] Syed SA, Mushtaq T, Umar N, Baig W, Shakeel CS, Zahid H. Smart face shield for the monitoring of COVID-19 physiological parameters: Personal protective equipment (PPE) for health-care workers (HCW's) and COVID-19 patients. Proc Inst Mech Eng H, 2022, 236(11): 1685-1691.

[4] Chawla G, Abrol N, Kakkar K. Personal Protective Equipment: A Pandora's Box. Indian J Crit Care Med, 2020, 24(5): 371-372.

[5] Verbeek JH, Rajamaki B, Ijaz S, et al. Personal protective equipment for preventing highly infectious diseases due to exposure to contaminated body fluids in healthcare staff. Cochrane Database Syst Rev, 2020, 4(4): CD011621.

[6] Hegde S. Which type of personal protective equipment (PPE) and which method of donning or doffing PPE carries the least risk of infection for healthcare workers. Evid Based Dent, 2020, 21(2): 74-76.

[7] You Jianping, Zhang Huilan, Yang Sha, Luo Hongxia & Zhu Jingci. Comparison of key pollution parts in the process of wearing and taking off personal protective equipment. PLA Hospital Management Journal, 2020, 8(6): 723-725+730.

[8] Jiang Shan, Gong Jiewen, Lu Ying, et al. Research and analysis on the reasonable selection of personal protective equipment for medical staff in designated hospitals for the treatment of novel coronavirus infection. Huaxi Medicine, 2023, 3: 387-391.