

Barriers to Proper PPE Management in a Pandemic

ABSTRACT

Background: Effective management of personal protective equipment (PPE) in healthcare settings is critical, especially during health crises like the COVID-19 pandemic. This study aims to identify barriers to effective PPE utilization and assess the impact of training frequency on PPE management.

Methods: Using quantitative and qualitative analyses, the study evaluated 100 survey responses and performed a chi-square test to examine associations between role types and training frequencies.

Results: Findings revealed that only 59% of respondents received yearly PPE training, with inadequate preparation, insufficient knowledge, and high costs identified as primary barriers.

Conclusion: Addressing these barriers through improved training and resource management is essential for enhancing PPE effectiveness and ensuring the safety of healthcare workers and patients.

Keywords: Personal Protective Equipment (PPE); Pandemic; PPE Shortages; Hypothesis; Healthcare Workers; PPE Management

1. INTRODUCTION

Personal Protective Equipment (PPE) has been a cornerstone of infection control during pandemics, designed to shield healthcare workers and the public from infectious agents. PPE includes essential items such as masks, gloves, gowns, and face shields, which serve to prevent direct contact with pathogens and reduce the risk of transmission (World Health Organization, 2020). The COVID-19 pandemic underscored the critical role of PPE in mitigating the spread of SARS-CoV-2, the virus responsible for the disease. Effective PPE use was linked to lower infection rates among healthcare workers and decreased transmission in high-risk settings (Ranney et al., 2020). Despite its importance, the management of PPE during the pandemic faced significant challenges, revealing systemic vulnerabilities that need addressing for future health emergencies. The history of PPE was traced back to as early as the eighth century B.C. (Toohill, 2023), where it was recorded from an ancient Greek poem "Homer's Odyssey," where there was a succinct explanation of somebody using gloves to protect his hands from thorns while working in his garden. Gloves then became popular in the 1760s in the medical industries where gloves were worn during patient exams. Both Physicians and Patients used obstetric gloves made from sheep intestines to protect themselves. In the 1840s, Charles Goodyear patented his "vulcanized rubber" this made surgical gloves become flexible enough to wear and were used at Johns Hopkins Hospital in the 1890s. By the early 1900s, surgical masks were made from cotton gauze and worn by surgery staff to thwart infection of open surgical wounds. During this same period, the first kind of respirators were invented and were usually used to shield miners from dust and gas, soldiers from chemical warfare and firefighters from smoke. PPE was initially devised to protect the human body as shown in Figure 1; however, in the medical industry, PPE does not only protect healthcare workers, but also provides a clean, sterile environment for patients in need of care.

A pandemic is defined as an epidemic occurring worldwide, or over a very wide area, crossing international boundaries and usually affecting many people (Kelly, 2011). In a more generalized form, a pandemic is defined as the worldwide spread of a new disease with millions of fatalities. Historical pandemic overviews report several pandemic worthies of note

such as the Black Death (1347 to 1351, with estimated fatalities of 75 million over a 450 million global world population); Spanish flu (1918 to 1919, accounted 50 million deaths); Asian flu (1957/58) and Hong Kong flu (1968/69) had a combined global mortality of 3 million; HIV/ AIDS infected about 60 million people and 35 million deaths. Other exotic diseases appeared later, like Ebola, Bovine Spongiform Encephalopathy (aka mad cow disease), severe acute respiratory syndrome (SARS) which appeared in 2002–3, H1N1 occurred in 2010, and finally COVID-19 in 2020 (Medscape, 2020). As a result of these, many demands of PPE in a pandemic span from the medical field leading eventually to shortages. Consequently, the heightened demands for PPE during a pandemic, primarily originating from the medical sector, often culminate in shortages. The shortage of PPE in 2020 was a foreseeable event, yet it still caught many by surprise. The United States saw a surge in demand for PPE in the late 1980s, driven by the discovery of the Human Immunodeficiency Virus (HIV) and the release of guidelines by the Centers for Disease Control (CDC) aimed at safeguarding healthcare personnel (Segal, 2016). The tragic events of the 2001 World Trade Center attack raised concerns about the vulnerability of healthcare workers to exposure to toxins in the event of bioterrorism and other future public health emergencies (O'Boyle et al., 2006).



Fig. 1. Different PPE Used in Healthcare Facilities (Chain, 2020)

In 2014, the Ebola Virus outbreak underscored the critical need to protect healthcare workers. This became painfully evident when two nurses, who had inadequate protection, treated an Ebola-infected patient at a Dallas hospital and contracted the virus themselves. Subsequent studies highlighted those global shortages of PPE played a significant role in the infections and tragic deaths of numerous healthcare workers in the West African countries most affected by the Ebola Virus. More recently, since early 2020 the US has experienced a severe shortage of personal protective equipment (PPE) needed by healthcare workers fighting the COVID-19 pandemic (Medscape, 2020) as shown in Figure 2. Previous studies have documented various barriers to PPE management. One significant issue is the supply chain disruption, which was evident during the early stages of the COVID-19 pandemic. Research indicates that global shortages of PPE led to inadequate protection for healthcare workers and increased vulnerability to infection (Cohen & Rodgers, 2020). Additionally, training deficits have been identified as a major barrier. Effective PPE use requires proper training, but many healthcare workers reported insufficient education on the correct usage and disposal of PPE (George et al., 2023). Compliance and behavioral factors also play a crucial role in PPE management. Studies have shown that even when PPE is available, inconsistent usage and improper application can undermine its effectiveness. Behavioral studies suggest that adherence to PPE protocols is influenced by factors such as perceived risk, comfort, and accessibility (Cohen & Rodgers, 2020). Organizational and systemic challenges further complicate PPE management, including issues related to policy enforcement and resource allocation.

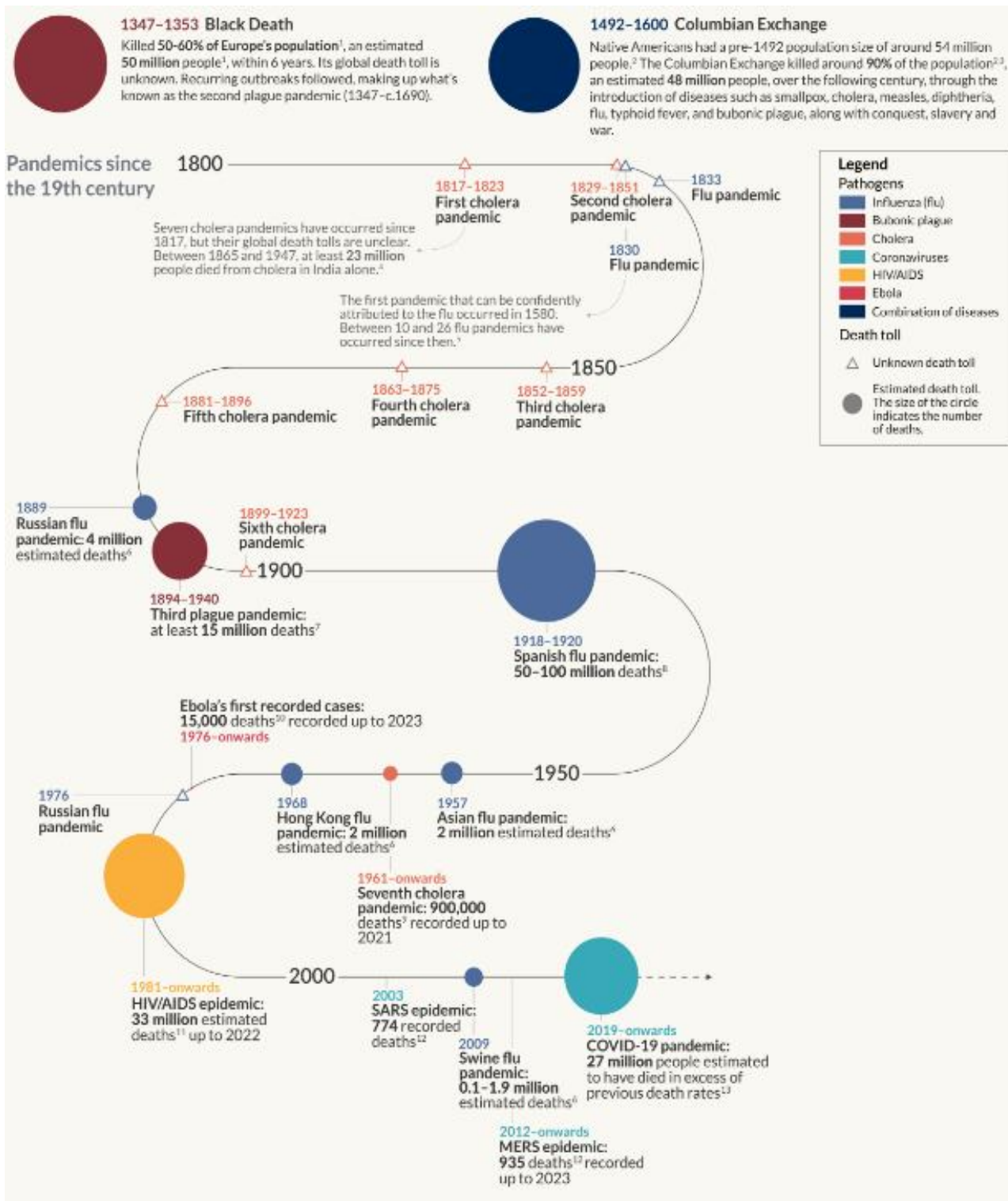


Fig. 2. Pandemics before the 19th century with Death Toll (Saloni, 2023)

Despite its crucial role, the management of PPE during pandemics has been fraught with challenges. Issues such as supply chain disruptions, inadequate training, and compliance difficulties have impeded the effective use of PPE. The COVID-19 pandemic highlighted these barriers, revealing gaps in preparedness and response strategies across various sectors (Best & Williams, 2021). As the world faces ongoing and future pandemics, understanding and addressing these barriers is essential for improving PPE management and ensuring better pandemic responses. The management of PPE during pandemics has been impeded by a range of barriers that hinder its effectiveness and accessibility. One major issue observed during the COVID-19 pandemic was the disruption in the global supply chain for PPE. Early in the pandemic, many countries experienced severe shortages of critical PPE, which compromised the safety of healthcare workers and

contributed to the spread of the virus. This shortage was exacerbated by export restrictions, panic buying, and the inability of manufacturing processes to keep up with sudden spikes in demand. According to a survey conducted by the World Health Organization (2020), 72% of healthcare facilities reported PPE shortages at some point during the pandemic, highlighting a critical gap in preparedness and response. In addition to supply chain disruptions, inadequate training for PPE use emerged as a significant barrier. Proper donning and doffing procedures, as well as the correct use of PPE, are essential to ensure their effectiveness. However, many healthcare workers reported insufficient training and confusion regarding PPE protocols, which led to improper use and increased risk of infection (George et al., 2023). Behavioral factors also played a role; research has shown that compliance with PPE guidelines is often influenced by factors such as perceived risk, discomfort, and ease of access (Cohen & Rodgers, 2020). These issues were further compounded by organizational and systemic challenges, including inconsistent policy enforcement and lack of resource allocation, which affected the overall effectiveness of PPE management strategies.

Addressing these barriers is crucial for improving PPE management in future pandemics. The lessons learned from the COVID-19 experience can inform better strategies for procurement, training, and policy development to enhance the resilience of healthcare systems against future threats. Effective management of PPE not only protects healthcare workers but also plays a vital role in controlling the spread of infectious diseases on a global scale. The primary objective of this study is to identify and analyze the barriers to proper PPE management during pandemics. By elucidating these challenges, the study aims to provide actionable insights for improving PPE strategies and ensuring better preparedness for future health crises.

To achieve these objectives, the study addressed the following research questions:

1. What are the key barriers to effective PPE management during a pandemic?
2. How do these obstacles affect the overall efficiency and efficacy of PPE in controlling infectious diseases?
3. What strategies can be implemented to overcome these barriers and improve PPE management in future pandemics?

2. METHODOLOGY

2.1 Research Design

This study adopts a mixed-methods research design, integrating both qualitative and quantitative approaches to provide a comprehensive understanding of the barriers to PPE management. The combination of qualitative and quantitative methods allows for a robust analysis of the multifaceted issues surrounding PPE use during a pandemic. To understand the barriers to effective PPE management in a pandemic, it is imperative to collect data from health care workers who have experienced shortages while performing their duties. For this work, a google form was created to ask questions with the goal of identifying barriers to PPE management in their respective healthcare workplace. A set of survey questions was given to health care workers as shown below:

1. What is your current role?
2. How often do you use PPE?
3. How often do you receive training on the usage of PPE or management
4. Have you ever experienced any difficulty obtaining the appropriate PPE for your job? If so, please describe the situation.
5. Did you experience shortages during the Pandemic?
6. Have you ever encountered resistance from colleagues or supervisors regarding the use of PPE?
7. If your answer to 6 above is yes, please describe the situation.
8. What do you believe is the most significant barrier to effective PPE management/availability within your healthcare organization especially during a pandemic?
9. What suggestions do you have for improving PPE management within your healthcare organization?

10. Have you ever been involved in a situation where PPE was not available or not used appropriately, resulting in a risk to patient safety? If so, please describe the situation.

11. How do you think PPE can be better managed in your healthcare organization in preparation for a pandemic?

2.2 Data Collection

For both quantitative and qualitative data collection, a structured questionnaire was developed based on a comprehensive review of existing literature on PPE management. The questionnaire includes closed-ended questions designed to measure the frequency, types, and impacts of barriers. The survey is distributed electronically to a targeted sample of healthcare workers, administrators, and PPE supply chain professionals using online survey tool Google Forms. The sampling frame includes healthcare institutions and professionals across different regions and healthcare settings (e.g., hospitals, clinics, long-term care facilities). Purposive sampling is used to select participants who have specific knowledge or experience related to PPE management. A target sample size of 100 respondents is set to achieve statistical significance and ensure generalizability of the findings.

2.3 Data Analysis Techniques

Descriptive statistics, including mean, median, mode, and standard deviation, are used to summarize survey responses and identify common barriers. Statistical chi-square tests were conducted to explore relationships between variables and test hypotheses regarding barriers to PPE management. Data were analyzed using statistical tools in Python. For the qualitative research analysis, a triangulation approach was adopted. Data from interviews, focus groups, and surveys are triangulated to ensure validity and reliability of the findings. A hypothesis was formulated for this project regarding barriers to proper PPE management in a pandemic as shown below:

Hypothesis: Training Frequency is Associated with Role Type

Null Hypothesis (H0): Training frequency is independent of the healthcare role.

Alternative Hypothesis (H1): There is a significant relationship between the two.

Chi-Square Test for Independence was performed to analyze the data inferentially to determine if there is a significant association between role type and training frequency. The Chi-Square test is a handy tool for exploring relationships between categorical variables. Chi-Square statistics is given by Eq.1.

$$\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e} \quad 1$$

Where:

f_o is the observed frequency

f_e is the expected frequency if NO relationship existed between the variables.

As depicted in equation 1, the Chi-Square statistic is based on the difference between what is actually observed in the data and what would be expected if there was truly no relationship between the variables. The hypotheses were tested at 95% confidence level (i.e., $P = .05$).

3. RESULTS AND DISCUSSION

Data were collected from 100 responders in healthcare across the United States. Of all responders that participated, 46% were either Registered Nurses (RN) or Licensed Practical Nurses (LPN), 17% are administrators, 16% are doctors, 15% are caregivers and 6% included other healthcare workers such as (therapists, pharmacists and non-contact staff) as shown in Figure 3. Of all these workers, 76% reported frequent use of PPE while 24% seldomly use PPE to carry out their duties.

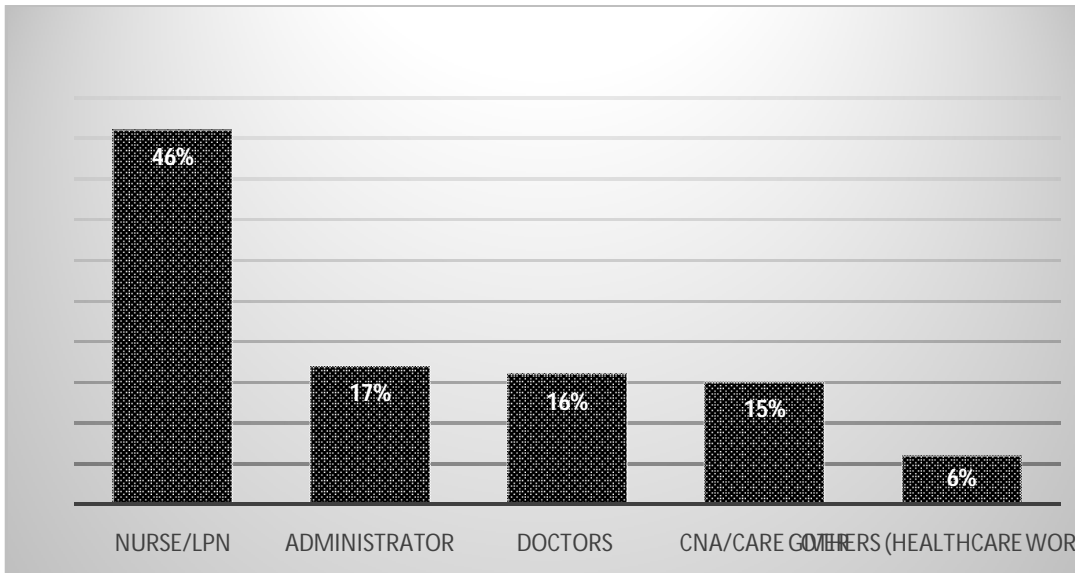


Fig. 3. Roles of healthcare survey responders

3.1 PPE Training Impact

Table 1 shows the training frequency for each role. Each row shows the percentage of individuals in a specific healthcare role receiving training on PPE management on a monthly, quarterly, weekly, or yearly basis. Most of Nurses/LPN training occurs yearly (58%). Similarly, the administrator receives yearly training at 53%, but a noticeable number are trained quarterly (23%). Like nurses, most doctors receive yearly training at 62% while CNA/Caregivers received more frequent monthly training (27%) compared to other roles. The vast majority of other healthcare workers are trained yearly (83%). For each role, there is a yearly training course for more than 50% of the responders.

On analysis of the data inferentially based on the hypothesis, Chi-Square Test was performed to determine if there is a significant association between role type and training frequency. In Figure 4, the heatmap displays the expected training frequencies if there were no relationship between the role and training frequency (i.e., under the assumption of independence). Lighter shades represent smaller expected values. The test result gave a Chi-square Statistic (X^2) value of 71.69 at a degree of freedom (df) of 12 and the critical value is 21.026. The *P-value* of .001 is significantly smaller than the standard significance level of $P = .05$. Thus, the null hypothesis was rejected, and we conclude that there is a statistically significant association between training frequency and the roles in healthcare. In other words, different roles receive PPE training at different frequencies.

Table 1. Training frequency for each healthcare role

Roles	Training Frequency			
	Monthly	Quarterly	Weekly	Yearly
Nurse/LPN	13%	22%	7%	58%
Administrator	12%	23%	12%	53%
Doctors	13%	25%	0%	62%
CNA/Care Giver	27%	20%	0%	53%
Others (Healthcare Worker)	0%	17%	0%	83%

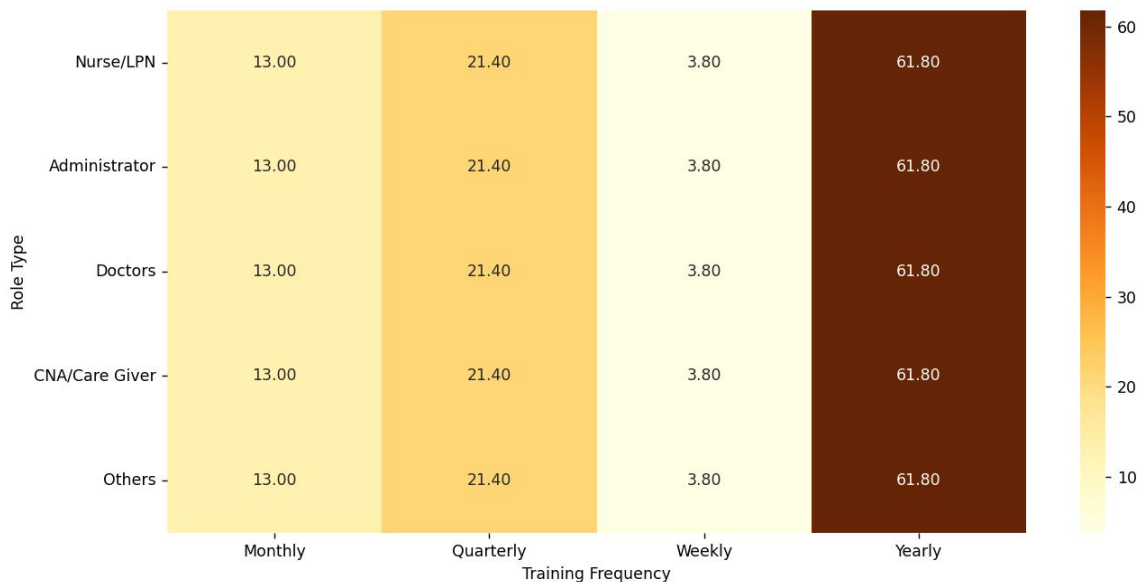


Fig. 4. Expected training frequency by role (based on independence)

3.2 Role-Specific Analysis

- Nurses/LPN:** They receive a considerable amount of training on a yearly basis (58%), with fewer nurses receiving monthly (13%) or weekly (7%) training. This indicates that PPE training for nurses tends to be concentrated yearly, which may be inadequate for maintaining consistent up-to-date knowledge during a pandemic.
- Administrators:** A large portion also receives yearly training (53%), but administrators show higher quarterly training (23%) compared to other roles. This suggests that administrators may have slightly more frequent refreshers than clinical roles like doctors.
- Doctors:** They overwhelmingly receive yearly training (62%) and virtually no weekly training (0%). Doctors might require more frequent updates, as yearly training may not be sufficient during rapidly changing pandemic conditions.
- CNA/Caregivers:** They have the highest percentage of monthly training (27%) compared to other groups, which suggests a proactive effort to keep caregivers regularly updated.
- Other Healthcare Workers:** Most of this group receives yearly training (83%), the highest across all roles. This may indicate a lack of focus on frequent updates for less directly involved healthcare roles.

3.3 Training Frequency Analysis

For yearly training, a significant proportion of all roles (53% to 83%) receives PPE training yearly. This trend highlights a potential gap, as PPE protocols and guidelines may evolve more frequently, especially during a pandemic. Monthly and weekly training are relatively rare across roles. CNA/Caregivers (27%) and Nurses (13%) are exceptions for monthly training. For roles like doctors and administrators, monthly or weekly refreshers could help keep them better prepared for sudden changes in pandemic conditions. The chi-square test revealed a significant association between role type and training frequency. Residual analysis can help identify specific cells where the observed data deviates most from the expected. A qualitative breakdown based on deviations shows that with an observed yearly training (58%) which is slightly lower than expected (61.8%), Nurses may benefit from more frequent training. For CNA/Caregivers, monthly training (27%) is much higher than expected (13%), indicating that this group receives more frequent updates, which is a positive sign for maintaining frontline readiness. The heavy reliance on yearly training (especially for doctors and other healthcare workers) may not be sufficient. More frequent, even if shorter, refresher training (monthly or quarterly) could improve

preparedness, especially during dynamic pandemic situations. CNA/Caregivers, who have the most frequent monthly training, may serve as a model for other groups. More critical roles like doctors and nurses should also receive more frequent updates to maintain PPE compliance and adaptability. Given the significant association between role and training frequency, organizations may benefit from developing role-specific PPE management training protocols, with higher-risk roles (e.g., frontline healthcare workers) receiving more frequent updates. These insights suggest that training frequency could be better optimized based on the role, especially given the significant association between the two variables.

To further investigate potential improvements in PPE training strategies, additional analyses and simulations were explored, and the residuals for each cell to identify where the largest differences between observed and expected frequencies lie were calculated. This was done to highlight which roles are either under- or over-represented in certain training categories.

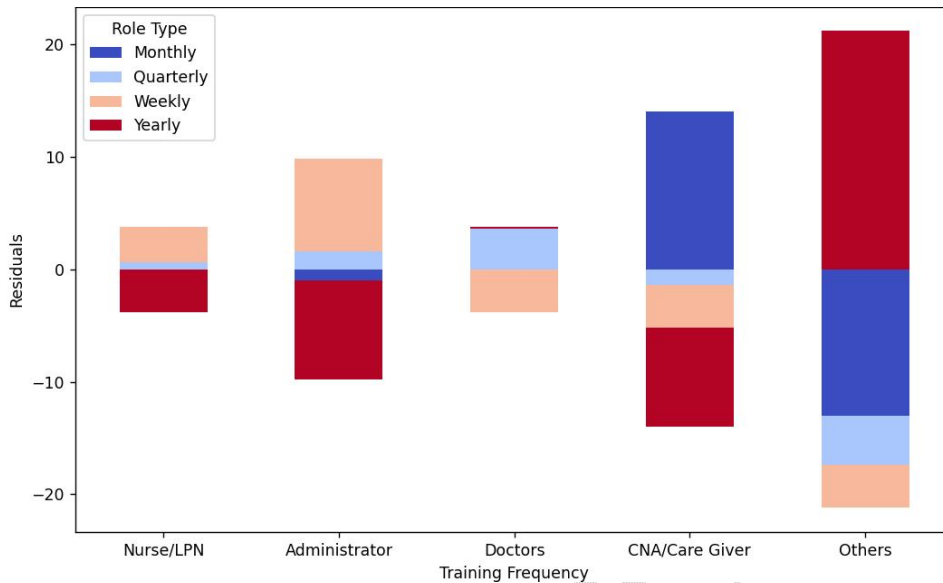


Fig. 5. Residuals from the chi-square test

The stacked bar chart of residuals shown in Figure 5 provides a clear visualization of the differences between the observed and expected frequencies of training sessions across various healthcare roles. Each bar represents a specific training frequency category—monthly, quarterly, weekly, and yearly—and is divided into segments corresponding to different roles (such as Nurse/LPN, Administrator, Doctors, CNA/Care Giver, and Others). This provides insights into where training is either overrepresented or underrepresented for certain roles and frequencies. For CNA/Caregivers, the monthly training residual is quite high, indicating they are receiving more frequent training than expected. Whereas for doctors, the lack of weekly training shows a significant negative residual, suggesting that this group may be underserved in terms of frequent training.

3.4 PPE Shortages During Pandemic

From the obtained data, 75% of the survey participants experienced PPE shortages during the pandemic while 25% didn't experience any form of shortages during the pandemic. In terms of PPE shortages, Figure 6 shows that at least 60% of each health care worker role faced shortages during the pandemic including nurses and doctors and Certified Nursing Assistant (CNA) who are in constant contact with the patients.

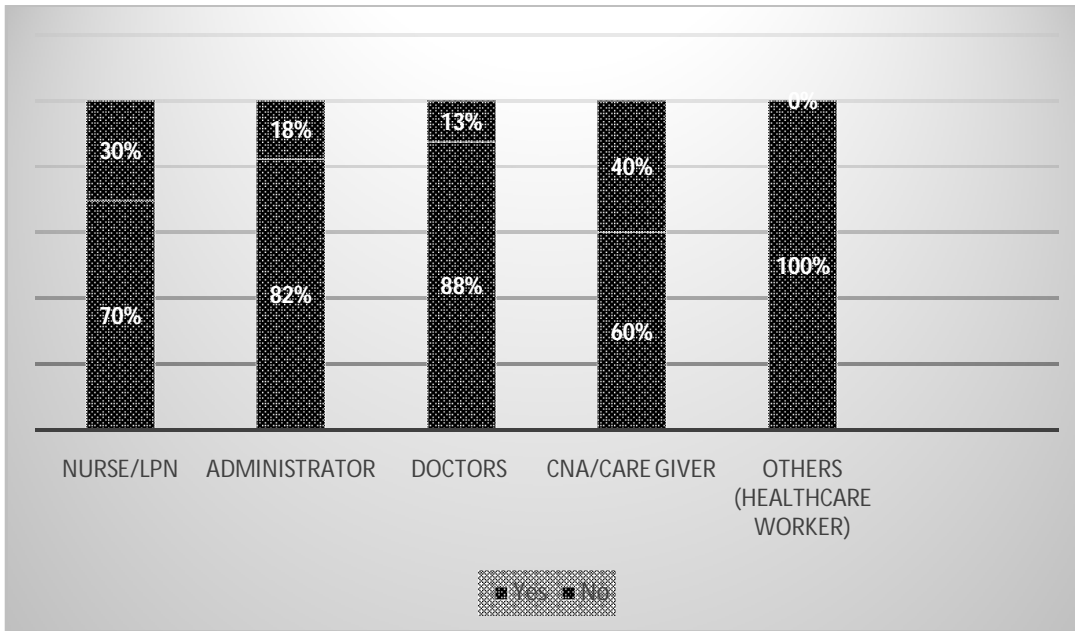


Fig. 6. PPE shortages among healthcare workers by role

3.5 Identification of Barriers to PPE Management

Response to the survey question on resistance from colleagues or supervisors regarding the use of PPE shows that there was little to no resistance from supervisors regarding the use of PPE (81%). Only 19% of responders had resistance using the right PPE and the resistance was because of shortage experienced during the pandemic. Suggestions were made on the barriers to PPE management during the COVID-19 pandemic as shown in Table 2. The quantitative descriptive analysis emphasizes the urgent need for effective management of personal protective equipment (PPE) within healthcare industries. One key finding is the inadequate frequency of PPE training, with only 59% of respondents reporting receiving yearly training. To ensure proper PPE utilization and minimize wastage, it is recommended that training sessions be conducted quarterly.

Table 2. Identified barriers to PPE management

Barriers to PPE Management in a Pandemic	Responders
Lack of preparation	41%
Insufficient knowledge	31%
Cost	22%
Wastage rather than proper usage	3%
Supply Chain	2%
Availability	1%
Total	100%

Consistent training is vital for ensuring that PPE is used correctly, thereby enhancing worker and patient safety through infection prevention measures. The analysis also revealed that while only 19% of respondents faced resistance from managers or supervisors regarding the acquisition of appropriate PPE, this resistance was primarily attributed to PPE shortages during the pandemic, which compelled managers to enforce reuse practices.

Furthermore, the study identified the top three barriers to availability and effective management of PPE during a pandemic as follows: Inadequate preparation; Insufficient knowledge; and Cost of PPE during the pandemic. Poor preparation leads to disorganized inventory systems, insufficient stockpiling, and delayed responses when PPE is needed. It can result in reactive, rather than proactive, procurement strategies, which slows down distribution and deployment. For the second top barrier, if responders are not adequately trained or knowledgeable about the proper selection, use, storage, and disposal of PPE, it leads to misuse, overuse, or underuse. This contributes to wastage and inefficiency. High percentages in the two top barriers (i.e., lack of preparation and insufficient knowledge) suggest that there might be an overlap in areas needing improvement. Addressing preparation might also improve knowledge and vice versa. High costs can limit the ability of institutions, especially smaller or underfunded organizations, to purchase adequate quantities of PPE. This may lead to rationing, reusing PPE beyond recommended limits, or seeking lower-quality alternatives. Wastage undermines efforts to conserve PPE supplies during critical times. Overuse or premature disposal of PPE may result in shortages, reducing the ability of responders to remain adequately protected over extended periods. 2% of the total responders agreed that supply chain is a barrier to PPE management. Supply chain disruptions can delay the procurement of PPE, especially in a global crisis where demand outstrips supply. It can create bottlenecks in distribution, leading to localized shortages even when global supply is adequate. Low availability directly affects the capacity of responders to protect themselves. Limited PPE forces difficult decisions, such as prioritizing certain responders or areas, potentially leaving others vulnerable to infection.

Addressing these three top barriers is crucial for improving PPE management strategies and enhancing overall safety measures within healthcare settings, particularly during times of crisis such as pandemics. By adequately preparing, increasing knowledge among healthcare staff, and addressing cost concerns, healthcare facilities can better equip themselves to handle future challenges related to PPE management and ensure the safety of both healthcare workers and patients.

4. CONCLUSION

In summary, this study highlights the pressing need for effective management of personal protective equipment (PPE) in healthcare settings, particularly in the face of ongoing and future health crises. The findings indicate that inadequate training frequency and significant barriers—such as poor preparation, insufficient knowledge, and high costs—hamper the proper utilization of PPE. The chi-square analysis underscores the importance of regular training, as only 59% of respondents reported receiving yearly instruction on PPE usage. This gap in training not only increases the risk of misuse but also contributes to wastage, undermining efforts to conserve critical resources during emergencies. To enhance PPE management and safety outcomes, healthcare facilities must prioritize comprehensive training programs and streamline their procurement processes. Implementing quarterly training sessions can significantly improve staff knowledge and readiness, fostering a culture of safety and efficiency. Additionally, addressing cost-related barriers through strategic partnerships and bulk purchasing agreements could ensure adequate supply levels, reducing reliance on substandard alternatives. By tackling these challenges head-on, healthcare organizations can better prepare for future challenges, ensuring the safety of healthcare workers and patients alike while improving overall infection control measures. Despite the valuable insights gained from this study, several limitations must be acknowledged. Firstly, the research may be subject to response bias, as participants could provide socially desirable answers or may not fully disclose the barriers they face. Additionally, the sampling frame may not encompass all regions or types of healthcare settings, potentially limiting the generalizability of the findings. Future research should investigate integrated approaches that address multiple barriers simultaneously and evaluate the effectiveness of various strategies in enhancing PPE management during pandemics.

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