

# Knowledge & Usage of Personal Protective Equipment for Prevention of Infection Among Frontline Health Care Workers During Covid – 19 Pandemic

NOSHEEN MAHMOOD<sup>1</sup>, SAIMA AAMIR<sup>2</sup>, HUMERA AKHLAQ<sup>3</sup>, ISMA SAJJAD<sup>4</sup>, SAJID HANIF<sup>5</sup>, KEFI IQBAL<sup>6</sup>

<sup>1</sup>Pathologist King Saud bin Abdul Aziz University for health sciences, Riyadh, KSA

<sup>2</sup>Pathologist King Saud bin Abdul Aziz University of health sciences, Riyadh KSA.

<sup>3</sup>Assistant Professor Oral Pathology, Sindh institute of oral health sciences. Jinnah Sindh Medical University Karachi.

<sup>4</sup>Assistant Professor Operative Dentistry, Sindh institute of oral health sciences. Jinnah Sindh Medical University Karachi

<sup>5</sup>Professor of Oral Pathology, Sindh institute of oral health sciences. Jinnah Sindh Medical University. Karachi

<sup>6</sup>Professor of Dental Materials, Sindh institute of oral health sciences. Jinnah Sindh Medical University Karachi

Correspondence to: Humera Akhlaq, Email: [humeraakhlaq@gmail.com](mailto:humeraakhlaq@gmail.com), Cell: 0321 8912767

## ABSTRACT

**Background:** The risk of transmission of novel SARS CoronaVirus-2 among health care workers can be reduced using personal protective equipment. It is critical to follow guidelines for appropriate use of protective gear to avoid its wastage. This study aimed to evaluate frontline healthcare workers' understanding of effective donning and doffing of protective equipment in the wake of recent emergence of corona virus disease. Physical impacts due to its prolonged usage were also identified.

**Material and Methods:** A cross sectional survey was conducted targeting frontline health care workers from June till July 2021. Data was analyzed using SPSS version 24. Descriptive analysis was performed for qualitative variables. Chi-square test was utilized to determine association between qualitative variables and  $p < 0.05$  was considered to be statistically significant.

**Results:** A total of 204 responses were received. Surgical masks (53.9%), gloves (51.5%), gowns (46.1%) and N95 respirator (40.7%) were most frequently used. Physicians had better knowledge on correct utilization of protective equipment as compared to non-physicians,  $p < 0.001$ . Only 55.9% and 47.1% participants knew correct donning and doffing sequence respectively. The most prevalent mistakes while doffing were touching front of mask and potentially contaminated surfaces followed by incorrect doffing sequence. Most respondents mentioned scarcity of protective gear. Around 53% participants did not attend any training session on utilization of personal protective equipment. Prolonged exposure to masks and gloves led to acne, facial marks and itching. Frequent practice of hand hygiene was linked with skin dryness and cracking,  $p < 0.001$ .

**Conclusion:** We observed lack of expertise in donning and doffing technique. Mostly mistakes occurred during doffing, so interactive workshops are required to train health care workers. Most common dermatological manifestations due to use of masks and gloves included acne, facial markings, and itching. Adverse effects of prolonged use of PPE can be avoided by having shorter duration of working hours and giving rest during the shifts.

**Keywords:** COVID-19; personal protective equipment; skin manifestation; pandemics.

## INTRODUCTION

The perceived notion of adhering to routine personal protection and hygiene methods in the healthcare setup has recently changed drastically. The reason for such a huge change is due to outbreak of novel SARS CoronaVirus-2 (SARS CoV-2), being identified in Wuhan in the People's Republic of China in December 2019.<sup>1</sup> With progression of time, the number of fatalities and positive cases being identified worldwide have increased rapidly. World Health Organization (WHO) declared the outbreak as pandemic on 11 March 2020.<sup>2</sup> Currently the total number of active cases worldwide have reached 234,809,103 as of 5 October 2021. While the recent death toll communicated by World Health Organization (WHO) is 4,800,375. In Pakistan, so far the total number of cases are 1,249,858 while 27,866 people have succumbed to the disease.<sup>3</sup>

The mode of transmission of corona virus is primarily through respiratory droplets or aerosols formation. It can also be transmitted via contact with contaminated surfaces.<sup>4</sup> Healthcare workers (HCWs) are extremely vulnerable to aerosols or respiratory droplets while

performing aerosols generating procedures during direct contact with corona virus disease (COVID-19) patients. Risk of transmission among HCWs can be reduced by accentuating the practice of preventive techniques on a regular basis. These include frequent hand washing, use of hand sanitizer and wearing personal protective equipment (PPE). PPE consists of barriers like fluid resistant gown, coverall, gloves, full-face shield or goggles. Respiratory protection is provided by N95 respirator or surgical mask if N95 is not available.<sup>5</sup> Proper utilization of PPE with correct donning and doffing is highly effective in preventing spread of virus. Extreme caution should be exercised to remove PPE in correct sequence and contaminated PPE should be discarded appropriately to avoid exposure to the pathogen. Removal of PPE using rigorous movements might result in contamination of skin and inadvertent self-inoculation or spread of virus to the patients.<sup>6</sup> Kang et al documented contamination of hands, fingers, wrist, and face after doffing PPE and this could be attributed to lack of training.<sup>7</sup> WHO and Center for Disease Control and Prevention (CDC) has released proper guidelines for healthcare professionals for using PPE.<sup>8</sup> These guidelines should be strictly observed as the supply of PPE is limited

especially in developing countries. So improper use may lead to exhaustion of restricted resources. Unfortunately, it has been observed that proper utilization and handling of protective equipment is not fully understood by healthcare professionals due to inadequate knowledge and training on practice of use of PPE. This problem can be addressed by conducting training and interactive sessions.

Wearing PPE for long periods of time is associated with difficulty in breathing, heat exhaustion and dehydration. Glasses can get fogged and there can be allergic skin reaction in the form of acne, rash or contact dermatitis.<sup>9</sup> This cross-sectional study was conducted to evaluate healthcare workers' knowledge and understanding of effective donning and doffing sequence as well as proper disposal of contaminated PPE in the wake of emergence of the novel corona virus COVID-19 at different healthcare centers across Karachi, Pakistan. This study also explored common mistakes encountered while doffing PPE as well as established the most prevalent health issues associated with extended use of PPE.

## MATERIALS AND METHODS

A cross-sectional survey was conducted after ethical approval from Institutional Review Board (IRB) of Jinnah Sindh Medical University, Karachi from June to July 2021. Subjects were recruited via non probability convenient sampling after taking informed consent. Sample size of 195 was calculated using Raosoft sample size calculator keeping margin of error at 7%.<sup>10</sup> Keeping in mind the possibility of low response rate, the survey was distributed to 250 HCWs. A total of 204 responses were received with response rate of 81.6 %. Participants in this study included physicians, dentists and members of para-medical staff including nurses, laboratory/radiology/dental technicians working in government and private health care facilities. The participants were recruited after taking informed consent and their response was kept anonymous. Incomplete forms were excluded from the study.

All findings were recorded in the proforma constituting closed ended questions. Demographic characteristics of the study participants such as age, gender, and level of education were recorded. Information was also gathered about their role as HCWs and place of employment whether working in government or private hospitals. Data was collected on the knowledge of type of PPE used, along with the current practices and skill of donning and doffing sequence and common mistakes made while removing PPE during the current outbreak. Approximate duration for which PPE is worn each day was documented. Any recent training/ interactive session or courses on utilization of PPE were also recorded. HCWs were enquired about breathing problems, heat exhaustion, dehydration and dermatological symptoms as a result of wearing PPE over extended hours. Data was entered and analyzed using SPSS IBM Version 24.0. Descriptive analysis was performed; mean  $\pm$  standard deviation was used for quantitative variables while categorical variables were analyzed using frequencies and percentages. HCWs were divided into two groups of physicians and non-physicians. Physicians included doctors and dentist while non-physicians included nurses, dental, laboratory and radiology technicians. Chi-square test was performed to

examine the relation between qualitative variables and student's t-test was used to analyze association between quantitative and categorical variables.  $p < 0.05$  was considered to be statistically significant

## RESULT

Study included 204 participants. Socio-demographic characteristics of the study participants are shown in **Table 1**. Most of the respondents 102 (50%) belonged to 20-30 years age group. There were 56.9% females and 43.1% males. Majority of participants (23.5%) were physicians, other categories included dentists, nurses, dental technicians, laboratory, and radiology technicians.

Table 1: Socio-Demographic Characteristics of participants.

Variables	Groups	N 204 (%)
Age Group (years)	20-30	102 (50.0)
	31-40	77 (37.7)
	41-50	23 (11.3)
	51-60	2 (1.0)
Gender	Male	88 (43.1)
	Female	116 (56.9)
Education level	Bachelor	82 (40.2)
	Diploma	75 (36.8)
	Masters/Fellowship	47 (23.0)
HCW Profession	Physician	48 (23.5)
	Dentist	40 (19.6)
	Nurse	39 (19.1)
	Dental Technician	30 (14.7)
	Laboratory Technician	28 (13.7)
	Radiology Technician	19 (9.3)
Working in	Government Hospital	113 (55.4)
	Private Hospital	91 (44.6)

Most of participants 151 (74%) believed that personal protective equipment is required by HCWs who have direct contact with COVID-19 patients while 137 (67.2%) respondents always wore PPE during attending COVID-19 patients. Most frequent items used in PPE were surgical masks 110 (53.9%), followed by gloves 105 (51.5%), gowns 96 (46.1%) and N95 respirator 83 (40.7%). Goggles, face shield and coverall were rarely worn. Average number of hours spent wearing PPE in a day was  $7.95 \pm 3.453$ .

Although 148 (72.5%) participants stated that they have correct knowledge of utilization of PPE, but further questioning revealed that only 55.9% and 47.1% HCWs were familiar with correct donning and doffing sequence respectively. Chi-square test revealed no significant association between HCWs profession and knowledge of sequence of donning and doffing,  $\chi^2(1.499)$ ,  $p0.221$  and  $\chi^2(1.57)$ ,  $p0.221$  respectively. Only a small percentage of HCWs performed fit test while wearing N95 respirator (21%). No significant association was found in performing fit test when physicians were compared with non-physicians,  $\chi^2(2.154)$ ,  $p0.142$ . Although majority of participants reported being cautious while removing PPE, but non-physicians were found to more careful while doffing PPE as compared to physicians,  $\chi^2(3.64)$ ,  $p0.050$ . **Figure 1** illustrates the most common doffing errors. However, no significant association was found between HCW groups in terms of mistakes made while removing PPE. Most of the participants 154 (75.5%) disposed PPE in biohazard bag and 175 (85.8%) performed hand hygiene after removing

PPE. 163(79.9%) participants believed that incorrect donning and doffing procedures resulted in wastage of PPE. The majority of HCWs 165 (80.9%) faced shortage and insufficient supply of PPE.



Figure 1: Doffing errors commonly reported by Health care workers

About 107 (53%) HCWs did not attend any kind of training session/course on the protocols for optimal utilization of personal protective equipment. Further inquiry demonstrated that about 55 (51%) participants responded that they did not have access to these courses, while 40 (37%) were unaware of availability of training sessions, and 12 (11%) thought it was unnecessary to attend the course. A chi square test showed a significant relation between HCWs' profession and the workshops attended. The physicians (60.7%) were more likely to attend training sessions as compared to non-physicians (37.4%),  $p=0.001$ . The majority of participants 127 (62.3%) reported that infection control department doesn't monitor and evaluate the current practice of wearing PPE. 112 (54.9%)

participants were aware about institutional policy and procedure on utilization of PPE.

Protracted use of masks and gloves in hot and humid climate resulted in several dermatological manifestations including acne 122 (59.8%), facial marks 118 (57.8%), redness 96 (47%) and itching 91 (44.6%). Acne was more likely to develop in subjects wearing N95 respirator 58 (69.9%),  $p=0.015$ .

A significant association was documented between frequent use of hand sanitizer and developing skin dryness and cracking using student t-test as displayed in **Figure 2**. Wearing PPE for prolonged duration was linked to developing heat exhaustion, sweating and distress in HCWs as documented in **Table 2**.

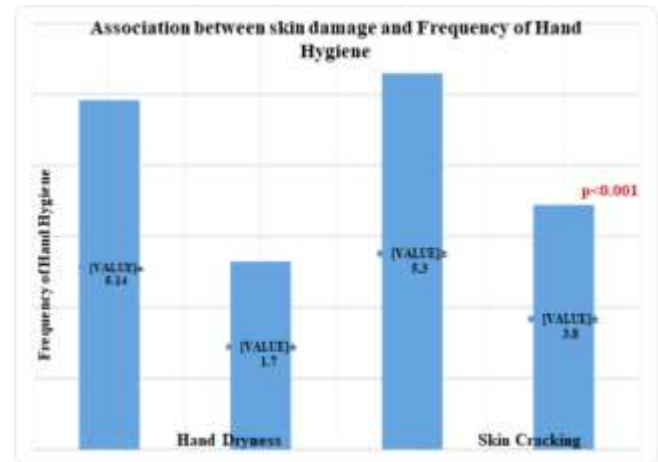


Figure 2: Association between skin damage and frequency of Hand Hygiene

Table 2: Association of Number of Hours of PPE used with Various Physical Factors

Variables	Groups	N	Duration of PPE use Mean±SD	p-value
Breathing difficulty	Yes	171	7.95±3.563	0.807
	No	33	7.91±2.865	
Heat exhaustion & Sweating	Yes	179	8.16±3.612	<0.001
	No	25	6.40±1.118	
Blurred Vision due to fogging of glasses	Yes	188	8.14±3.526	<0.001
	No	16	5.69±0.704	
Anxiety/ Distress	Yes	159	8.28±3.673	0.001
	No	45	6.78±2.184	

## DISCUSSION

PPE is an essential element of infection control since it minimizes the risk of infection transmission among health care personnel. Its indiscriminate use not only drains scarce supplies, but also makes HCWs more susceptible to infection, posing a risk to the health-care system. This study provided an overview of health care professionals' knowledge of correct utilization, donning and doffing practice, disposal of contaminated PPE and common mistakes made while removing PPE during COVID-19 pandemic. Adverse effects of prolonged use of PPE on

health of HCWs were also assessed. Availability of training opportunities among HCW managing COVID-19 was also analyzed in this survey.

According to our study, surgical masks were the most frequent item used in PPE, followed by gloves, N95 respirators, and gowns. Goggles, face shield and coverall were seldom used. Similarly, Tabah et al reported that HCWs wore gowns (67%) and N95 masks (58%) while attending COVID-19 patients. In contrast to our findings, 62% of the subjects in their study wore face shields or visors.<sup>11</sup> A study conducted by Ahmed et al to determine

availability of PPE among United States (US) and Pakistani doctors during COVID-19 pandemic, revealed that majority of US doctors had access to personal protective equipment while most of the PPE items were not readily available for doctors in Pakistan.<sup>12</sup> A systemic review on the use of PPE against respiratory infections across Pakistan revealed that protective gear was available in limited stocks and its reuse was common.<sup>13</sup> Our study showed that HCW wore PPE for average 7.95 hours which is quite high as compared to Tabah et al who reported a median of 4 hours.<sup>11</sup>

Although majority of participants in our research had good knowledge about utilization of PPE but on further questioning it was discovered that only half of them were familiar with correct donning and doffing techniques. This finding is comparable to Bains et al who reported proper understanding of donning method by 52.9% dental postgraduates and 43.7% graduates. Only 47.9% postgraduates and 46.1% graduates were aware of correct doffing procedure.<sup>14</sup> Kwon et al observed donning and doffing practice in HCWs treating Ebola virus patients. They discovered that 27% HCWs did not follow proper donning method with most prevalent errors occurring while wearing gloves. Almost everyone made a mistake when it came to removing PPE.<sup>15</sup> Fit test is an important parameter in evaluating the effectiveness of N95 respirator. Training of HCW ensures optimal mask fit. Fit test was performed by only 21% of our study participants. This figure is significantly lower than that reported by Tabah et al, who found that 49% of participants performed the fit test.<sup>11</sup> Our research revealed that common doffing mistakes included touching front of the mask and potentially contaminated surfaces as well as following incorrect doffing sequence. Likewise, Phan et al demonstrated that 90% of HCW removed PPE incorrectly and majority of the errors occurring while taking off the gown and touching contaminated surfaces.<sup>6</sup> Kwon et al established that most of mistakes were encountered while doffing gowns, gloves, shoe covers, and performing hand hygiene.<sup>15</sup> The majority of HCWs in our study disposed PPE in a biohazard bag and performed hand hygiene after removing PPE. This is in contrast to Alao et al. who revealed that only 40% of HCW correctly disposed of PPE.<sup>16</sup> Zellmer and colleagues carried out a study to investigate variation in doffing PPE by health care workers and it was demonstrated that only 50% of them removed PPE appropriately. The proportion of HCWs who removed and discarded PPE properly was even lower.<sup>17</sup> Even though majority of respondents in our study stated that infection control department didn't evaluate the current practice of wearing PPE but close monitoring and evaluation by infection control department may effectively reduce the mistakes. Additionally performing doffing procedure in conjunction with vocal commands lowers mistakes made.<sup>18</sup>

Workshops with hands-on training, interactive sessions and utilization of simulation modalities can be beneficial in better understanding of use of PPE.<sup>14</sup> More than half of the respondent in our survey had not received any formal training regarding the appropriate donning and doffing of personal protective equipment. The main reasons were inability to access the training and a lack of prior knowledge about the course. Furthermore, our study also showed that physicians were more likely to attend training

sessions as compared to non-physicians. Our findings are consistent with Alao et al who illustrated that 47.8% HCW completed training on correctly wearing and removing PPE.<sup>16</sup> However, this is in contrast to the findings reported by Tabah et al who revealed that around 83% participants attended courses on protocols for proper utilization of PPE.<sup>11</sup> According to survey conducted by Royal College of Nursing in the United Kingdom, 23% nurses working in high risk areas did not attend any training on type of PPE and 26% were not trained on donning, doffing and disposing of PPE.<sup>19</sup> Ahmad et al reported low risk of contracting COVID-19 infection in those HCWs who had adequate access to PPE and had received proper training on hand hygiene and utilization of PPE.<sup>20</sup>

Extreme care must be exercised in wearing PPE to avoid unnecessary wastage resulting in its shortage. Around 80% participants in our study believed that PPE gets wasted due to incorrect techniques of donning. Besides 81% HCWs experienced shortage of PPE. Scarcity of personal protective equipment has been reported globally during the pandemic. Inadequate production or interruption in the supply of PPE due to skyrocketing prices may result in delay in delivery of PPE. Misuse and wastage of PPE can be minimized by having clearly outlined institutional policies and procedures in place. Ahmed et al recognized limited stock, interrupted supply, increased cost, administrative and political issues responsible for shortage of PPE in Pakistani health institutions.<sup>12</sup> Tabah et al also documented that around 52% participants faced unavailability of PPE forcing them to reuse protective gear.<sup>11</sup> A survey conducted by Royal college of nursing UK also revealed shortage of surgical masks and eye protection.<sup>19</sup> During the COVID-19 pandemic, a qualitative assessment of frontline HCWs' experience with PPE in UK indicated a shortage of PPE, resulting in its reuse, and endangering HCWs to infection.<sup>21</sup> In Italy, scarcity of PPE resulted in a higher rate of infection and fatality among frontline healthcare workers.<sup>22</sup>

Another major aspect of the study was to evaluate physical impacts due to continuous usage of PPE. Heat exhaustion, excessive sweating, dehydration, breathing difficulty, fatigue and discomfort were mentioned as the most common adverse effects. The main contributory factors were wearing protective gear for long shifts in Karachi's hot and humid climate, especially if breaks were not provided during the shift. These findings are in accordance with those of Tabah et al who also observed that HCWs experienced heat (51%), thirst (47%), headaches (28%) and fatigue (20%) on wearing PPE during long duty hours. The average time spent wearing PPE without a break was 4 hours.<sup>11</sup> 77% of white British nurses were noticed to have heat exhaustion and sweating when wearing PPE.<sup>19</sup> Lee et al have documented breathing difficulty leading to increased inspiratory and expiratory flow resistance by 126% and 122% respectively in subjects wearing N95 respirators.<sup>23</sup> This emphasizes the importance of having shorter shifts while wearing protective gear as well as having breaks during the long duty hours so that HCWs can get themselves hydrated.

HCWs in our study also experienced dermatological symptoms such as acne, facial markings, skin redness and

itching caused by prolonged use of masks and gloves in a hot and humid climate. Acne was more likely to appear in people who wore N95 respirators. Frequent use of hand sanitizer was associated with dryness and cracking of skin. These findings are in accordance with a meta-analysis to identify skin manifestations in HCWs due to the use of PPE during the COVID-19 pandemic. An increased number of cases of contact dermatitis, dryness, and irritation were recorded. Nasal bridge, hands, cheeks, periorcular, and perioral regions were the most frequently involved areas.<sup>24</sup> A study conducted in Hubei, China documented a high prevalence (97%) of skin manifestations including dryness, redness, erythema and itching in front line health care workers using PPE during the pandemic. Most common area affected was nasal bridge. Furthermore, it was discovered that longer duration of wearing PPE was associated with high probability of developing dermatitis. Likewise, hand dryness was related to frequent hand hygiene (>10 times daily).<sup>9</sup> Skin irritation was also reported by nurses in the survey conducted by Royal College of Nurses, UK.<sup>19</sup>

Main limitation of our study was self-administered questionnaire, and the findings represent individuals' personal opinions and views. They may or may not be representative of actual practice. A more accurate assessment of donning and doffing technique can be done by direct observation of the procedure. Similarly evaluation of skin lesions by a dermatologist can give a detailed insight into the adverse effects of PPE. Some reluctance to participate in the survey was observed due to heavy workload and lack of interest by HCWs. This study was conducted only in Karachi, so we cannot generalize our findings to rest of healthcare institutions in other cities of Pakistan.

## CONCLUSION

Personal protective equipment prevents infection transmission, but it's also imperative to consume it appropriately and carefully to avoid wastage of already limited resources. HCWs should be provided with essential protective gear to ensure their safety. We discovered a lack of competency in the practice of donning and doffing. The majority of the participants did not perform the fit test. Most of the mistakes were encountered during removing PPE. As a result, there is a compelling need to fill the gap in the understanding and knowledge of use of PPE. It is for this reason, interactive training sessions, and workshops using simulation should be introduced, monitored and modified as per needed at the workplace with details regarding a donning, doffing and disposal of personal protective equipment. These training sessions should be made accessible to all health care professionals. Close monitoring and evaluation by infection control department should be enforced. Most common skin manifestations included acne, facial markings, skin redness and itching. These can be attributed to use of masks and gloves in a hot and humid climate for long period. Adverse effects of prolonged use of PPE can be avoided by having shorter duration of working hours and giving rest during the shifts.

## REFERENCES

1. Wang Y, Wang Y, Chen Y, Qin Q. Unique epidemiological and clinical features of the emerging 2019 novel coronavirus pneumonia (COVID-19) implicate special control measures. *J Med Virol.* 2020 Jun;92(6):568-576. doi: 10.1002/jmv.25748. Epub 2020 Mar 29. PMID: 32134116; PMCID: PMC7228347.
2. WHO announces COVID-19 outbreak a pandemic (2020). Available online at <http://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19/news/news/2020/3/who-announces-covid-19-outbreak-a-pandemic>. [Accessed 25 September 2021].
3. WHO Coronavirus Disease (COVID-19) Dashboard. Available online at <https://covid19.who.int/> [Accessed 05 Oct 2021]
4. Shereen MA, Khan S, Kazmi A, Bashir N, Siddique R. COVID-19 infection: Origin, transmission, and characteristics of human coronaviruses. *J Adv Res.* 2020 Mar 16;24:91-98. doi: 10.1016/j.jare.2020.03.005. PMID: 32257431; PMCID: PMC7113610.
5. Park SH. Personal Protective Equipment for Healthcare Workers during the COVID-19 Pandemic. *Infect Chemother.* 2020 Jun;52(2):165-182. doi: 10.3947/ic.2020.52.2.165. PMID: 32618146; PMCID: PMC7335655.
6. Phan LT, Maita D, Mortiz DC, Weber R, Fritzen-Pedicini C, Bleasdale SC, Jones RM; CDC Prevention Epicenters Program. Personal protective equipment doffing practices of healthcare workers. *J Occup Environ Hyg.* 2019 Aug;16(8):575-581. doi: 10.1080/15459624.2019.1628350. Epub 2019 Jul 10. PMID: 31291152; PMCID: PMC7157959.
7. Kang J, O'Donnell JM, Colaianni B, Bircher N, Ren D, Smith KJ. Use of personal protective equipment among health care personnel: Results of clinical observations and simulations. *Am J Infect Control.* 2017 Jan 1;45(1):17-23. doi: 10.1016/j.ajic.2016.08.011. PMID: 28065328.
8. World Health Organization. Rational use of personal protective equipment for coronavirus disease (COVID-19) and considerations during severe shortages: interim guidance, 2020. Available: <https://apps.who.int/iris/handle/10665/331695> [Accessed 05 Oct 2021]
9. Lan J, Song Z, Miao X, Li H, Li Y, Dong L, Yang J, An X, Zhang Y, Yang L, Zhou N, Yang L, Li J, Cao J, Wang J, Tao J. Skin damage among health care workers managing coronavirus disease-2019. *J Am Acad Dermatol.* 2020 May;82(5):1215-1216. doi: 10.1016/j.jaad.2020.03.014. Epub 2020 Mar 18. PMID: 32171808; PMCID: PMC7194538.
10. Raosoft Sample size calculator. Retrieved from: <http://www.raosoft.com/samplesize.html>
11. Tabah A, Ramanan M, Laupland KB, Buetti N, Cortegiani A, Mellinshoff J, Conway Morris A, Camporota L, Zappella N, Elhadi M, Povoia P, Amrein K, Vidal G, Derde L, Bassetti M, Francois G, Ssi Yan Kai N, De Waele JJ; PPE-SAFE contributors. Personal protective equipment and intensive care unit healthcare worker safety in the COVID-19 era (PPE-SAFE): An international survey. *J Crit Care.* 2020 Oct;59:70-75. doi: 10.1016/j.jccr.2020.06.005. Epub 2020 Jun 13. Erratum in: *J Crit Care.* 2021 Jun;63:280-281. PMID: 32570052; PMCID: PMC7293450.
12. Ahmed J, Malik F, Bin Arif T, Majid Z, Chaudhary MA, Ahmad J, Malik M, Khan TM, Khalid M. Availability of Personal Protective Equipment (PPE) Among US and Pakistani Doctors in COVID-19 Pandemic. *Cureus.* 2020 Jun 10;12(6):e8550. doi: 10.7759/cureus.8550. PMID: 32670687; PMCID: PMC7357309.
13. Chughtai AA, Khan W. Use of personal protective equipment to protect against respiratory infections in Pakistan: A systematic review. *J Infect Public Health.* 2019 Jul-Aug;12(4):522-527. doi: 10.1016/j.jiph.2019.01.064. Epub 2019 Feb 7. PMID: 30738757; PMCID: PMC7102795.

14. Bains VK, Bains R, Gupta V, Salaria SK. Knowledge of COVID-19 and its implications in dental treatment, and practices of personal protective equipment among dentists: A survey-based assessment. *J Educ Health Promot*. 2021 Feb 27;10:79. doi: 10.4103/jehp.jehp\_763\_20. PMID: 34084826; PMCID: PMC8057157
15. Kwon JH, Burnham CD, Reske KA, Liang SY, Hink T, Wallace MA, Shupe A, Seiler S, Cass C, Fraser VJ, Dubberke ER. Assessment of Healthcare Worker Protocol Deviations and Self-Contamination During Personal Protective Equipment Donning and Doffing. *Infect Control Hosp Epidemiol*. 2017 Sep;38(9):1077-1083. doi: 10.1017/ice.2017.121. Epub 2017 Jun 13. PMID: 28606192; PMCID: PMC6263164
16. Alao MA, Durodola AO, Ibrahim OR, Asinobi OA. Assessment of Health Workers' Knowledge, Beliefs, Attitudes, and Use of Personal Protective Equipment for Prevention of COVID-19 Infection in Low-Resource Settings. *Advances in Public Health*. 2020 Aug 24;2020.
17. Zellmer C, Van Hoof S, Safdar N. Variation in health care worker removal of personal protective equipment. *Am J Infect Control*. 2015 Jul 1;43(7):750-1. doi: 10.1016/j.ajic.2015.02.005. PMID: 26138659; PMCID: PMC7132814.
18. Zamora JE, Murdoch J, Simchison B, Day AG. Contamination: a comparison of 2 personal protective systems. *CMAJ*. 2006 Aug 1;175(3):249-54. doi: 10.1503/cmaj.060094. PMID: 16880444; PMCID: PMC1513425.
19. Royal College of Nurses. Second personal protective equipment survey of UK nursing staff report: use and availability of PPE during the COVID-19 pandemic, Available: <https://www.rcn.org.uk/professional-development/publications/rcn-second-ppe-survey-covid-19-pub009269> [Accessed 30 September 2021]
20. Ahmad J, Anwar S, Latif A, Haq NU, Sharif M, Nauman AA. Association of PPE Availability, Training, and Practices with COVID-19 Sero-Prevalence in Nurses and Paramedics in Tertiary Care Hospitals of Peshawar, Pakistan. *Disaster Med Public Health Prep*. 2020 Nov 5:1-5. doi: 10.1017/dmp.2020.438. Epub ahead of print. PMID: 33148365; PMCID: PMC7943947.
21. Hoernke K, Djellouli N, Andrews L, Lewis-Jackson S, Manby L, Martin S, Vanderslott S, Vindrola-Padros C. Frontline healthcare workers' experiences with personal protective equipment during the COVID-19 pandemic in the UK: a rapid qualitative appraisal. *BMJ Open*. 2021 Jan 20;11(1):e046199. doi: 10.1136/bmjopen-2020-046199. PMID: 33472794; PMCID: PMC7818840.
22. Savoia E, Argentini G, Gori D, Neri E, Piltch-Loeb R, Fantini MP. Factors associated with access and use of PPE during COVID-19: A cross-sectional study of Italian physicians. *PLoS One*. 2020 Oct 12;15(10):e0239024. doi: 10.1371/journal.pone.0239024. PMID: 33044978; PMCID: PMC7549784.
23. Lee HP, Wang de Y. Objective assessment of increase in breathing resistance of N95 respirators on human subjects. *Ann Occup Hyg*. 2011 Oct;55(8):917-21. doi: 10.1093/annhyg/mer065. Epub 2011 Sep 5. PMID: 21893677.
24. Montero-Vilchez T, Cuenca-Barrales C, Martinez-Lopez A, Molina-Leyva A, Arias-Santiago S. Skin adverse events related to personal protective equipment: a systematic review and meta-analysis. *J Eur Acad Dermatol Venereol*. 2021 Oct;35(10):1994-2006. doi: 10.1111/jdv.17436. Epub 2021 Jun 29. PMID: 34077565.