COVID-19

# Knowledge and practice of Protective Personal Equipment (PPE) among healthcare providers in Saudi Arabia during the early stages of COVID-19 pandemic in 2020

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Keywords

COVID-19 • Pandemic • Protective personal equipment • Donning • Doffing • Healthcare providers

Summary

**Introduction**. *Healthcare providers are at high risk of becoming infected when taking care of patients who have COVID-19, especially while attending aerosol generating procedures. Protective personal equipment must be used in the correct manner to prevent transmission of the disease. Published protocols on protective personal equipment (PPE) donning and doffing have been issued by disease control agencies. Methods. A questionnaire-based cross-sectional study was designed. An online anonymous questionnaire, which was validated and tested for reliability, focused on PPE related knowledge, donning and doffing practices of healthcare providers across the eastern region of Saudi Arabia. Results. A total of 312 healthcare providers across the eastern region of Saudi Arabia participated in the study, 208 physicians (66.7%) and 104 non-physicians (33.3%). Results indicate poor practice regarding PPE donning (13.8% reported the correct sequence) and PPE doffing (3.5% reported the correct sequence) among participants. In addition, practice and confidence scores regarding other issues with PPE were analyzed. Based on questionnaire responses, being male (T = 2.825; p = 0.008), being a non-physician (T = -2.120; p = 0.014) and being an allied medical professional (F = 5.379; p = 0.003) were significantly associated with higher confidence levels. Also, being a consultant was significantly associated with higher practice scores (F = 4.774; p = 0.008). Conclusion. The study demonstrates deficiencies among healthcare providers in following the recommended practices for correctly using PPE during the pandemic. Poor practice in PPE donning and doffing necessitates additional educational and training programs focused on infection control practices.*

## Introduction

In December 2019, the world became aware of a highly contagious respiratory infectious disease that first presented itself in Wuhan, China [1]. The disease is caused by a novel coronavirus known as severe acute respiratory virus 2 (SARS-COV-2) [2]. While the original source of the virus remains unidentified, available genetic data suggest a zoonotic origin [3], and human-to-human transmission has been confirmed. Respiratory infection can be transmitted by respiratory droplet particles, which range from 5-10 micrometers in diameter. Droplet transmission occurs when an individual moves into close proximity to an infected person who is exhibiting respiratory symptoms such as sneezing and coughing. The transmission of COVID-19 can occur either directly through mucosal surfaces, such as the mouth, nose, and conjunctiva, or indirectly, by touching the patient's surroundings where the droplets have fallen [4]. Airborne particles are capable of being suspended in the air for long periods of time, ranging between 1.5 h for 3 μm diameter particles to 12 h for 1 μm diameter particles, compared to 10 μm diameter particles that will settle in 8.2 minutes [4, 5]. Airborne particles can also travel more than one meter [5]. As one mode of transmission of COVID-19 is droplet particles [6], airborne transmission might be possible during aerosol generating procedures including the following: endotracheal intubation, open suction, bronchoscopy, nebulized treatment, manual ventilation, turning the patient to a prone position, disconnecting the patient from the ventilator, non-invasive positive pressure ventilation, tracheostomy, and cardiopulmonary resuscitation [5].

On February 11, 2020, the World Health Organization (WHO) named the disease, Corona Virus Disease 2019 (COVID-19) [7]. In March 2020, Saudi Arabia registered its first case of COVID-19 [8]. Due to the rapid spread of the disease, on March 11, 2020, WHO recognized COVID-19 as a global pandemic [9]. As of the date of this manuscript's writing, the total number of cases across the globe had reached more than 80 million, with more than one million deaths occurring worldwide [10]. Healthcare providers (HCPs) are at high risk of becoming infected themselves while caring for patients who are positive for COVID-19. The main mode of transmission is respiratory droplets; therefore, being in close proximity to an individual who has

 https://doi.org/10.15167/2421-4248/jpmh2021.62.4.2177

tested positive for the virus while they sneeze and/or cough, or performing aerosol generating procedures on these patients such as intubation, tracheostomy, and endotracheal suction on, are considered to be very high sources of transmission of the disease to HCPs [6]. Healthcare providers of any age who have certain chronic medical illness have a higher chance of severe COVID-19 infection. These medical conditions include the following: moderate to severe asthma, chronic kidney disease, chronic lung disease, diabetes mellitus, hemoglobin disorders, immune compromised state, liver disease, pregnancy, serious cardiac and cerebrovascular conditions, obesity (BMI > 30), and smoking [3].

Because of the high risk of exposure to SARS-COV-2, as well as a variety of other pathogens, protective personal equipment (PPE) is an important tool for preventing disease transmission, when used in the correct manner [11]. The United States Centers for Disease Control and Prevention (CDC) has published a protocol that describes how to put on (don) and take off (doff) PPE when caring for patients with COVID-19 [12]. Lack of basic knowledge about how to properly use PPE might increase the risk of infection, even when the provider wears all the required equipment. WHO has estimated that 89 million medical masks, 76 million gloves, and 1.6 million face masks have been needed worldwide each month during the pandemic [13].

Rise in demand without a secure chain of supply, as well as misuse of equipment, increases the chance of exhausting PPE supplies. Therefore, healthcare providers need to know how and when to best use PPE to get maximum protection, while preserving resources.

In our study we want to evaluate whether HCPs in this region of the world have the required knowledge to practice safe and efficient PPE usage especially during this pandemic. To the best of our knowledge, there is currently only one published study, conducted in Canada, where PPE donning and doffing sequences among HCPs during COVID-19 were evaluated. A total of 175 HCPs in Toronto, Canada completed a survey on knowledge and usage. Only 86 participants (50%) put on (donned) the PPE in the correct order and only 60 participants (35%) took off (doffed) PPE in the correct order [5]. These figures are quite shocking and carry a high risk of cross contamination due to inappropriate use of PPE which increase the chance of infections in HCPs. Our aim is to study PPE practice and knowledge among HCPs in Saudi Arabia during COVID-19 and to compare our results to the world's published figures.

## Methods

### Study design and data collection

Our study protocol was approved by the Institutional Review Board of King Fahd University Hospital, Khobar, Saudi Arabia. It employed a descriptive, cross-sectional design. Our literature review did not found any previously published validated questionnaire that specifically assess the practice of donning and doffing PPE. We created a new questionnaire that is simple, short and written in language familiar to the healthcare providers. The items of the questionnaire were tested on a small sample (about 50) of respondents to ensure that the items can be understood and correctly interpreted by the intended respondents. A panel of experts in the field from infection control specialty and infectious disease medical specialty were tasked with evaluating the validity of the questionnaire. We prepared an online anonymous questionnaire using Google forms. In this study we included all healthcare providers across the eastern region of Saudi Arabia. The questionnaire covered demographic data including age and gender, and profession, as well as preexisting medical conditions and other risk factors. Importantly, we focused on the respondents' knowledge of PPE practice, especially how to put on (don) and take off (doff) PPE. Participants were also asked about the sources of their information about COVID-19-related safety measures, as well as whether PPE was available in their institute, and what types were available. Using convenience and snowball sampling methods, the questionnaire was distributed using electronic email lists of healthcare providers working at the three major COVID-19 centers in the eastern region of Saudi Arabia. Contact information was obtained from the Saudi Commission for Health Specialties (SCFHS) and recognized medical societies. Informed consent was obtained from all participants. The questionnaire was sent to 1710 healthcare providers. Data were collected between June 21 to August 30, 2020. A total of 350 healthcare providers voluntarily responded to the questionnaire, which correspond to a response rate of 20.4%. We included all HCPs who sent back completed forms, and excluded those who were medical volunteers or medical students who were not allowed to provide direct medical care for patients at that time. Finally, 312 participants were enrolled in the study.

### Scoring

Information regarding the confidence in and actual practice of the HCPs using the recommended PPE during the COVID-19 pandemic was taken from 4 questions included on the questionnaires. 2 questions were about practices, and 2 questions were about confidence. The answer "yes" was coded as 1, and "no" was coded as 0. Total confidence and practice scores were obtained by adding the values for each question separately, with a maximum of 2 points possible for each variable. These were then interpreted as the higher the score, the higher the level of practice or confidence regarding the use of recommended PPE during the COVID-19 pandemic. We considered the levels of practice and confidence of the HCPs on each variable as low if their score was 0 points, moderate if their score was 1 point, and high if their score was 2 points.

### Statistical analysis

Data are presented using number, percentage, mean, and standard deviation, as appropriate. For between group

comparisons, the Mann-Whitney U test or the Kruskal Wallis test was applied. A P-value of $< 0.05$ was considered statistically significant. Normality tests were conducted using the Shapiro Wilk test. A correlation procedure was conducted to determine linear agreement between confidence and practice scores. All data analyses were performed using Statistical Packages for Social Sciences (SPSS) version 21 Armonk, NY: IBM Corporation.

## Results

Responses from a total of 312 HCPs were included in the study. Table I shows the demographic characteristics of the participating healthcare providers. More than two thirds (67.9%) of respondents were in the youngest age group (24-34 years), more than half (55.1%) were female, and a majority were physicians (66.7%). The most common participating job positions were resident physician (27.9%) and consultant physician (22.1%). Of the 87 residents, more than one-third (34.5%) were first year level (R1), followed by third year (R3) (24.1%) and fourth year (R4) (19.5%). Figure 1 shows the department specialties of the participated HCPs. The most frequently participated specialty was ear, nose, and throat (ENT) (13.5%), followed by both nursing and family medicine (9.9% each). Physical therapy, oral and maxillofacial surgery, neurosurgery, and intensive care were the least participated specialties (0.3% each).

Figure 2 shows the COVID-19 related risk factors among the participants. Responses show that the most common COVID-19- related risk factor among the HCPs was

**Tab. I.** Socio demographic characteristics of the participated healthcare providers (n = 312) during the early stages of COVID-19 pandemic in 2020, Saudi Arabia.

| Study data | N (%) |
|---|---|
| **Age group** | |
| 24-34 years | 212 (67.9%) |
| 35-44 years | 60 (19.2%) |
| 45-54 years | 26 (08.3%) |
| 55-64 years | 11 (03.5%) |
| ≥ 65 years | 03 (01.0%) |
| **Gender** | |
| Male | 140 (44.9%) |
| Female | 172 (55.1%) |
| **Practitioner type** | |
| Physician | 208 (66.7%) |
| Non-physician | 104 (33.3%) |
| **Job description** | |
| Resident Physician | 87 (27.9%) |
| Consultant Physician | 69 (22.1%) |
| Specialist/Fellow Physician | 44 (14.1%) |
| Nurse | 31 (09.9%) |
| Radiology technician | 24 (07.7%) |
| Laboratory technician/specialist | 20 (06.4%) |
| Respiratory therapist | 14 (04.5%) |
| Emergency medical technician | 10 (03.2%) |
| General practitioner | 02 (0.60%) |
| Other | 11 (03.5%) |
| **Resident level (n = 87)** | |
| R1 | 30 (34.5%) |
| R2 | 15 (17.2%) |
| R3 | 21 (24.1%) |
| R4 | 17 (19.5%) |
| R5 | 04 (04.6%) |

**Fig. 1.** Participated department specialties.

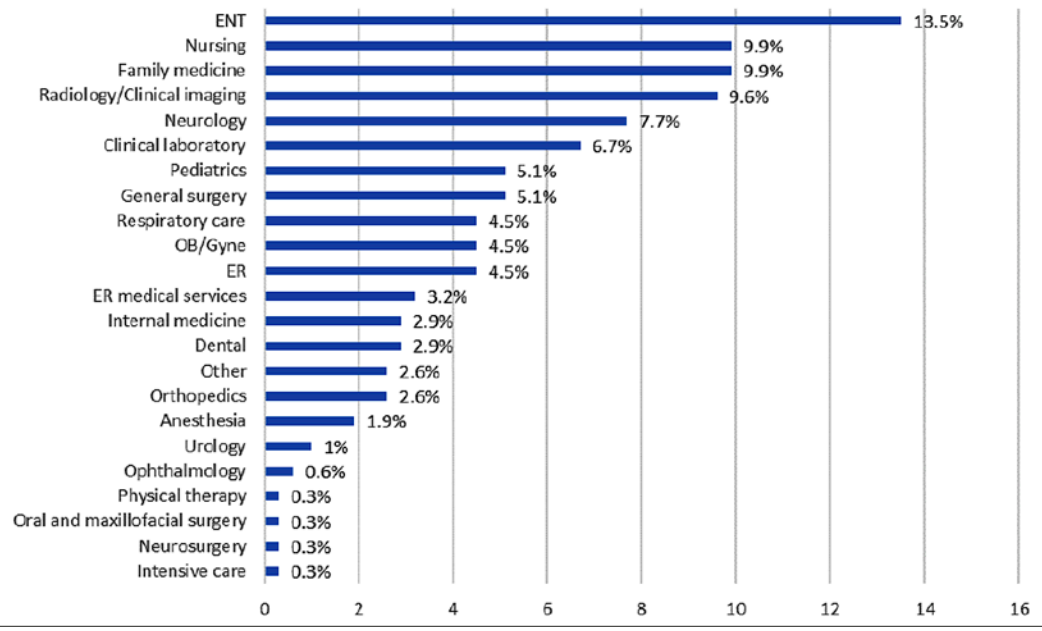


Fig. 2. Diseases associated with higher risk of COVID-19 among the study participants.

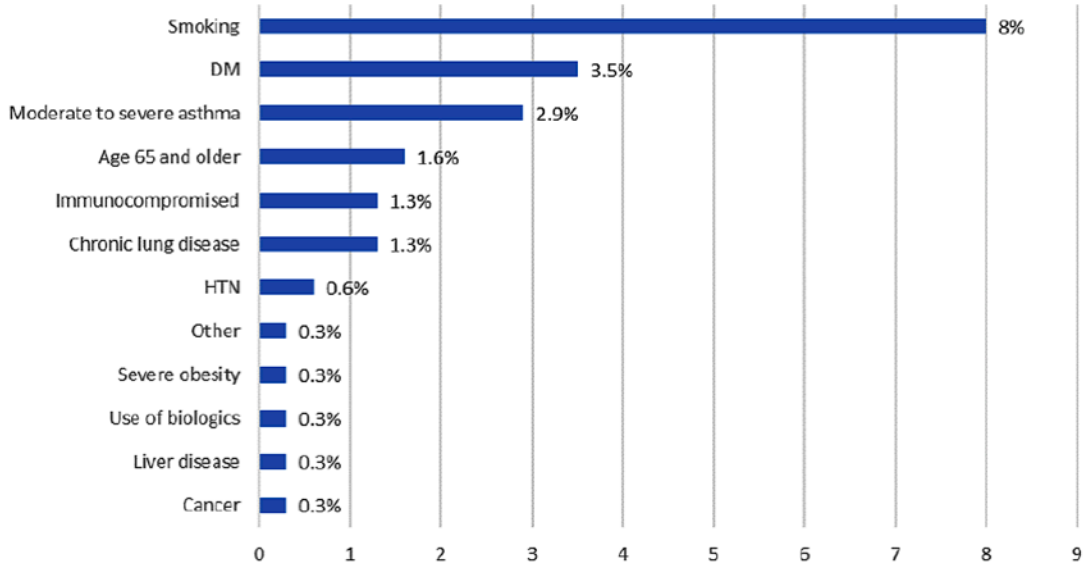



Fig. 3. Generating procedures performed on suspected COVID-19 patients by the participants.

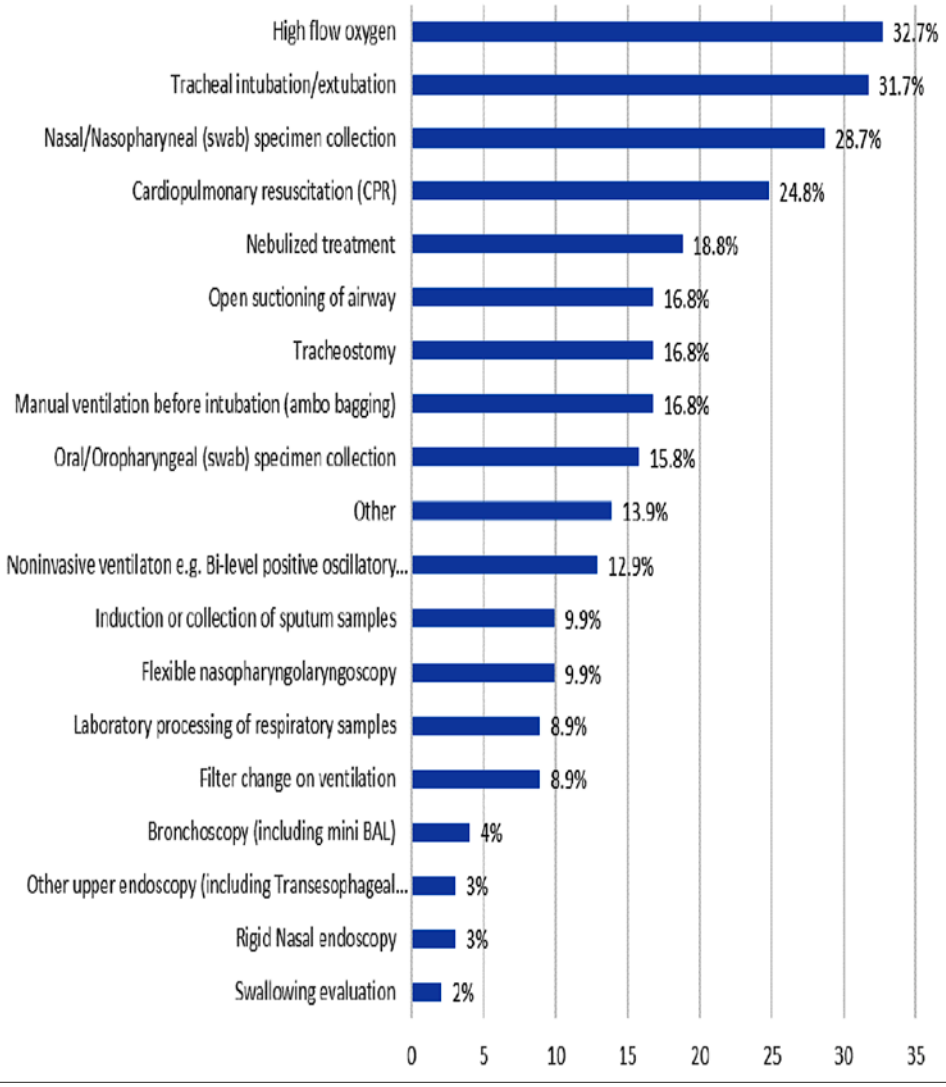


Fig. 4. Reported sources of information regarding COVID-19 safety practices.

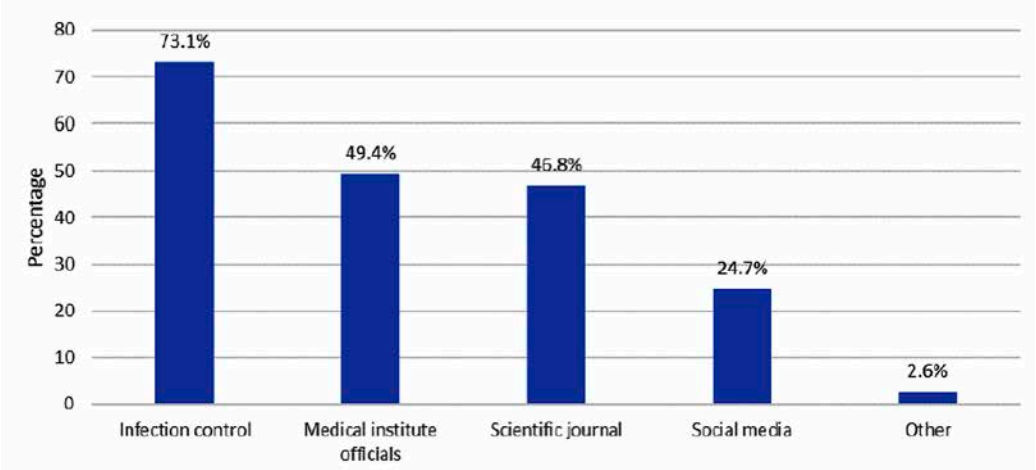
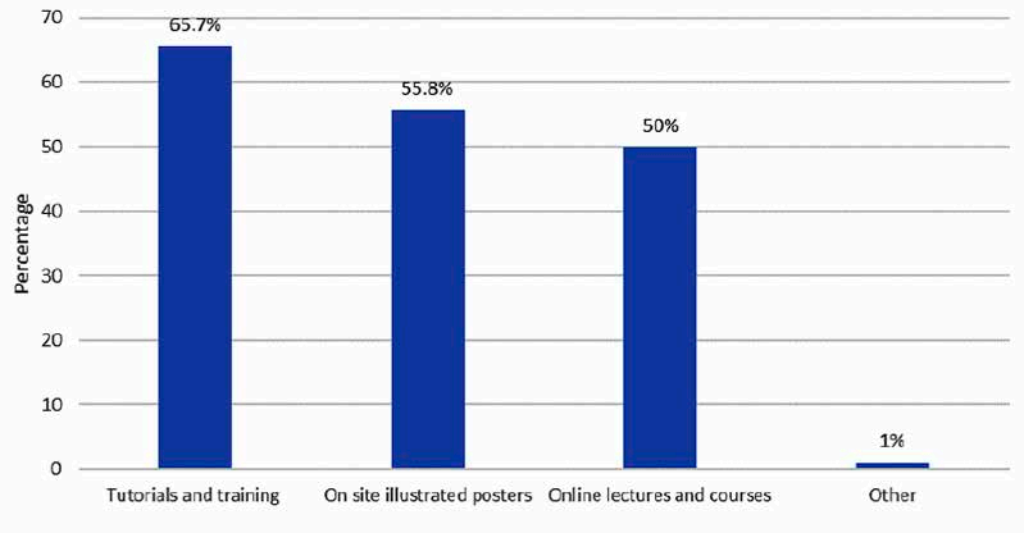



Fig. 5. Necessary sources of knowledge and skills needed to improve performance on appropriate infection control practices reported by the participants.




smoking (8%), followed by Diabetes Mellitus (DM) (3.5%) and bronchial asthma (2.9%) (Fig. 2). Figure 3 shows the aerosol generating procedures performed and/or attended by the participants on a suspected COVID-19 patients. The most frequently reported procedures performed on suspected COVID-19 patients were high flow oxygen (32.7%), followed by tracheal intubation/extubation (31.7%) and nasal/nasopharyngeal (swab) specimen collection (28.7%). Swallowing evaluation was the least reported procedure (2%) (Fig. 3).

Figure 4 describes the sources of information regarding COVID-19 safety practices reported by the participants. The most reported sources of information regarding COVID-19 safety practices were infection prevention and control information leaflets (73.1%), followed by medical institute officials (49.4%) and scientific journals (46.8%). Figure 5 shows the participants favorable sources of knowledge and skills needed to improve performance on appropriate infection control practices. The need for tutorials and training were major concerns reported by the HCPs (65.7%) in regard to how their performance on appropriate infection control practices could be improved, on-site illustrated posters was reported second (55.8%) and online lectures and courses were reported third (50%).

Table II describes the assessment of the participating HCPs' general knowledge of COVID-19 and the recommended PPE. The results indicate that the HCPs had good knowledge of the following statements: "knowledge about the sequence of donning (putting on) and doffing (taking off) of PPE" (74% yes), "had been tested for an N95 mask/respirator in the past 2 years" (70.2% yes), and "received formal training regarding the use of recommended PPE for airborne transmitted

infection at the current institution" (66.3% yes). On the other hand, HCPs indicated poor knowledge with regard to the statement "knowledge about the indications of re-fit testing prior to 2 years" (36.2% yes).

Each participant's answers to the sequence of PPE donning and doffing were reviewed and scored as correct or incorrect based on the CDC guidelines. Table III describes the assessment of participant's practices toward the recommended PPE during the early stages of the pandemic. HCPs responses indicated poor practices regarding the correct sequence of donning of PPE (13.8%) and the correct sequence of doffing of PPE (3.5%). Table IV shows the assessment of the level of confidence of HCPs in using the recommended PPE during the COVID-19 pandemic. Based on our investigations, HCPs showed high confidence in both statements, "confident wearing the right level of equipment to keep safe" and "confident in practicing the right PPE donning and doffing techniques" (94.6% each).

Table V presents descriptive statistics on confidence in and practice of using recommended PPE during the COVID-19 pandemic. According to the results, the total mean confidence score was 1.89 (SD 0.42) out of 2 points, and, based on the given criteria, 92.9% were classified as having high confidence, 3.2% as having moderate confidence, and 3.8% as having low confidence levels. With regard to practice, the total mean score was 0.017 (SD 0.39) out of 2 points, with 83.3% having a low practice level, while the remaining HCPs had moderate (16%) or high (0.6%) practice levels.

Figure 6 depicts the correlation (Pearson-r) between confidence and practice level scores. Based on these results, there was no significant correlation observed

**Tab. II.** Participant's General knowledge about COVID-19 and the recommended PPE (n = 312).

| Statement | Yes (%) |
|---|---|
| Have you ever provided care to a suspected or confirmed COVID-19 patient? | 181 (58.0%) |
| Were you present when any aerosol generating procedures (AGP) was performed on a suspected or confirmed COVID-19 patient? | 101 (32.4%) |
| Have you received formal training in the use of recommended PPE for airborne transmitted infections at your institute? | 207 (66.3%) |
| Have you been fit tested for an n95 mask/respirator in the past 2 years? | 219 (70.2%) |
| Do you know the indications for re-fit testing prior to 2 years? | 113 (36.2%) |
| Do you know the sequence of donning (putting on) and doffing (taking off) PPE? | 231 (74.0%) |

**Tab. III.** Assessment of practices toward the recommended PPE during the early stage of COVID-19 pandemic (n = 312).

| Statement | Correct answer N (%) |
|---|---|
| Correct sequence of donning (putting on) of PPE | 43 (13.8%) |
| Correct sequence of doffing (taking off) of PPE | 11 (03.5%) |

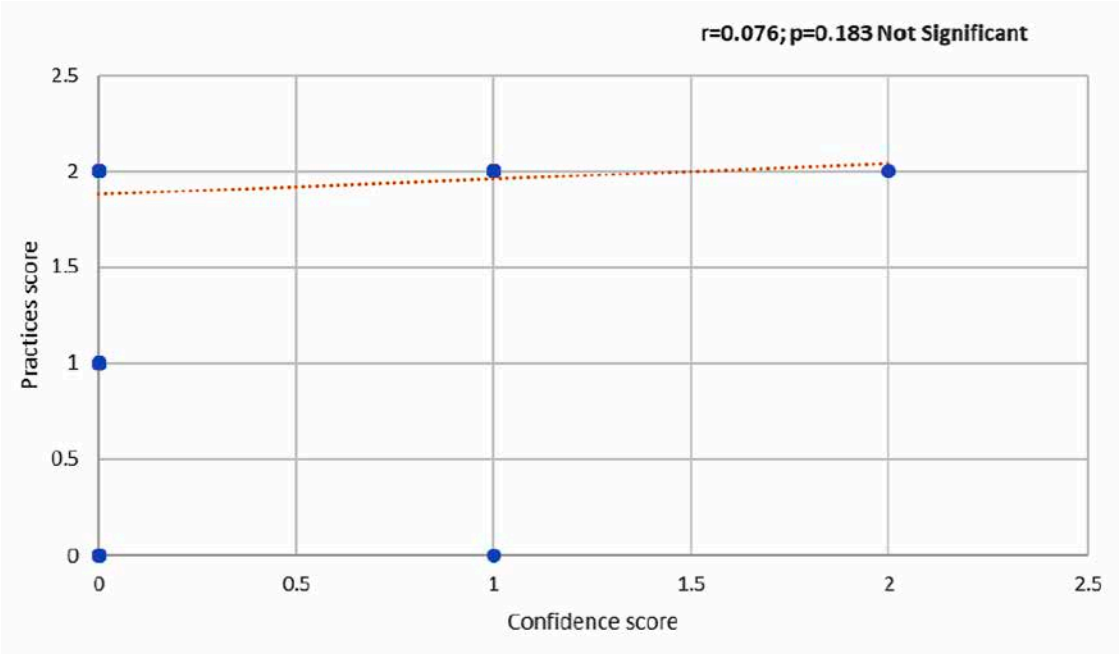
**Tab. IV.** Assessment of confidence in using the recommended PPE during the early stage of COVID-19 pandemic (n = 312).

| Statement | Correct answer N (%) |
|---|---|
| Confident wearing the right level of equipment to keep you safe | 295 (94.6%) |
| Confident practicing the right PPE donning and doffing techniques | 295 (94.6%) |

**Tab. V.** Descriptive statistics of the practice of and confidence in using the recommended PPE during the early stage of COVID-19 pandemic (n = 312).

| Variables | N (%) |
|---|---|
| **Confidence score (mean ± SD)** | 1.89 ± 0.42 |
| **Level of confidence** | |
| Low | 12 (03.8%) |
| Moderate | 10 (03.2%) |
| High | 290 (92.9%) |
| Practice score (mean ± SD) | 0.17 ± 0.39 |
| **Level of practice** | |
| Low | 260 (83.3%) |
| Moderate | 50 (16.0%) |
| High | 02 (0.60%) |

Fig. 6. Correlation (Pearson-r) between confidence and practices score among the participating healthcare providers.




Tab. VI. Statistical association between confidence and practice scores in relation to the sociodemographic characteristics of the participated healthcare providers (n = 312).

| Factor | Confidence score | | Practices score | |
|---|---|---|---|---|
| | Mean ± SD Total (2) | T/F-test; p-value | Mean ± SD Total (2) | T/F-test; p-value |
| **Age group 1** | | | | |
| < 35 years | 1.92 ± 0.33 | T = 1.778; 0.306 | 0.20 ± 0.43 | T = 1.943; 0.062 |
| ≥ 35 years | 1.83 ± 0.55 | | 0.11 ± 0.31 | |
| **Gender [1]** | | | | |
| Male | 1.96 ± 0.22 | T = 2.825; **0.008 [3]** | 0.16 ± 0.40 | T = -0.641; 0.340 |
| Female | 1.83 ± 0.52 | | 0.19 ± 0.39 | |
| **Healthcare provider [1]** | | | | |
| Physician | 1.86 ± 0.47 | T = -2.120; **0.014 [3]** | 0.17 ± 0.40 | T = 0.000; 0.859 |
| Non-physician | 1.96 ± 0.28 | | 0.17 ± 0.38 | |
| **Job description [2]** | | | | |
| Resident | 1.92 ± 0.31 | F = 5.379; **0.003 [3]** | 0.11 ± 0.32 | F = 4.774; **0.008 [3]** |
| Consultant | 1.84 ± 0.48 | | 0.34 ± 0.57 | |
| Specialist/fellow | 1.74 ± 0.66 | | 0.09 ± 0.28 | |
| Allied medical | 1.98 ± 1.89 | | 0.21 ± 0.41 | |
| **Resident level (n = 87) [2]** | | | | |
| **R1** | 1.80 ± 0.48 | F = 1.842; 0.116 | 0.10 ± 0.31 | F = 0.308; 0.866 |
| **R2** | 2.00 ± 0.00 | | 0.07 ± 0.26 | |
| **R3** | 2.00 ± 0.00 | | 0.14 ± 0.36 | |
| **R4** | 1.94 ± 0.24 | | 0.12 ± 0.33 | |
| **R5** | 2.00 ± 0.00 | | 0.25 ± 0.50 | |

[1] P-value has been calculated using Mann Whitney U test; [2] P-value has been calculated using Kruskal Wallis test; [3] Significant at p < 0.05 level.

between confidence and practice scores (r = 0.076; p = 0.183). Table VI describes the statistical association between confidence and practice scores in relation to the demographic characteristics of the participating healthcare providers. We found that being a male (T = 2.825; p = 0.008), being a non-physician (T = -2.120; p = 0.014) and an being allied medical professional (F = 5.379; p = 0.003) had significantly higher correlation with higher confidence level. On the other hand, being a consultant had significantly lower correlation with better practice scores (F = 4.774; p = 0.008) (Tab. VI).

## Discussion

By the time the WHO declared COVID-19 a worldwide pandemic, healthcare systems have made many strategies to meet the challenges of COVID-19. Healthcare providers play an essential role at the front lines, providing care for patients. In this study, we aimed to evaluate the preparedness of our HCPs to maintain infection prevention and control measures as well as to emphasis the importance of following the recommended PPE usage guidelines. If not properly used, PPE could pose serious risk for self-contamination [14]. The CDC has published guidelines for HCPs to adhere to when they are dealing with confirmed or suspected COVID-19 cases [15]. Before providing care for these cases, HCPs must receive comprehensive training on which type and when PPE is needed, how to put on (donning) and take off (doffing) PPE, the limitations of PPE, and proper disposal of PPE. Face-to-face practice, video lectures, and computer simulation leads to fewer errors in comparison with traditional written protocols [14]. HCPs must demonstrate competency while performing these infection control policies [15, 16]. Donning and doffing the PPE must be practiced. More than one method might be acceptable. Following the health care institution's infection control policies is critical for the safety of oneself and others. The CDC has published a protocol for donning and doffing PPE [15]. Using this protocol has been reported to lead to a lower risk of infection when compared to no guidance [14]. Correct donning sequences are as follows: 1) gather required PPE items needed; 2) perform hand hygiene; 3) put on the isolation gown; 4) put on an N95 or higher fit-tested respirator; 5) put on the face shield or goggles; and 6) put on gloves. By following this protocol, the HCP is now ready to deal with the patient [15, 17]. Correct doffing sequences are as follows: 1) remove gloves; 2) remove gown; 3) exit the room; 4) perform hand hygiene; 5) remove the face shield or goggles; 6) remove and discard the respirator; 7) end with additional hand hygiene [15, 17].

According to the responses on our survey, more than half of the participants provided care to suspected or confirmed COVID-19 patients, and approximately one third were present during an aerosol generating procedure. These numbers indicate the risk of work-related exposure to the virus among these HCPs. To evaluate PPE knowledge, HCPs were asked the order in which they would don (put on) and doff (remove) PPE equipment. In our study, 231 participants (74%) assumed that they knew the correct sequence. A total of 295 participants (94.6%) showed confidence regarding following the right sequence of donning and doffing. However, only 43 participants (13.8%) demonstrated the right sequence of donning, while only 11 participants (3.5%) demonstrated the right sequence of doffing. These results raise concerns about the risk of COVID-19 nosocomial infection among HCPs. To the best of our knowledge, there is currently only one published study, conducted in Canada, where PPE donning and doffing sequences among HCPs during COVID-19 were evaluated. A total of 175 HCPs in Toronto, Canada completed a survey on knowledge and PPE usage. Only 86 participants (50%) put on (donned) the PPE in the correct order and only 60 participants (35%) took off (doffed) PPE in the correct order [18]. Comparing to our results, these percentages were higher, indicating better donning and doffing performance among those participants. This could be explained by the way those HCPs were trained before conducting their study. They had a mandatory COVID-19 PPE training, with a hands-on demonstration of PPE donning and doffing by an occupational health and safety team. In addition, a video of the proper PPE usage sequence and printed instructional materials were given to all HCPs. However, these findings raise concerns about PPE practice, especially the doffing technique.

Based on experiences from past infectious disease outbreaks, self-contamination rates can reach as high as 46-90% among HCPs during doffing [19, 20]. Occupational infection with COVID-19 has been investigated, and studies from China and Italy have shown that 3.8 and 11% of confirmed cases, respectively, were among healthcare providers [21, 22]. Even when HCPs presume that they are correctly trained on PPE usage, many factors might contribute to self-contamination during doffing. These include difficulty differentiating between dirty (outside) and clean (inside) surfaces, poorly fitting PPE, forceful movements, incorrect doffing sequences, and inconsistent PPE training [23]. In a study that focused on contamination of health care personnel during removal of PPE, 435 participants were observed during doffing of PPE. Skin and clothes contamination occurred in 200 participants (46%), which occurred most frequently during removal of gloves (52.9%) and gowns (37.8%) [24].

Adhering to infection and prevention control (IPC) guidelines, including the use of PPE, was studied by Houghton et al. [7]. They found that healthcare providers are more likely to adhere to the IPC guidelines when clearly communicated. PPE-trusted quality and usage training are critical in achieving HCP adherence [7]. In one Canadian study, adherence to the PPE protocol was found to be only 56% among physicians. To address these lapses in donning and doffing, a model was adopted in which two physicians were assigned to work together for patient care. One physician performed patient assessment, while the other acted as a spotter for donning and doffing [25].

Tong et al. assessed the risk of nosocomial infection of SARS-CoV-2 among frontline healthcare providers in a cohort study that was conducted on 222 frontline medical staff serving in Wuhan during the COVID-19 outbreak. None of the staff were infected. This could be explained by the extensive training and safety reviews provided to the staff. The authors suggest that preventing occupational infection is an achievable goal [26].

The National Institute of Safety and Health (NIOSH) in the United States demands an annual respirator fit test to ensure tight fitting and proper safety for the HCP before it

is used in the workplace [27]. NIOSH research confirms that there is a 10% chance of fit test failure after one year using the same respirator. A fit test must be repeated even before one year is past if there have been any physical changes that may affect the tight fitting of the respirator (e.g. significant weight loss of more than 20 Ibs, major dental work, facial scarring or cosmetic surgery) [27]. In our study, HCPs showed poor knowledge for the need of retest, as only 36.2% knew about it.

Based on our analysis, there were no significant correlations between the confidence and practice scores ($r = 0.076$; $p = 0.183$), despite inconsistent high confidence and poor practice. These results can help us to understand PPE practice issues among our HCPs and how to best direct attention to improve their practice. We found that 210 (67.30%) participants preferred tutorials and training monitored by infection control instructors, and 179 (56.41%) preferred onsite illustrated posters (patient room, ER, OR, etc.).

The demand for PPE is increasing worldwide, and it has become greater during the current pandemic. In a cross-sectional study by Suleiman et al., which included 308 physicians from different specialties, only 57 frontline doctors (18.5%) reported that all of the types of PPE were available to them. This lack of equipment increases risk of infection [28]. In our study sample, only 130 respondents (41.6%) reported that all of the PPE types were available. Powered Air-Purifying Respirators (PAPRs) were not always available according to 101 (32.3%) of respondents, and N95, FFP2, or FFP3 respirators were not always available according to 97 (31.0%) of the respondents. The CDC has published a PPE burn rate calculator in the form of a spread-sheet-based model. Each day, the number of confirmed and suspected COVID-19 cases can be added, along with the number of full boxes of PPE items in stock. This tool estimates PPE consumption (burn rate) [29], and can help health care institutions adjust for their future need of supplies.

Our study has several limitations. First, participants were enrolled using convenience and snowball sampling methods, which could have limited the external validity. Second, we were only able to nominally investigate HCP knowledge about PPE, using self-reported surveys within a limited time period. However, this investigation gives us a glance into current COVID-19 related PPE knowledge and practice among our HCPs. Our results reflect findings of previous studies on donning and doffing PPE practices, but, due to lack of standardized methodologies, comparison is limited. Piché-Renaud P-P, et al. investigated the use of personal protective equipment (PPE) among HCPs. Their cross-sectional survey also found deficiencies in reporting PPE doffing sequence. Therefore, they created an online module to reinforce and improve infection control and prevention measures learning and practices, with special focus on donning and doffing sequences [18]. In another study, a self-reported survey was used to assess knowledge, attitude, and practice of HCP toward Middle East Respiratory Syndrome (MERS) infection. They concluded that HCP showed good knowledge and positive attitude but low to average practice toward MERS [30]. Further investigations and researchs will be required to fill the knowledge gaps and to overcome the practice challenges. Our team suggests a multi-center study that recruits an appropriately sized sample with participants who work on the frontlines, as well as other HCPs. In addition, it will be important to modify and standardize the survey to more thoroughly investigate knowledge and practice.

## Conclusions

Our study results demonstrate deficiencies among the participating healthcare providers in following the recommended practices for correctly using PPE during the early stages of the COVID-19 pandemic. Poor practice in PPE donning and doffing necessitates additional educational and training programs focused on infection control practices. Additionally, there must be further assessment of HCPs practices to achieve the improvement required to decrease the risk of infection transmission.

## Institutional review board statement

The study was conducted according to the guidelines of the Declaration of Helsinki, and was approved by the Institutional Review Board (IRB) of Imam Abdulrahman Bin Faisal University (IRB - 2020 - 01 - 183).

## Data availability

The dataset used in this research are available upon request from the corresponding author. The data are not publicly available due to restrictions i.e., privacy or ethical.

## Supplementary materials

Questionnaire template for knowledge and practice of recommended (PPE) during COVID-19 pandemic.

## Acknowledgements

Funding sources: this research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

The authors acknowledge Editage for English language editing.

## Conflict of interest statement

The authors declare no conflict of interest.

## Authors' contributions

Conceptualization, MA; Methodology, SA and AA; Project administration, NA; Resources, ZA, AA and AA; Supervision, MA; Writing - original draft, SA and FA; Writing - review & editing, MA, SA and FA. All authors have read and agreed to the published version of the manuscript.

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Received on May 25, 2021. Accepted on September 21, 2021.

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**How to cite this article:** Ashoor M, Alshammari S, Alzahrani F, Almulhem N, AlMubarak Z, Alhayek A, Alrahim A, Alardhi A. Knowledge and practice of Protective Personal Equipment (PPE) among healthcare providers in Saudi Arabia during the early stages of COVID-19 pandemic in 2020. J Prev Med Hyg 2021;62:E830-E840. https://doi.org/10.15167/2421-4248/jpmh2021.62.4.2177