Clothing Comfort of Medical Personal Protective Equipment during COVID-19

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Abstract

Personal protective equipment (PPE) for healthcare workers is crucial, especially when dealing with infectious disease like the panademic COVID-19. PPE levels, design characteristics and materials should be considered. Purpose of this study is to highlight difficulties facing frontline healthcare PPE usage in the Arab region during this pandemic. In this paper, methodology included online interview and questionnaire to understand the needs of healthcare workers regarding PPE. Resultant data directed this paper to review many aspects from different fields that helps having proper medical PPE configuration. In conclusion, the physiology of medical staff's PPE has been considered being the most important comfort aspect, since ~70% of the participants in the current survey encountered heat stress while doing their job, within a room temperature range of 20-30℃.

Keywords:

Personal protective equipment (PPE), COVID-19, Infection control, second contamination, medical clothing, material engineering, designing protective wear

1. Introduction

Personal protective equipment (PPE) has been developed through the years to provide fortification to many sectors, while doing high-risk jobs. Regarding the medical sector, the clothes should be designed to prevent contamination with pathogens (e.g. body fluids, viruses and bacteria) to the health care workers (HCWs). According to an article published in June 2020, in the international council of nurses website, more than 230000 HCWs have contracted COVID-19 (Howard Catton, 2020). Not only wearing a complete PPE is sufficient, but also the order and way of wearing and taking them off are very crucial to prevent a second contamination (Lisa Casanova, et al. 2008; Amrita John, et al. 2017). PPE is categorized from level A till level D, a combination with different types of chemical resistant clothing and respiratory protection (Alex W H Chin, et al. 2020).

The recent hit of severe acute respiratory syndrome coronavirus (SARS-CoV-2) has put the HCWs into risk of getting infected with this virus. Understanding the transmission of the virus gives information that can be used when designing the medical PPE. Respiratory transmission is believed to be the most common scenario, which occurs when the infected

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patient produces droplets, via sneezing, coughing, etc., in which these droplets bearing the virus travel and contact another person (Michael Holland, et al, 2020).

The stability of SARS- CoV-2 on different surfaces has been investigated, by many researchers since the pandemic started. The virus was found stable on the surface of cloth and the outer layer of surgical mask for 2 and 7 days, respectively (Alex W H Chin, et al. 2020). While Sean Ong, et al. (2020) found that there are no traces of virus on the PPE of hospital staff (including gowns, visor mask, and N95 masks) except for the front of shoes. Although the transmission of SARS-CoV-2 to humans through inanimate surfaces has not been known yet, the world health organization (WHO, 2020) recommended to keep the environment clean and disinfected (Günter Kampf, 2020).

Even though several studies reviewed PPE, in the current paper the pandemic COVID-19 was in focus within the Arab world medical staff. Designing aspects were considered as well as new textile materials. PPE definition, factors influencing selection and levels of protection were literate.

2. Literature Review:

2.1.*Personal Protective Equipment PPE*

2.1.1. *PPE Definition:*

Personal protective equipment, referred to as "PPE", is an equipment worn to minimize exposure to hazards that cause serious injuries or illnesses. These injuries and illnesses may result from contact with infectious, chemical, radiological, physical, mechanical, electrical, or other workplace hazards (OSHA, 2020). Precisely, PPE was defined by the Occupational Safety and Health Administration (OSHA) as “specialized clothing or equipment, worn by an employee for protection against infectious materials” (CDC, 2020).

PPE Kit includes gloves (protect hands), safety glasses-goggles (protect eyes), masks (protect mouth/nose), respirators (protect respiratory tract from airborne infectious agents), earplugs or muffs, face shields (protect face, mouth, nose, and eyes), hard hats, shoe covers, coveralls, vests, aprons, gowns and full body suits (protect skin, clothing) (WHO, 2020). Recently, as for Coronavirus pandemic 2019 (COVID-19), was first detected in Wuhan, China, in December 2019. The PPE kits are given to the frontline workers managing the COVID-19 (Iti Dubey, 2019).

PPE aims to create a barrier between healthcare workers and an infectious material from the patient, reduce the risk of transmitting micro-organisms from healthcare workers to patient(s), also to protect patient’s family/visitors. (Binit Sureka, et al. 2019 & The Northern Ireland Regional Infection Prevention and Control Manual, 2020)

2.1.2. *Factors Influencing PPE Selection:*

It begins with an analysis of the hazards that responders may encounter as biological agents protection (viruses like COVID-19), duration of protection, type of agent, HCW’ needs such as: environmental conditions (indoor & outdoor weather and climates such as rain, snow, extreme temperatures, and humidity), weight/Comfort (for respiratory and cutaneous protection, easiness of use (dexterity/mobility including PPE donning and doffing), availability of various PPE sizes, visibility easiness, cleaning (Launderability), PPE usage training and the unit cost of the PPE kits (Ashcroft J., et al. 2020).

2.1.3. *PPE Levels of Protection:*

There are four basic levels of PPE (figure 1); Level A: the highest level of respiratory, eye, skin and mucous membrane protection. Level B: high level of protection used for unknown environment entry, skin & eye protection is needed. Level C: used for known airborne substance with measured concentration, that needs air-purifying respirators, air periodic monitoring must be performed. Level D: used for nuisance contamination only. It requires only safety shoes/boots and coveralls (John L Hick, et al., 2003).

Fig. 1: The PPE suit classification by CHEMM (Chemical Hazards Emergency Medical Management)

2.2.*Designing Medical PPE*

The medical PPE should act as a barrier between the outside pathogens and the skin. In that sense, the desired properties of the fabric that is in contact with human skin differs from those that in direct contact with air, as schematically illustrated in figure2.

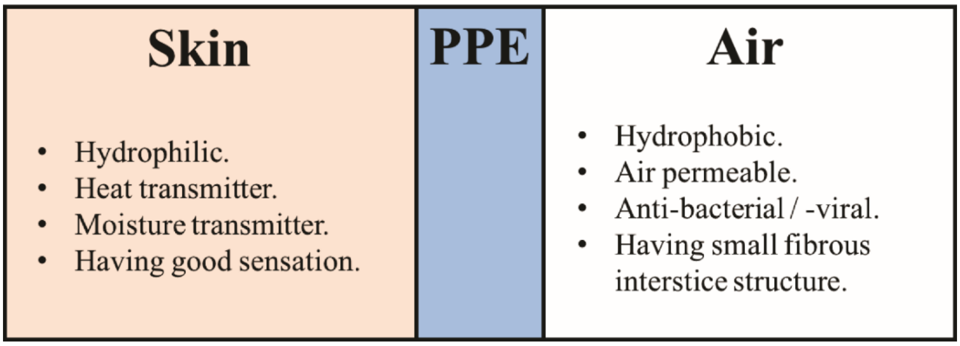

Fig. 2: Schematic model shows the PPE properties that should be beard according to the interface

One can simply speculate that the outer surface needs to be: hydrophobic (to prevent the body fluids to penetrate the PPE), anti-bacterial/viral, having small fibrous interstice structure (to prevent the penetration of pathogens, including the viruses and bacteria), and air permeable. On the other hand, the inner surface, which is basically related to the comfort of the wearer, needs to be: hydrophilic (to adsorb the sweat), heat and moisture transporter (generated by the body), and having good sensation.

Therefore, the barrier effectiveness and comfort are the main factors of designing a proper medical PPE. One can speculate that the barrier effectiveness would be more important than being comfort. However, it should be noted that comfort would be compromised for the sake of functionality, as the discomfort does not only affect the performance of the HCWs, but also it can be a life threatening (Bianca-Michaela Woelfling, et al., 2019). In the following section, barrier effectiveness and comfort are discussed.

2.2.1. *Medical-wear PPE Barrier efficiency*

There are many factors that can influence the barrier efficiency of the medical PPE. These factors are discussed as follows:

2.2.1.1. Fabric structure

Nonwoven fabrics, such as spunlace, spunbond, and melt-blown, have a fibrous network which works as a filtration media. Therefore, they are used for producing medical PPE, along with other advantages such as, low cost and disposability. Masks for instance are usually made of a melt-blown layer sandwiched between two spunbond layers; called SMS fabric. Those fabrics usually consist of microfibers, in which their interstice structure plays a crucial role in filtration of undesired particles, and they are referred to as 'pore size'. The larger the pore size is, the lower barrier efficiency the medical PPE bears.

Therefore, the nonwoven fabrics can be illuminated to provide them with new properties. However, illuminating the nonwoven fabrics can reduce the air permeability (Eryuruk, S H, et al., 2017).

Qin X & Wang S (2006) could increase the filtration efficiency of polypropylene spunbond and melt-blown fabrics by depositing electrospun poly (vinyl alcohol) nanofibers onto them. It has been found that the filtration efficiency increased from 6% to 95%, and from 30% to 100% for the spunbond and melt-blown fabrics; respectively.

2.2.1.2. Assembling techniques

The assembling method, in which the fabric layers are joined together can affect the barrier efficiency. There are several assembling techniques that can be used depending mainly on the type of the fibers; such as: conventional sewing (using needles and threads), bonding (for non-thermoplastic fabrics)., and welding (for thermoplastic fabrics) (Prabir Jana, 2011).

Eryuruk, S H, et al. 2017 have found that using the conventional sewing to join spunbond and SMS fabrics to facilitate the water to penetrate through the sewing holes, resulting in low water permeability resistance. On the other hand, joining the nonwoven fabric layers by ultrasonic welding provides higher water permeability resistance; especially for SMS fabrics compared to spunbond fabrics. However, ultrasonic welding technique is only applicable when the content of synthetic fibers is above 65%.

2.2.1.3. Air permeability

Air permeability of the fabric is important for the thermal comfort. Vinay et al. 2012 investigated the effect of the nonwoven fabric type on the air permeability and stiffness. It has been found that polypropylene spunlace fabric has the highest air permeability and lowest stiffness, while the SMS fabric has opposite results, and spunbond fabric has moderate results. Moreover, it has been found that increasing the fabric weight results in decreasing the air permeability and increasing the stiffness.

2.2.1.4. Fabrication of hydrophobic surfaces

There are great efforts have been put into fabricating hydrophobic surfaces. The lotus-effect approach has inspired many researchers to mimic the surface structure of the lotus leave, where hierarchical microstructures trap the air, and allow the water droplets to roll off their surfaces. Obtaining a superhydrophobic surface can be done through fabricating a hierarchical nano/micro-structure along with low surface free energy. There are many reported techniques to fabricate hydrophobic and superhydrophobic surfaces; such as sol-gel methods, phase separation, plasma treatments, etching, layer by layer, etc. (Elena Celia et al., 2013).

A well-known technique to fabricate a superhydrophobic fabric surfaces is coating the surface with organosilane precursors (Junping Zhang, 2013; Hoefnagels H. F., et al., 2007; Lei Wu, et al., 2013; Chao-Hua Xue, et al., 2013; Guangming Pan, et al., 2018). To improve the surface affinity to the organosilane precursors, the surface is usually pretreated with plasma or chemical etching (Chao-Hua Xue, 2013), depending on the substrate type.

2.2.1.5. Fabrication of anti-bacterial surfaces

Many research works have been focused on fabrication of antibacterial cotton surface. Metal nanoparticles such as silver, and metal oxide nanoparticles, such as titanium dioxide and zinc oxide have been proved to enrich the cotton fabrics with antibacterial activity and self-cleaning (Ngo Vo Ke Thanh & Nguyen Thi Phuong Phong, 2009).

2.2.2. *Medical-wear PPE Comfort Compliance*

COVID-19 disease can result in infection and death of health workers. For severely injured and unstable victims of disasters, such as COVID-19 pandemic, emergency physicians and nurses might have to perform life-saving procedures, wearing level-C PPE, in warm zones for incompletely decontaminated victims (Baker DJ. 1996; Laurent JF et al. 1999; Kim et al. 2016). In hospitals, at the beginning of the pandemic, air-conditioning or even fans were prohibited, assuming they might be sources for COVID-19 transmitions. Comfort is usually divided into:- Thermal, sensorial, fit, size and mobility, in terms of the various clothing items. The major factors seem to face PPE comfort compliance are; first: easiness to put-on and take-off the PPE, bearing in mind wearer avoiding contamination, second: minimising overheating either physicians or nurses, and third: size fitting gowns; for big built to small sized personal. Each aspect of these can be emphasized as follows: First aspect regarding PPE comfort compliance: easiness to put-on (Don) and take-off (Doff) the PPE, known as Donning and Doffing of full PPE for healthcare providers. There are some different ways given to physicians and nurses to put on and take off their COVID-19 PPE; it can be summarized as follows: to put on PPE size should be ensured to be the correct one, then healthcare provider should sterilize hands, putting on isolation gown taking into consideration that all straps should be fastened, this may need assistance by another healthcare provider (CDC, 2020). Gloves, respirator, facemask, googles or face-shield should be worn. Taking off COVID-19 PPE, it follows some crucial points; after removal of gloves, healthcare provider should remove his/her own gown by untying or even breaking the straps carefully, from shoulders gown should be pulled out away from the body, raping and dispose PPE gown.

Clothing mobility is one of the most important factors that affect clothing comfort. Recently, improvements have been made to textile materials, patterns, sewing, etc., and products pursuing mobility, one of them is protective clothing on the market (Kanakaraj P. and Ramachandran R., 2015; Nayak et al., 2014; Sau-Fun et al., 2011); mobility known as dexterity in the medical field can encompass size fitting for gowns and easiness of use for PPE. Shape of sleeve can lead to ease of movement, which is essential for medical staff, in 2015 Tran, Thi Anh Dao, et al. established a comparison for the ergonomics between two common sleeve structures (classic and raglan sleeves); these sleeve structures were chosen to be tested because they are the most common in professional gown. Raglan gave a comfortable feeling, while classic sleeves showed slightly uncomfortable sensation.

PPE comfort compliance is a major factor affecting physicians and nurses treating COVID-19 patients. A good PPE should accommodate from clothing comfort perspective, easiness to don and doff of the PPE, minimizing overheating while worn and finally a better fit of size. Sustainability is currently seen as a must in all fields; especially in apparel as being the second most polluting industry. Also McKee M. (2020) mentioned that FFP3 respirator (a disposable shaped mask with a valve that filters air), is the most effective face mask; it is always wise to reserve disposable frontline workers who come in contact with COVID-19 patients.

2.2.3. *Trends in potential materials for medical PPE*

2.2.3.1. Phase changing materials

Phase changing materials (PCMs) have been studied for firefighting protective clothing (Rene Rossi 2014). As it can react to the change in temperature, it can provide thermal regulation to the wearer. Microencapsulated Phase Change Materials (MPCMs) can be integrated into fibers, or coated onto fabric (Shu-Hwa Lin, 2012). MPCMs can absorb the heat and store it when the temperature rises, then release it when the temperature falls. Therefore, MPCMs can be used for thermal balancing by dealing with the heat storage. There are several materials that can be used as MPCMs. The most common material is paraffin waxes, as it has a melting point of 18 – 36 ℃ (Mahmoud, et al. 2016).

2.2.3.2. Refreshing materials

Refreshing materials, such as menthol have been recently studied for integration in healthcare textiles. Menthol is an organic substance that activates TRPM8 receptors in the skin when applied, which provides a cooling sensation, so that it is used in many cooling therapies. Angus M. Hunter, et al. (2018) studied the menthol gel effect on the skin, and have found that menthol gel increased cutaneous blood flow, without affecting the core temperature of the body. Raffaella Mossotti et al. (2015) fabricated a refreshing sensation cotton fabric, by impregnating the fabric with menthol-PCL micro- and nano-capsules.

2.2.3.3. Cooling devices

Air- and liquid circulating garments have been created to provide reduction in heat during working in hot climate (Mahmoud, et al. 2016).

3. Methods:

Three interviews were conducted with physicians of COVID-19 isolation area; working in UAE and Saudi Arabia. A questionnaire, (See the supplementary information) having 17 questions, was designed using Google Forms and sent to HCWs online in 5 countries (Egypt, UAE, Saudi Arabia, Oman, and Qatar). More 4 questions were added later as will be discussed below. It should be noted that some questions will appear to the respondent depending on answers of other ones.

The questionnaire comprised six main sections. The first section consisted of basic questions about the gender, country and whether the respondent have worked in infection-controlled areas that are related to COVID-19. The answer of the latter one will determine if the respondent will continue the questionnaire. The second section is mostly related to the used PPE by the respondents. The third and fourth sections are questions about the mask and gown; respectively. The fifth section concerns the thermal comfort and respondents' worries. Finally, the sixth section is about the PPE training, respondent's commitment, and infection.

4. Results and Discussion:

4.1. *Interview Results and Discussion:*

First Interviewee, regarding HCW medical wear during COVID-19, mentioned that it is a three-part suit and there is of course a full PPE which equivalent to those three. 1st part; head cover including full ears with the N95 mask, over eye goggles or face shield or both. 2nd part: full suite which can include one part that covers feet as well, and both arms of course then to be covered by plastic apron during examining patients (this apron to be discarded in-between patients, the last part is feet and hands covers, overshoes for feet and protective water proof gloves for hands, this is the full uniform. Regular scrub suites are beneath all this. It is not a one size wear; the PPE suites and the gloves and the masks come in different sizes, still the remaining face shields/goggles/ aprons fixed free size. PPE is changed once we are going out of infected rooms to clean areas, no matter how long we stay inside; yet nurses stay longer times near bed sides; so they keep the suite for longer period of time. Nurses and physicians have the same wear, just sizes are different. PPE are disposed into special waste bins. Problems are mainly; overheating is enormous, PPE is not reusable and many hospitals run out of resources, to resupply them as quick as the finish, other places are asking their staff to reuse some of PPE during whole day (like face shield and the suite).

Second Interviewee, two layers are worn when treating a COVID patient, 1st layer is the surgeon's wear which is Pants and T-shirt like suit, 2nd layer is the outer one and is composed of Surgeon's Apron with the N95 plus Faceshield and Gloves. PPE comes in 3 different sizes Medium, Large and X-Large. The PPE is taken off and disposed in special bins immediately. Help is needed from another member of staff to fasten Apron properly form the back. As a recommendation; an overall well ventilated Apron is needed, which is fastened from front and at the same time securing from contamination exchange.

Third Interviewee, three layers outfit is worn during COVID time, 1st inner layer is gown, gloves, head cover and feet cover. 2nd layer, overall from head till end of legs and PAPR (Powered Air Purifying Respirator) which works as ventilator pumping Oxgyen during interaction with a patient. 3rd outer layer, just for surgeons who works with dialysis for patients, surgeon's gown and gloves. Beneath all that regular scrub suites. There are different sizes for PPE. It is changed after each patient, then discarded in special bins; yellow hazard bag. Nurses use faceshield and not PAPR, still N95 for nurses and physicians. Nurses wear overall layer but usually do not use gowns beneath their scrub suites regularly. COVID physicians face a lot of difficulties while wearing all those layers, such as being overheated, sweating and being nervus from being infected. As a recommendation PAPR should be provided for all staff, different PPE sizes should always be available, besides reasonable financial compensation, and educational sessions are needed.

4.2. *Survey Results and Discussion:*

4.2.1. Basic information

The number of the responses were 48. However, only 27 (16 females and 11 males) were valid. The reason for the unconsidered responses were either because of the repeadation, which can be known from the answers of open questions, or that the participant does not work in infection-controlled areas that are related to COVID-19. In the latter case, the participant was not able to continue answering the questionnaire, as mentioned earlier.

It has been found that most of the participants use more than one kind of PPE for protection. Masks, gloves, gowns, face shields, headcovers, overshoes, googles, and aprons are used by the participants as 85.2, 82.2, 77.8, 74.1, 66.7, 55.6, 37, and 29.6%; respectively, as shown in figure 3. A combination of wearing a mask, gloves, a gown, a face shield, and a headcover was found to be used by ~48% of the participants.

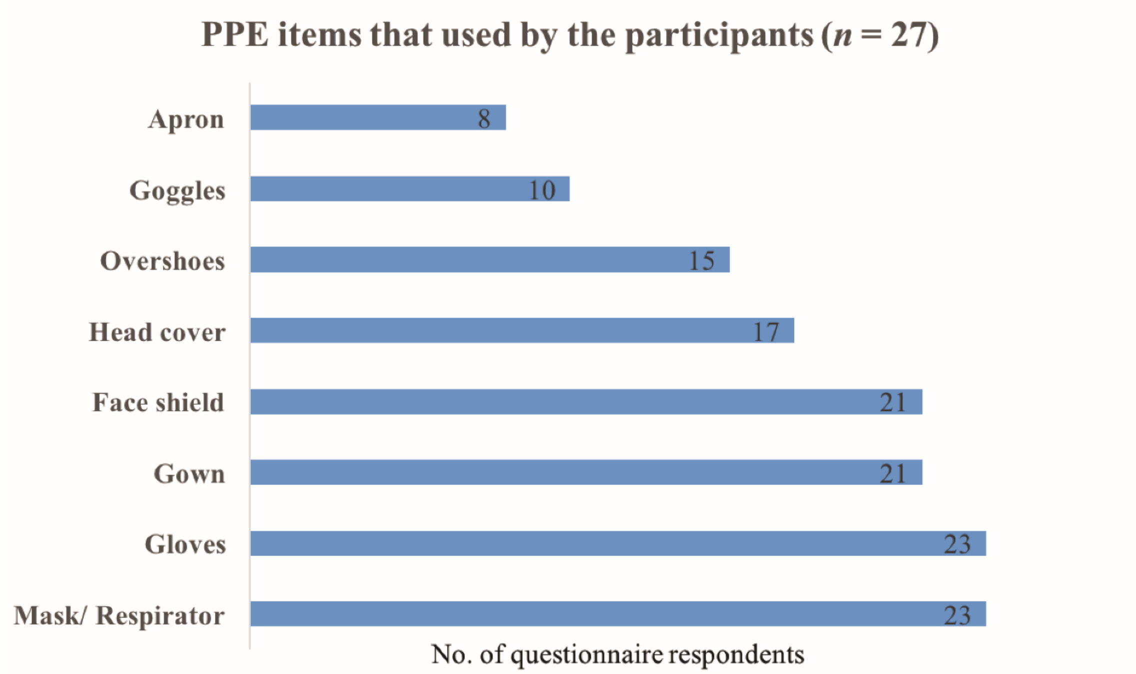

Fig. 3: Bar chart shows the number of the participants using PPE items.

4.2.2. *Discomfort during wearing PPE gear*

About 40% of the participants do not feel comfortable while wearing the mask. Surprisingly, this finding does not significantly relate to the type of mask, whether it is N95 respirator or a surgical mask. The reasons of the discomfort while wearing the mask is shown in figure 4.

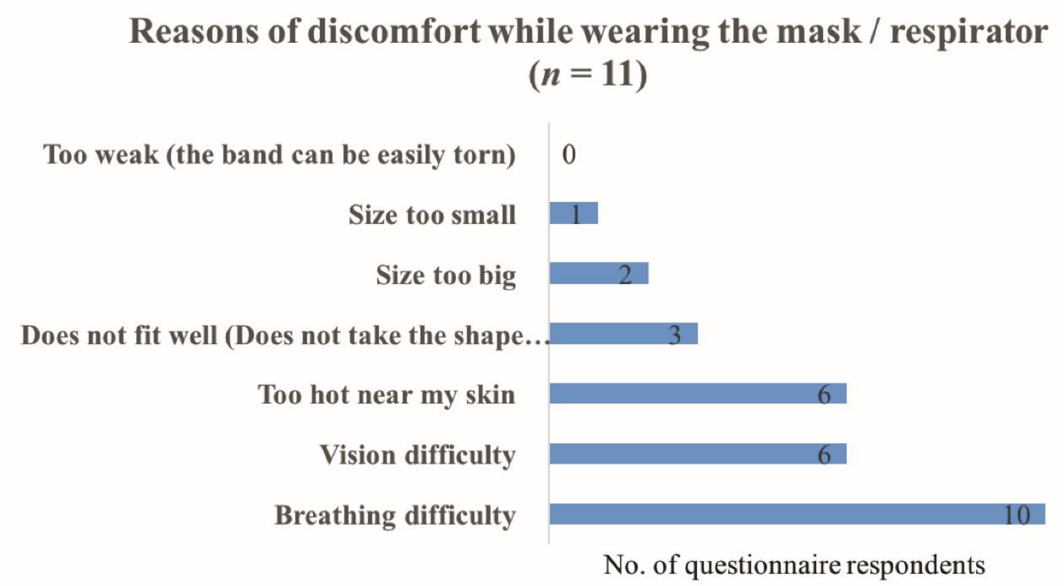

Fig. 4: Bar chart shows the reasons of feeling discomfort while wearing the mask / respirator, according to the participants.

Breathing difficulty, vision difficulty, and feeling hot account for the major discomfort reasons. Regarding the discomfort while wearing the gown, only ~18.5% responded that they do not feel comfortable; mainly because of the difficulty in mobility (see figure 5). Generally, ~70% of the participants feel overheated while wearing their PPE gear.

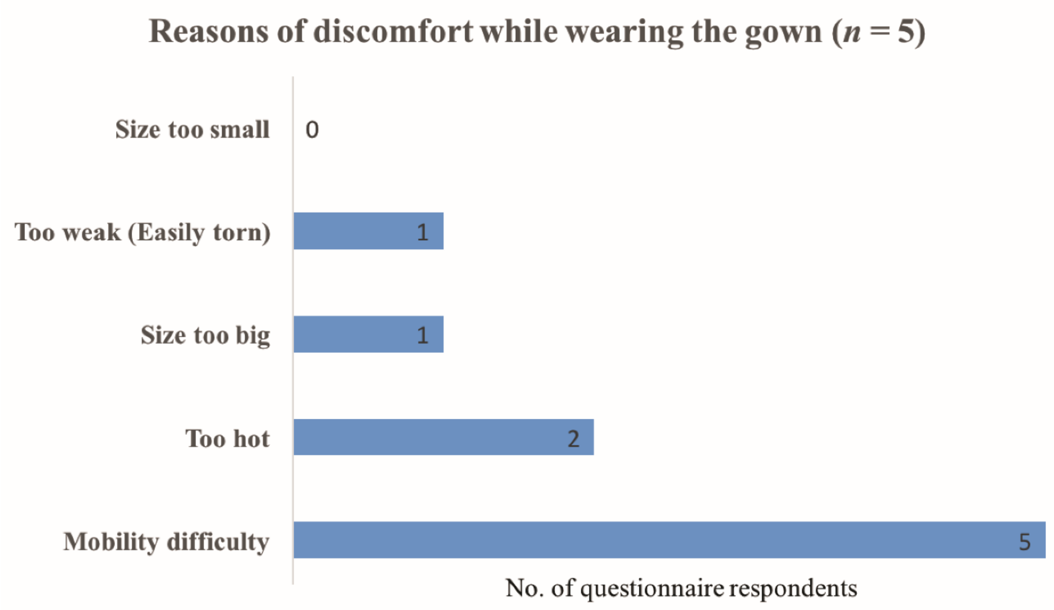

Fig. 5: Bar chart shows the reasons of feeling discomfort while wearing the gown, according to the participants.

4.2.3. *PPE size*

While about half of the participants have been provided with a variety of sizes in their organizations, 50% of the female participants do not find their sizes. An article published by BBC (Zoe Kleinman, 2020) emphasized the concern, indicating that large sector of female HCWs have difficulty in finding their sizes.

4.2.4. *Number of clothing layers*

As the number of the layers wore by the HCWs is a significant value when it comes to comfort, a question about the layers' number was included in the survey. It has been found that, two thirds of the participants wear 3-4 layers, including the inner clothes and the scrub suit. This could be the reason that 70% of the participants encounters heat stress, as the air between layers works as thermal insulator; the more the layers are there, the more thermal insulation the wearer encounters.

4.2.5. *Concerns while wearing PPE*

An open question regarding the participant concerns regarding the PPE. The answers could be summarized into the protection concern, and the thermal comfort. Some of the participants expressed about their anxiety that the PPE they are wearing would not be sufficient enough to prevent the infection. Others were feeling overheated while wearing the PPE gear.

4.2.6. *Training, commitment, and infection*

The number of respondents to the three-added questions were 11. About half of them received a training for using PPE properly. Among the 11-repondents, two participants got infected with the COVID-19, who described that their commitment to wearing the available PPE was less than 50%. Even though the sample was very small to give us a good indication, it is still seen that the commitment to wearing the PPE is very important.

Some aspects should be taken into consideration in the PPE; PPE gown, mask and gloves should be disposed into special dangerous hazards trash (Interviewed Physician).

How to make it easier to Don and Doff a PPE gown, from apparel point of view? If ties are made, to allow personnel to tie from front, as shown in photo, so that medical provider him/herself is capable to put on and take off the entire PPE.

How to Minimise overheated personnel and steaming of glasses? From interview done through this research, overheated physicians during COVID-19 curing is clear. Using better breathable and at the same time degradable nonwovens might be a good resolve. So that it would diminish overheated personnel and at the same time preserve community from non-disposed waste. In most cases, vents are used to minimise this overheating feeling, such as in sportswear; the case is totally different that PPE is not to secure infection free if vents are implemented. Protection requirements often contradict the need for heat dissipation, leading to excessive clothing insulation which creates a negative impact on wearer (McQuerry, M. L. 2016).

From survey done through this research, 70% of the healthcare providers think being overheated during COVID-19, is one the major obstacles they face. Steaming of glasses usually occurs (McKee, M. 2020). Using masks which can expand the zone of breathing within the area of the mask itself before moving to the outer atmosphere might be a good resolution for glass steaming; so that water vapour coming from wearer mouth penetrate the mask's material and not going upwards leaking out through the adjustable nose-clip above.

How to make it easier to find a proper fitting PPE gown, from apparel point of view? It might be by having a one size gown, provided with soft elastane from both sides at the waistline and the known side-seam in garment field. Raglan sleeves would be a good choice to fit size variations, this was in-line with a study for dental surgeon by Tran, Thi Anh Dao, et. al. (2015); in this specific study thermal comfort and mobility were found as biggest obstacles for medical personnel.

This finding would be applied into medical PPE in order to provide a refreshing sensation to the wearer instead.

Although, there are test methods essential during COVID-19, one of them is AFNOR Spec S76-001 (2020): the French guide for minimum requirments, methods of testing and how to use facial masks, as mensioned in the guide this barrier is not intended to be used by HCW in contact with patients. On the other hand, 1910.120 App A - Personal protective equipment test methods by OSHA emphesises how to assess PPE from gaseous diffusion, prior to test method a visual inspection should take place ensuring no tears or any defaults within vents, zippers…etc. Test is done using Ammonia and PPE entigrity is checked by manikin copying humanbeing practicing various movements (OSHA, 2021). This current paper was limited to reviewing PPE properties, it is recommended to extend research to test a number of PPE in the Arab world.

5. Conclusion:

Configuring medical PPE is quite a challenge, since it should act as a barrier between the outside pathogens and the skin and provide comfortability to the wearer. Therefore, the properties of the inner and outer surfaces are different. For instance, while the inner surface should be hydrophilic to adsorb the sweat, the outer surface should be hydrophobic to prevent the body fluids from penetrating into the skin. Thus, the methods for applying the desired finishes into the fabric surface should be wisely considered. In fact, Bianca-Michaela Woelfling et al. (2019) measured the effectiveness of the firefighting PPE after impregnating it with perfluorocarbon, to give it repellency properties for both water and oil. It has been found that the impregnation method impedes the inner surface from adsorbing the sweat, and thus using spray impregnation has been recommended.

Through literature reviewed in this paper, it has been found that the fabric type, its construction, finishes, and the assembling technique have a great influence on the barrier efficiency.

Comfort is an essential factor that should be considered in the medical PPE. It is understood that the barrier efficiency is certainly necessary, especially when it comes to deal with a novel virus, like COVID-19. Nevertheless, not only discomfort affects the performance of the wearer, but also could be a life threat. The physiology of the medical PPE has been found to be the most important comfort aspects, since ~70% of the participants have encountered heat stress while doing their job, within a room temperature range around 20 - 30 ℃. The heat gain by the body should balance with the heat loss, by eliminating the heat storage from the equation, and subsequently this balance will stabilize the core body temperature (Rene Rossi, 2014). As the clothing is the interface between the body and the ambient conditions, it has a significant role in thermal balancing. Also, the ambient conditions, and the nature of the physical activity, the wearer does, contribute to that.

According to the FDA (2020), wearing N95 respirator seals around the nose and mouth area, which reduces the risk of getting contaminated (from the gap between the mask and the face). Even though the respirator N95 seals around the nose and mouth area, the number of participants experienced discomfort wearing the mask was equal to the surgical mask, especially because of breathing difficulty (~37%).

In addition, it has been found that female HCWs have a problem finding their sizes. And therefore, it is recommended to provide design solutions to produce a PPE that can fit many sizes.

Supplementary information

Questionnaire about COVID-19 medical wear

a. Basic information

Gender: □ Male □ Female

Country: ---

Q1: Do you work in infection-controlled areas? □ Yes □ No

If YES, please answer the following questions:

Q2: What is the roughly room temperature inside the infection-controlled areas?

--- °C.

Q3: What kind of personal protective equipment (PPE) do you use?

□ head cover

□ Face shield

□ Goggles

□ Mask/ Respirator (if CHECKED, please go to Q4 and Q5)

□ Gloves

□ Gown (if CHECKED, please go to Q6-Q12)

□ Apron

□ Overshoes

b. Discomfort during wearing PPE gear

Q4: What kind of mask/ respirator do you use? Please see the following pictures and answer.

□ N95 respirator.

□ Surgical mask.

□ Other. Please specify: ---

Q5: Do you feel comfortable while wearing the mask/ respirator? □ Yes □ No

If NO, what is the reason:

□ Breathing difficulty.

□ Vision difficulty.

□ Does not fit well (Does not take the shape of my face).

□ Size too big.

□ Size too small.

□ Too hot near my skin.

□ Too weak (the band can be easily torn).

□ Other. Please specify: ---

Q6: What kind of gown do you use? Please see the following pictures and answer.

□ With an attached head cover.

□ Without an attached head cover.

□ Other. Please specify: ---

	
No. 1	**No. 2**

Q7: Do you know the material of your gown? □ Yes □ No

If Yes:

□ Cotton □ Polyester □ Other: …

Q8: Do you feel comfortable while wearing the gown? □ Yes □ No

If NO, what is the reason:

□ Mobility difficulty.

□ Size too big.

□ Size too small.

□ Too hot.

□ Too weak (easily torn).

□ Other. Please specify: ---

c. PPE size

Q9: Does the gowns come in different sizes? □ Yes □ No

Q10: Can you find your size, that fits you properly? □ Yes □ No

d. Number of clothing layers

Q11: How many layers do you have to wear, including the inner clothes, and the scrub suit? --- layers

Q12: Do you feel overheated during wearing your PPE? □ Yes □ No *e. Concerns while wearing PPE*

Q13: In general, do you have any worries regarding wearing your PPE? □ Yes □ No
If Yes, please tell us why? ---

f. Training, commitment, and infection

Q14: Have you ever received training for using PPE properly? □ Yes □ No

Q15: How do you describe your commitment to wearing the available PPE?
□ Less than 50%
□ More than 50%

Q15: Have you got infected with COVID-19? □ Yes □ No

END OF QUESSTIONNAIRE

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