Physiological Impacts of Personal Protective Equipment on Health Care Workers

Anum Arif[1], Ahsin Manzoor Bhatti[1], Akhter Hussain[1], Mohammad Tariq[1], Osama Hadi[1], Syed Hashim Ali Inam[2]

[1]Combined Military Hospital,
[2]Combined Military Hospital Medical and Dental College,Lahore, Pakistan
Abdul Rehman Road, Lahore Cantt, Lahore, Pakistan

ABSTRACT

Introduction: Since the outbreak of the Ebola virus, its design has constantly been evolving to serve the purpose of protection without hampering the efficiency. In a study conducted in 2019, before the advent of COVID 19, it was found that performing precarious laboratory or clinical works while wearing PPE involved various restrictions compared to the same work without PPE. The objective of this study is to identify the influence of personal protective equipment on physiological parameters and the individual wellbeing of healthy workers. **Methods:** This Pilot Quasi-experimental study was performed on 12 volunteers fitting the inclusion criteria. Candidates were seated comfortably and their baseline resting pulse rate, respiratory rate, oxygen saturation via pulse oximeter, blood pressure, and End-tidal CO2 were recorded via a portable monitor. All candidates were asked to wear a KN95 mask along with a 3 ply mask over it and wear anti-fog goggles. All the above-mentioned parameters were recorded again after five minutes of comfortable sitting and ten minutes of brisk walk. **Result:** Significant difference is found between resting EtCO2 and after wearing of PPE (P = 0 .044). After a brief exercise, the further rise in EtCO2 is also significant (P = 0.002). There is no significant rise in pulse after wearing PPE (P = 0.092) but on exertion after wearing PPE, the rise in pulse is statistically significant (P = 0.002). The rest of the variables, such as the rise in respiratory rate, blood pressure, and fall in oxygen saturation rise has no statistical significance. **Conclusion:** Personal protective equipment has proven to rise in end-tidal carbon dioxide and tachycardia, which can lead to headache, dizziness, and respiratory discomfort. All of the factors can hamper the health care workers' performance and can adversely affect their efficiency.

Keywords: covid-19, end tidal CO^2, personal protective equipment, physiological

Corresponding Author:
Anum Arif
Email: DrAnumArif@yahoo.com, DrAnumArifkhan@gmail.com
Telephone: 03222398424, 03422398424

INTRODUCTION

Personal Protective Equipment (PPE) is defined as an equipment that is designed to protect individuals from explosive, chemical, biological, radiological, and nuclear hazards (O'Brien et al., 2011). It has become a significant and (fascinating) subject during the current corona virus (COVID-19) pandemic (Daigle et al., 2020; Mahmood et al., 2020; Malik, 2020). Since the outbreak of the Ebola virus, its design has constantly been evolving to serve the purpose of protection without hampering the efficiency (Honda and Iwata, 2016). CDC has included the following as the components of PPE: hand gloves, gowns, and aprons for clothing and skin protection, masks and respirators to protect mouth and nose from respiratory tract from airborne infectious agents, eyewear protective glasses for eyes protection and face shields for nose, mouth and face protection (Center for Disease Control and Prevention, 2020). All of the elements come with their own restrictions. In a study conducted in 2019, before the advent of COVID 19, it was found that performing lab work while wearing PPE involves various restrictions paralleled to the same work short of PPE. For instance, long-duration of work in PPE may cause heat stress, several layers of gloves limit dexterity, and face shields may alter the light leading to difficulties with vision (Yánez Benítez et al., 2020). Thus, carrying out intravenous cannulation and intubation becomes signifcantly slower compared to personnel with the same expertise performing the same task under standard conditions.

Roberge JR et al evaluates that face mask can lead to an increase in breathing rate and heart rate might be related to resistance in breathing, workload, physical capability, associated apprehension, and increased retention of CO_2 (Roberge et al.,

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2010). He finds no significant effect of face mask on SpO2, which is contrary to another study that finds significant SpO_2 falls only during procedures lengthier than 60 minutes (Beder et al., 2008).

This shows that there are some mechanisms affecting healthcare workers' physiology, overall comfort, and efficiency in performing day-to-day task at their respective inpatient setups. However, no literature reviews have validated the hypothesis with scientific evidence and few literature is found supportive of a conclusive effect of all PPE equipment. The objective of the study was to identify the influence of personal protective equipment application on physiological parameters and individual well-being of healthy workers.

METHODS

After getting approval from the institutional review committee of Combined Military Hospital Lahore on 1st June, 2020, this pilot Quasi-experimental study was conducted in the department of surgery. Informed consent of 12 volunteers was taken. It was conducted over an hour, after a briefing session on volunteers inclusion criteria having an age range between 25 to 50 years old, and no comorbids like hypertension, diabetes mellitus, and chronic obstructive airway disease with functional class 1. Volunteers who met those requirements were recruited. After obtaining informed consent, their demographic variables including sex, age, comorbid, body height, body weight, BMI, smoking habit, and activity level were recorded. Daily walking of less than 6 km was categorized as a mild activity, daily walking between 6 to 10 km was categorized as moderate activity, and daily walking more than 10 km daily was categorized as a strenuous activity. Candidates were seated comfortably and their baseline resting manual respiratory rate, manual blood pressure via a sphygmomanometer, pulse rate, oxygen saturation via pulse oximeter, and End-tidal CO_2 were recorded via portable $EtCO_2$ monitor (Wuhan Union medical technology). All candidates were asked to wear a KN95 mask (AKC, Sialkot Pakistan) along with a 3-ply disposable ordinary surgical mask (AH surgical, Faisalabad) over it and make it airtight seal via tapping all over and wear anti-fog goggles. A circuit was created to connect the $EtCO_2$ monitor with an endotracheal tube via a filter. All candidates were requested to take 4 shallow breaths and exhale into the endotracheal tube to record their $EtCO_2$.

All the above-mentioned parameters were recorded again after five minutes of comfortable sitting. Health care workers were then asked to do a brisk walk for 10 minutes and all the parameters were obtained again. Data entry was done through the statistical package for social science (SPSS) software, version 22. The mean and the standard deviation were calculated for quantitative variables. Frequency and percentages were computed for qualitative variables. According to the most popular test of inter-item consistency, the reliability in this study used Cronbach's alpha coefficient, which was 0.754. Mean scores were compared by sample T-test. $P \leq 0.05$ was considered statistically significant.

RESULT

A total of 12 candidates were recruited in the study. Based on the results of the study, the mean age is 30.75 ± 8.529, an equal number of both gender, and 8 vounteers (66.7%) are innormal BMI. In terms of occupation, 4 vounteers (33.3%) are house officers, 3 volunteers (25%) are residents

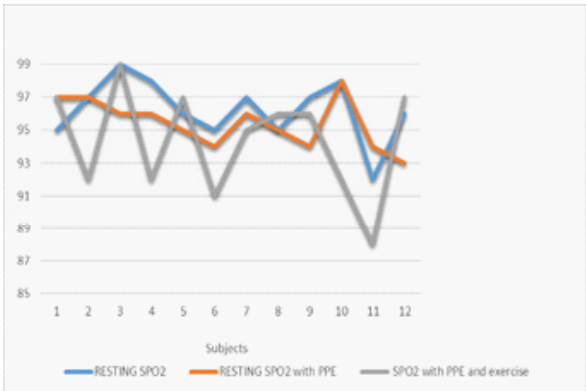

Figure 2. Comparison of Oxygen Saturation

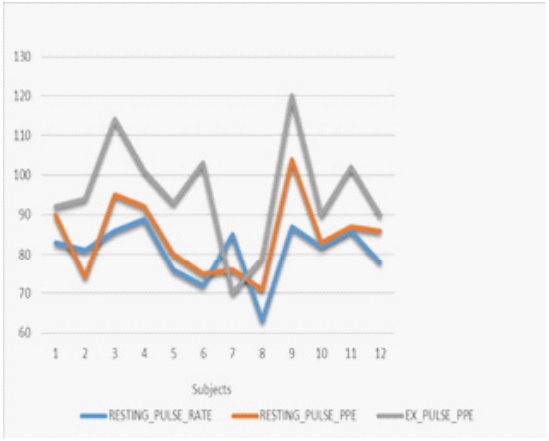

Figure 1. Comparison of Pulse Rate

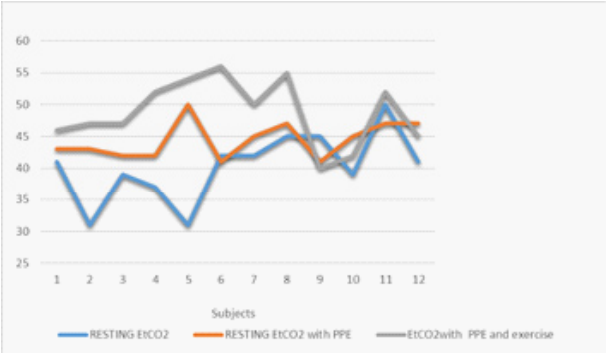

Figure 3. Comparison of Resting End Tidal Carbon Dioxide

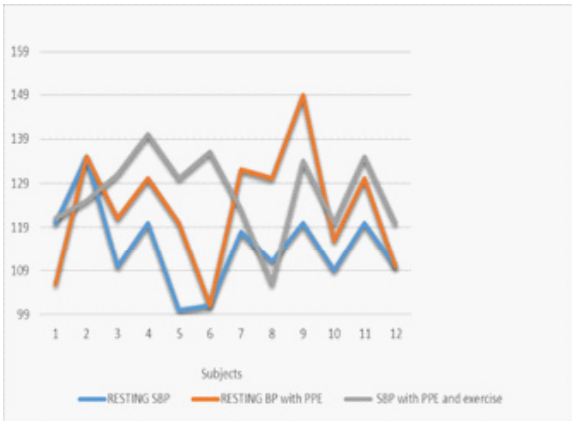

Figure 4. Comparison of Systolic Blood Pressure

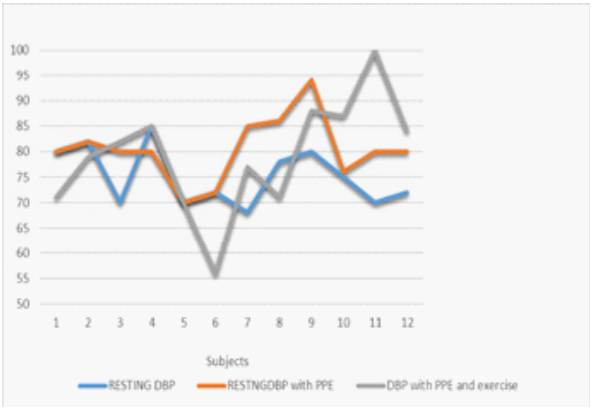

Figure 5. Comparison of Diastolic Blood Pressure

and OT technicians, and 2 volunteers (16.7%) are consultants. Moreover, 11 volunteers (91.7%) are nonsmokers, and the activity level is moderate in 10 individuals (83.3%).

All the variables when the volunteers took a break wearing PPE were then compared with the

Table 1. Comparison of Physiological Parameters

		Mean	Std. Deviation	P value
Pair 1	Resting pulse-resting with PPE	3.75	7.034	0.092
Pair 2	Resting pulse-pulse with PPE and exercise	15	12.656	0.002
Pair 3	Resting RR-resting RR with PPE	1.25	7.2	0.56
Pair 4	Resting RR-RR with PPE and exercise	1.75	8.6888	0.5
Pair 5	Resting SaO_2-SaO_2 with PPE	0.833	1.749	0.127
Pair 6	Resting SaO_2-O_2 with PPE and exercise	1.917	2.968	0.047
Pair 7	Resting $EtCO_2$-Resting with PPE	4.167	6.365	0.044
Pair 8	Resting $EtCO_2$-EtCo2 with PPE and exercise	8.583	7.561	0.002
Pair 9	Resting SBP-Resting SBP with PPE	8.833	11.392	0.021
Pair 10	Resting SBP- SBP with PPE and exercise	12.25	13.343	0.009
Pair 11	Resting DBP-RestingDBP with PPE	5.25	6.797	0.022
Pair 12	Resting DBP- DBP with PPE and exercise	4	12.358	0.286

Paired Samples Test

SaO_2 = Oxygen saturation, $EtCO_2$ = End tidal Carbon-dioxide, RR = Respiratory rate, SBP = Systolic blood pressure , DBP =Diastolic blood pressure

variables when they took 10 minutes of exercise wearing PPE as shown in Table 1. Changes in these outcome variables on an individual basis are charted in Figures 1-5. Figures 1 to 5 depict the comparison between variation in pulse rate, oxygen saturation, systolic blood pressure, diastolic blood pressure and end tidal CO_2 of volunteers.

Internal consistency correlation shows the following results:

-Positive correlation between resting $EtCO_2$ and age, occupation, and BMI,

-Resting $EtCO_2$ with PPE has a positive correlation with age, gender, and occupation,

-$EtCO_2$ with PPE and exercise showed a positive correlation with gender and activity level.

DISCUSSION

Much has been emphasized on the availability of PPE along with trainings in donning and doffing proper technicians to prevent disease transmission (O'Brien et al., 2011). It has been found that literature does support significant discomfort faced by health care workers (HCW) while wearing different designs and modifications of PPE in terms of bending, lifting arm, squatting, and walking, which represents that some levels of evidence exist in terms of discomfort being reported by all HCWs which may affect their delivery of patient care and overall performance. However, at very sparse levels they have validated the physiological changes that occur and adversely affect the health and efficiency of workers (O'Brien et al., 2011; Garibaldi et al., 2019; Akbar-Khanzadeh, Bisesi and Rivas, 1995).

Beder A et al. have observed the oxygen saturation (SpO_2) by a pulse oximeter and established a reduction in the blood O_2 saturation level of the surgeons after surgery, which is statistically noteworthy. They illuminate that it is likely that there are some hypoxemia consequences due to the content of the inspired air from the amplified CO_2 content of the inspired air due to the exhaled CO_2 getting increased in inspired air (Beder et al., 2008). Beder et al. (2008) find a positive correlation between resting SpO_2 while wearing PPE and after a brief exercise, but the statistically significant rise is found only after the exertion (p-values are 0.127 and 0.047 respectively). Bader et al give this hypothesis but they do not measure any evidence of a rise in $EtCO_2$ (Beder et al., 2008). The reference range for $EtCO_2$ is found to be 35-45 mmHg. Moreover, hypercapnia can extant with confusion, headaches, light-headedness, rise in pulse, dyspnea, and flushed skin (Beder et al., 2008; Patel et al., 2020). In this present study, it is found that there is a significant rise in $EtCO_2$ just after donning (P 0.044), and there is a significant (P 0.002) rise after exertion further validating our results. If the hypercapnia develops gradually over time, symptoms may be absent (Beder et al., 2008). Cases of hypercapnia may be starker and may end up in the inability to breathe. In these cases, symptoms such as depression, and muscle twitches, seizures, papilledema, can be seen (Beder et al., 2008). Since masks are airtight, the built-up of CO_2 is very rapid and this retained CO_2 ,when inhaled, can lead to devastating symptoms (Patel et al., 2020).

Significant tachycardia observed amongst study participants is similar to as seen in the literature (Daigle et al., 2020; Mahmood et al., 2020; Malik, 2020). This condition can be explained due to discomfort, stress, and a response to desaturation.

However, contrary to most of the literature research, in this study, any statistically significant escalation in diastolic blood pressure is not found. However, an increase in systolic blood pressure is statistically significant as shown by many previous authors (Daigle et al., 2020).

High microclimate temperature, humidity, and skin temperature are documented inside the facemask (Daigle et al., 2020). It further enhances after exercise, which ends up in an escalation in heat, humidity, and extraordinary breathing resistance among the subjects wearing the facemasks. This can explain the tachypnea observed in the respondents but it is not statistically significant in this present research, contrary to most of the previous literature reported (Daigle et al., 2020).

Furthermore, it is also noted that high breathing resistance makes it challenging for the volunteers to breathe and take sufficient oxygen. Scarcity of oxygen stimulates the sympathetic nervous system and the resultant increase in heart rate (Daigle et al., 2020).

Out of all the defined parameters, the rise in $EtCO_2$ seems to have the most hazardous consequences. It is the very first time in literature when the hypothesis is being validated with not only a most probable explanation but also with a binding scientific evidence. There has been a positive correlation between BMI and $EtCO_2$ either at rest or exertion, a negative correlation was observed with gender, smoking, and daily activities.

All the alterations in physiology can cause not only uncomfortable feeling, unfitness, fatigue and hamper the delivery of tasks that they may be done easily in normal situation but can also endanger their life. These physiological changes may prove lethal for those who are already with a failing cardiovascular and respiratory system.

Since KN-95 masks are the most widely used in Pakistan during the COVID-19 pandemic, it is of paramount importance that they affect HCWs' physiology and ultimately their performance and should be taken into consideration while assigning them duty hours and assessing their performance. Moreover, there is a need to develop better PPE so that HCWs can work comfortably and more efficiently in future epidemics.

CONCLUSION

Personal protective equipment has proven to rise in end tidal carbon dioxide and tachycardia which can lead to headache, dizziness and respiratory discomfort. All of the factors can hamper health care workers' performance and can adversely affect their work efficiency.

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