Original Article

Effect of Personal Protective Equipment on Physiological Parameters of Healthcare Professionals in Cardiopulmonary Resuscitation: A Manequin Study

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Abstract

Background: Use of personal protective equipment (PPE) has become an important element of hospital equipment due to the COVID-19 pandemic. In this process, use of PPE has been quite challenging for healthcare workers, and it's thought that use of PPE causes stress on the body and lack of attention. This study aimed to examine effects of PPE use during cardiopulmonary resuscitation (CPR) on various physiological parameters and attention. ***Methods:*** 27 volunteers were included in study and participants were divided into two groups with PPE and without PPE. The physiological parameters of the volunteers were reported before and after each application. Advanced Cardiac Life Support application was applied on a model (SimMan Resusci Anne QCPR Laerdal. Stavanger, Norway). ***Results:*** In measurements made before and after CPR without the use of PPE, in addition to weight loss, the increase in lactate, glucose and end-tidal carbon dioxide (ETCO2) was found to be statistically significant. Among the parameters evaluated after CPR, increase in heart rate, weight loss, lactate, perfusion index and $ETCO_2$ was statistically significant. When both groups were evaluated with initial IPAQ scores and Beck Anxiety Inventory, no statistically significant difference was detected between the groups. ***Conclusion:*** The study shows that use of PPE has serious physiological effects on the user, especially in procedures that require intense physical effort, such as CPR.

Keywords: ***Emergency Care, Protective equipment, Resuscitation.***

1. Introduction

The emergence of highly contagious diseases such as Ebola, severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS), influenza, and the most recently declared COVID-19 pandemic has increased the importance of protective medicine [1]. The use of personal protective equipment (PPE) is highly important in terms of preventing the spread of these diseases, the continuity of the treatment and care processes of patients, and the health and safety of healthcare professionals [2]

The World Health Organization (WHO) recommends personal protective equipment for healthcare workers, especially when it is necessary to perform procedures with close contact on patients: gloves, apron (non-sterile, preferably liquid impermeable and long-sleeved), medical (surgical) mask, N95/FFP2 mask, face shield during aerosol-generating procedures. It is recommended to use glasses. In addition, it is recommended that overalls, caps and foot protectors be used on a patient-by-patient basis, especially in cases where contact with the patient's body fluids and secretions may occur. In addition to personal protective equipment, some precautions need to be taken in cardiopulmonary resuscitation of COVID-19 patients [3]. All necessary equipment and medications should be available, especially since the presence of people bringing and taking equipment to the intervention room may increase viral transmission. When patients need intubation when indicated, the number of people in the room should be minimized[4]

Although the use of PPE can be used to create an acceptable and safe working environment for healthcare workers, it also causes physiological and psychological stress on healthcare workers due to reasons such as decreased visibility, decreased breathing ability, increased body temperature, and decreased visual and auditory communication. . For example, cardiopulmonary resuscitation (CPR) performed in the emergency room due to cardiac arrest causes severe aerosolization. Performing CPR, especially while using PPE, increases physical stress [5]. For these reasons, personal protective equipment needs to be revised in a new pandemic that may develop.

The study, carried out by 27 volunteer physicians, aimed to examine the effects of PPE use on physiological parameters and attention in a multifaceted manner.

2. Methods

The study was carried out experimentally on a mannequin by applying CPR to volunteers divided into two groups with a crossover design. The applications were carried out at Ankara University Department of Emergency Medicine between 22 June 2021 and 30 July 2021. Approval was obtained by the Ethics Committee of the Ankara University Faculty of Medicine (Decision No: İ6-393-21, 17 June 2021).

Criteria for inclusion in the study; The requirement was to be over 18 years of age, have written and verbal consent, and be working as a physician. Exclusion criteria from the study; The criteria were being under 18 years of age, not providing written consent, pregnancy, having a chronic disease requiring medication, a history of major surgery within 30 days, and having a visual, hearing, or mobility disability. Abnormal arrhythmia, systolic blood pressure, body mass index (BMI), fingertip oxygen saturation, and capillary glucose were evaluated during the pre-study examination. During the examination, people with a temperature above 37.8°C were excluded from the study.

Volunteer physicians were randomly divided into groups of two. Volunteers in each group (two people) performed Advanced Cardiac Life Support both using personal protective equipment and without using personal protective equipment. The order of cardiopulmonary resuscitation application (1st application and 2nd application) performed by volunteers in each group (two people) using personal protective equipment and without using personal protective equipment is random. Between the CPR practices with and without PPE, the volunteers were given a rest period of at least 72 hours. Before each application, the physiological parameters and demographic data of the volunteers were obtained, and the basal CT results were recorded in the study form. After completing CPR with PPE, the volunteers immediately removed their PPE. At the end of each application, the volunteers were allowed to rest for 20 minutes, and then their physiological parameters and cancellation test results were recorded in the study form. After a session with PPE, the volunteers were questioned about the presence of symptoms related to PPE and, if any, the symptoms themselves; the information was recorded in the study form. The temperature and relative humidity of the environment were also recorded in the study form.

Advanced Cardiac Life Support was applied for 20 minutes in a 24m² laboratory, on a model (SimMan Resusci Anne QCPR Laerdal. Stavanger, Norway) in accordance with the ACLS guideline [6].During the application, the first volunteer applied chest compressions for two minutes, the second volunteer applied a balloon-covered mask for 30 chest compressions, and two minutes later, two volunteers were displaced. The researcher in the study verbally instructed practitioners to change positions every two minutes during CPR. Volunteers performed five two-minute chest compression cycles during 20 minutes of CPR, repositioning every two minutes. In this study, only cardiac compression from advanced cardiac life support was evaluated, and ventilation, drug administration, defibrillation and other applications were excluded from the evaluation.The quality (speed and depth) of cardiac compression performed by the physicians participating in the study was evaluated and implemented by the physician conducting the study.

Age, height, and weight characteristics of the participants were recorded. BMI was calculated by considering height and weight. Smoking was recorded. The International Physical Activity Questionnaire (IPAQ) and Beck Anxiety Inventory (BAI) were administered immediately before the procedure. A cancellation test (CT) was performed before and after both procedures with and without PPE. Volunteers in each group (two people) performed the Advanced Cardiac Life Support (ACLS) application both while using and not using PPE. The order of CPR application by the volunteers in each group with and without personal protective equipment were random. C-level PPE was used. In this research, level C was used as PPE upon the recommendations of the World Health Organization and these are; It consists of N95 type inner mask, surgical outer mask, air-waterproof medical disposable coverall, vinyl long inner glove, powder-free non-sterile latex outer glove, disposable medical shoe cover, panoramic medical glasses and protective visor (Figure 1).

Appendices

Legends to figure

Figure1. As recommended in this research, level C was used as PPE. N95 type inner mask, surgical outer mask, air-waterproof medical disposable overalls, vinyl long inner gloves, powder-free non-sterile latex outer gloves, disposable medical shoe covers, panoramic medical glasses and visor. **(In order for the figure to be better understood and seen during printing, color must be used.**

2.1. Statistical Analysis

A chi-square test was used to evaluate categorical data, a paired-sample t-test was used to evaluate the difference between the two groups in normally distributed data, a Wilcoxon signed-rank test was used to evaluate the difference between the two groups in non-normally distributed data, and a Mann–Whitney U test was used to evaluate subgroups and $p < 0.05$ was considered significant.

3. Results

In keeping with the inclusion criteria, 27 volunteer health workers were included in the study. Three volunteers were excluded because they had abnormal vital signs during the pre-session examination. The study was completed with a total of 24 volunteer health workers. Of the participants, 16 were male and 8 were

female. The mean age was 28.6±1.7 years; the mean height was 173.4±8.8 cm; and the mean body weight was 76.7±18.3 kg. Body mass index (BMI), calculated based on height and weight values, ranged between 16.7 and 31.6, with a mean of 25.1±4. Other data are shown in Table 1

In the comparison of baseline IPAQ scores, 9 (37.5%) of the participants were inactive, 13 (54.2%) were minimally active, and 2 (8.3%) were very active. According to the Beck Anxiety Invantory, 14 of the volunteers (58.3%) had no symptoms of anxiety, while 6 (25%) had mild anxiety, and 4 (16.7%) had moderate anxiety symptoms. The median time to finish was 213 (25th–75th percentile: 156–231) seconds, and the median number of errors was 3.5 (25th–75th percentile: 1–6.75) in the baseline CT performed with the volunteers before the sessions.

There was no statistically significant difference between the physiological parameters measured in the pre-CPR sessions with and without PPE except capillary glucose level ($p > 0.05$). This statistic also showed that the admission vital parameters of the participants in both groups were clinically evenly distributed. The increase in HR, lactate, glucose, and ETCO2 was found to be statistically significant in the post-CPR measurements compared to those taken pre-CPR without PPE ($p<0.05$), while the changes in other parameters were not significant ($p>0.05$) (Table 2). A statistically significant difference was found in HR, DBP, body weight, glucose, lactate, $ETCO_2$, and perfusion index (PI) in pre-CPR and post-CPR sessions with PPE ($p < 0.05$) (Table 2) In the CPR procedure with PPE, compared to the CPR procedure without PPE, the differences between physiological values before and after the procedure were found to be significant in heart rate, weight loss, lactate, $ETCO_2$ and PI. (Table 3).

Table 1. Descriptive Statistics

Parameters (n=24)	**Descriptive Data**
Gender, n (%)	
Male	*16 (%66,7)*
Female	*8 (%33,3)*
Age	28,6±1,7
Mean±SD	29 (25-32)
Median (min-max)	
Height (cm),	173,4±8,8
Mean±SD	
Body Weight (kg)	76,7±18,3
Mean±SD	
BMI	25,1±4
Mean±SD	26,1 (16,7-31.6)
Median (min-max)	
BMI Classification, n (%)	
Under-weight	2 (%8,3)
Normal	9 (%37,5)
Pre-obese	11 (%45,8)
Obese Type 1	2 (%8,3)
IPAQ, n (%)	*9 (%37,5)*
Inactive	*13 (%54,2)*
Minimal Active	*2 (%8,3)*
Very Active	
Smoking , n (%)	
Using	12 (%50)
Not using	12 (%50)
BAI, n (%)	14 (%58,3)
	6 (%25)
No signs of anxiety	4(%16,7)
Mild anxiety	
Moderate anxiety	

Note: *SD = standard deviation; min = minimum; max = maximum; BMI = Body Mass Index; IPAQ = International Physical Activity Score; BAI = Beck Anxiety Scale*

Table 2: Physiological parameters

Parameters	**Using PPE**			**Not using PPE**			
	Pre CPR	**Post CPR**	**P ***	**Pre CPR**	**Post CPR**	**P ****	**P *****
Body Temperature (°C)	36,5 (36,5-36,6)	36,6 (36,6-36,7)	0,582	36,5 (36,5-36,6)	36,5 (36,5-36,6)	0,533	0,523
SBP (mm-Hg)	119,6±12,8	121±22,8	0,749	121,8±13,1	125,7±16	0,578	0,369
DBP (mm-Hg)	75,5±10,2	80,3±11,8	**0,015**	77,3±9,2	77±11,3	0,582	0,457
MAP (mm-Hg)	90,2±10,2	93,9±12,3	0,057	92,2±10,2	93,3±11,4	0,12	0,353
HR (beat/min)	81±13,4	100,5±16,3	**<0,001**	82,6±11,5	97,7±13,9	**0,012**	0,317
Body Weight (kg)	*76.71±18.31*	75.95±18.21	**<0,001**	76.59±18.38	76.43±18.33	0,471	0,383
PI (%)	7,4±2,7	5,3±3,1	**<0,001**	7,1±2,8	7,4±3,1	0,642	0,661

Blood glucose (mg/dL)	101,7±10,9	87,3±9,3	**<0,001**	94,6±9,1	83,8±8,7	**0,008**	**0,019**
Lactat (mmol/L)	0,85 (0,45-1,97)	1,55 (1,3-1,9)	**<0,001**	0,8 (0,6-1,07)	1,20 (0,92-1,97)	**<0,001**	0,452
$ETCO_2$ (mmHg)	28,5 (27-31)	31(28-34,7)	**0,028**	28,5 (27-30)	30 (27-32,7)	**0,035**	0,448
SpO^2 (%)	98 (97-98)	98 (97-98)	0,067	98 (97-98)	98 (97-98)	0,240	0,225

Note: *PPE = Personal Protective Equipment; SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; MAP = Mean Arterial Pressure; HR = Heart Rate; PI = Perfusion index; $ETCO_2$ = End Tidal Carbon dioxide; SpO2 = Oxygen Saturation, min = Minutes. CPR= Cardiopulmonary resuscitation. ES = Effect Size. P* value= P value obtained by comparing the parameters measured before and after the procedure using PPE; P** value= P value obtained by comparing the parameters measured before and after the procedure not using PPE; P***value= The p value obtained as a result of comparing the parameters measured without and using PPE before performing CPR. Normally distributed parameters are given as mean+standard deviation; Parameters that are not normally distributed are given as median and IQR (25th-75th percentile). In comparisons between groups, Student's t test was used for continuous variables and Mann Whitney U was used for non-normally distributed and ordinal variables. P<0.05 was considered significant.*

Table 3: The difference in the parameters before and after CPR according to the use of PPE

Parameters	Using PPE	Not using PPE	P
Δ Body Temperature (°C)	0,1(0,1-0,1)	0[(-0,1)-0,1]	0,078
Δ SBP (mm-Hg)	6,5[(-2)-12,75]	4[(-5,25)-9,00]	0,666
Δ DBP (mm-Hg)	3[(-1)-9]	1[(-6,5)-3,75]	0,087
Δ MAP (mm-Hg)	3[(-0,3)-10,1]	1,33[(-5,5)-4,5]	0,401
ΔHR (beat/min)	20,88±10,46	15,13±10,49	**0,016**
Δ Body Weight (g)	350(250-500)	150(62,5-200)	**<0,001**
Δ Body weight percentage change	0,437(0,324-0,613)	0,191(0,103-0,232)	**<0,001**
ΔPI (%)	-2,07±2,14	0,30±2,61	**0,001**
ΔBlood glucose level (mg/dL)	-12[(-23)- (-4,25)]	-7[(-16,5)- (-3,5)]	0,302
ΔLactat (mmol/L)	0,65(0,4-1,1)	0,4(0,1-1,02)	**0,004**
Δ CO_2 (mmHg)	2,5 (0-6,75)	1,5(0-5,75)	**0,006**
ΔSpO^2 (%)	0(0-0)	0(0-0)	0,083

Note: *PPE = Personal Protective Equipment; SBP = Systolic Blood Pressure; DBP = Diastolic Blood Pressure; MAP = Mean Arterial Pressure; HR = Heart Rate; PI = Perfusion index; CO_2 = Carbon dioxide; SpO2 = Oxygen Saturation, min = Minutes. P value= The p value obtained by comparing the difference between the parameter values measured before and after CPR using PPE and the difference between the parameter values measured before and after CPR without using PPE. Normally distributed parameters are given as mean+standard deviation; Parameters that are not normally distributed are given as median and IQR (25th-75th percentile). In comparisons between groups, Student's t test was used for continuous variables and Mann Whitney U was used for non-normally distributed and ordinal variables. P<0.05 was considered significant.*

4. Discussion

In the study, the effects of using PPE while performing CPR on physiological parameters and attention were investigated in a multifaceted manner according to the ACLS guidelines. The effects of PPE can be more clearly observed by following the changes caused by the performance of CPR by having individuals perform CPR both with and without PPE. Overall, results have indicated that PPE significantly affects the physiological parameters of the wearer [1].

Lactic acid has played an important role in the traditional theory of muscle fatigue and the limitation of endurance exercise performance. Although lactate was increased in both sessions in the present study, this increase was statistically greater in the session with PPE. Consistent with the literature, the fact that weight loss was statistically more significant in the session with PPE showed the effects of the level-C equipment on sweating. In their study on treadmill use with level-C equipment, Coca et al. found that fluid loss through sweating was significant [7] .In the present work, we observed that the perfusion index decreased statistically significantly after the session with PPE; on the contrary, it increased during the session without PPE. It is believed thought that there is sympathetic activation with the use of PPE added to the stress of the CPR procedure, which may result in peripheral vasoconstriction. In studies of healthy adults, it was found to correlate best into demonstrating hypoperfusion in critically ill patients [8]. The higher EtCO2 level after the PPE session can be explained by the accumulation of CO2, causing the CO2 released exhaled during exhalation to be rebreathed due to the rebreathing of the N95 type mask used during the procedure. Similarly, in this study, it was shown that EtCO2 increased with the use of the N95 mask type [9].

Although a 1% decrease in oxygen saturation between sessions with and without PPE was statistically significant in the study, its clinical significance remains uncertain. In the literature, SpO2 decrease has been found with long-term use of N95 for at least 30 minutes; this could explain the fact that there was no significant change in saturation in the present study since the procedure time was 30 minutes [10]. The heart rate increase in the session with PPE was statistically higher than the session without PPE. Martin-Rodriguez et al. found that the use of PPE during resuscitation increased heart rate. This may be due to the additional weight and heat stress caused by PPE [11]. While sweating could be tolerated in the session without PPE, it created heat stress with the effect of the overalls in the session with PPE. When the temperature change between the measurements before and after the procedure in the sessions in the study was compared, the statistically significant difference between the session with and without PPE also supported this finding.

5. Limitation

Among the limitations of the study are that CPR was performed on a model, the number of volunteers was low for reliable evaluation

in subgroups of demographic data, and physiological data were measured within a certain range, not continuously. Volunteers attitudes toward a simulated CPR may differ from attitudes toward an actual CPR. In this study, volunteers focused solely on chest compressions and exhalations, but in real-life situations they may be distracted by other important interventions (e.g., intubation, defibrillation).

The strengths of the study are that it is a single-center prospective study, volunteers are the control group, and thus, only the effect of PPE can be observed by fixing individual metabolic variables. Since it was single-center and prospective, there was no data loss observed in non-prospective studies in the study. Since the study group and the control group were the same group and the sessions were conducted by a single researcher, changes due to metabolism and session conditions were fixed. By performing CPR both without and with PPE, the changes that CPR could create could be monitored, thus the effect of PPE could be observed more clearly.

6. Conclusion

The present study showed that the use of PPE, especially in procedures that require intense physical effort such as CPR, have serious physiological effects on the user. Impairment of attention and cognitive functions may occur due to increased temperature, sweating, thermal stress caused by increased carbon dioxide, especially with rebreathing masks such as N95 masks, and anxiety due to the changing microclimate created by PPE. Body, IPAQ and smoking parameters vary in the volunteers included in our study. This is a limitation of our study, as measurements for study participants with poor physical condition may affect the general findings. The use of PPE can cause serious physiological effects including tachycardia, dehydration, and fatigue on healthcare workers. This study allows for a deeper understanding of the physiological changes caused by PPE on the user, as well as the precautions that can be taken regarding the problems that may be encountered.

Ethics approval and consent to participate

Informed consent was signed by all study participants. All mentioned ethical aspects and related consents were taken into consideration during the conduct of this study. Approval was obtained by the Ethics Committee of the Ankara University Faculty of Medicine (Decision No: İ6-393-21, 17 June 2021).

List of abbreviations

PPE: Personal protective equipment, CPR: Cardiopulmonary resuscitation, ETCO2: End-tidal carbon dioxide, SARS: Severe acute respiratory syndrome, MERS: Middle East respiratory syndrome, WHO: World Health Organization, BMI: Body mass index, ACLS: Advanced Cardiac Life Support, IPAQ: The International Physical Activity Questionnaire, BAI: Beck Anxiety Inventory, CT: Cancellation test, SBP: Systolic Blood Pressure, DBP: Diastolic Blood Pressure, MAP: Mean Arterial Pressure, HR: Heart Rate, PI: Perfusion index, SpO2: Oxygen Saturation

Data Availability

The data that support the findings of this study are available on request from the corresponding author

Conflicts of Interest

The authors declare they have no competing interests, and all authors confirm accuracy.

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Authors' contributions

Cagatay Yanik: Writing original draft, Visualization, Methodology, Investigation, Data curation.
Omer Yusuf Erdurmus: Writing – review & editing, Methodology, Investigation, Formal analysis, Proof reading.
Sinan Genc: Methodology, Investigation, Proof reading
Ayca Koca: Methodology, Investigation, Providing language help.
Ahmet Burak Oguz: Methodology, Investigation
Muge Gunalp Eneyli: Theory development , Writing-Original draft and Editing.
Onur Polat: Writing-Original draft and Editing.

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