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Original article

# The effect of personal protective equipment on cardiac compression quality

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ABSTRACT

*Introduction:* Cardiac compression is a cumbersome procedure. The American Heart Association suggests switching of cardiopulmonary resuscitation (CPR) provider every 2 min to prevent any decrease in resuscitation quality. High quality CPR is associated with improved outcomes. Previous studies have highlighted the difficulties in providing high quality CPR particularly while wearing personal protective equipment (PPE). This study aimed to evaluate the impact of personal protective equipment (PPE) use on CPR quality in prehospital cardiac arrest situations.

*Methods:* In this prospective simulation study, we compared the cardiac compression qualities and fatigue rates among prehospital health care professionals (HCPs) who were or were not using PPE.

*Results:* A total of 76 prehospital HCPs comprising 38 compression teams participated in this study. The mean compression rate was 117.71 ± 8.27/min without PPE and 115.58 ± 9.02/min with PPE ($p = 0.191$). Overall compression score was 86.95 ± 4.39 without PPE and 61.89 ± 14.43 with PPE ($p < 0.001$). Post-cardiac compression fatigue score was 4.42 ± 0.5 among HCPs who used their standard uniform and 7.74 ± 0.92 among those who used PPE ($p < 0.001$). The overall compression score difference between the two conditions was 25.05 ± 11.74 and the fatigue score difference was 3.31 ± 0.98.

*Discussion:* PPE use is associated with decreased cardiac compression quality and significantly higher fatigue rates than those associated with the use of standard uniforms. Routine use of mechanical compression devices should be considered when PPE is required for out-of-cardiac arrests.

## African relevance

- There is a risk of Covid-19 infection during aerosol generating procedures such as Cardiopulmonary resuscitation.
- Cardiopulmonary resuscitation quality depends on compression quality.
- Using personal protective equipment affects cardiopulmonary resuscitation quality.

## Introduction

The COVID-19 outbreak began in December 2019 in China and rapidly spread worldwide. The World Health Organization declared it as a pandemic on 11 March 2020 [1]. To prevent the spread of COVID-19 infection via contact and airborne transmission, healthcare professionals (HCPs) have been recommended to use personal protective equipment (PPE) [2,3]. In comparison with the use of standard uniforms, fatigue occurs earlier and more frequently with the use of PPE, especially during strenuous procedures [4,5]. Furthermore, symptoms, such as headache, could be observed owing to prolonged mask usage [6,7].

Cardiac compression, which is an important component of cardiopulmonary resuscitation (CPR), is a laborious procedure. The American Heart Association suggests switching of resuscitators every 2 min to prevent alterations in resuscitation quality [8]. Guidelines published after the outbreak recommends that the resuscitation of COVID-19-suspected or -positive patients should be done using a minimum number of resuscitators [9].

Prehospital HCP teams responding to emergencies mostly consist of two CPR-capable personnel. An additional resuscitator is usually not available in out-of-hospital cardiac arrests. This study aimed to evaluate how the use of PPE impacts CPR quality in prehospital cardiac arrest situations.

## Methods

This prospective simulation study was conducted in the training

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room of a prehospital emergency health services. The study was conducted in accordance with the Helsinki Declaration and approved by a local ethics committee (decision number: 2020/06-73).

Physicians, nurses, and paramedics working at prehospital emergency health services at city centrum were invited to participate in the trial. Voluntary participants who (a) were already in charge and performed CPR routinely as part of their job, (b) those who had an experience with advanced cardiac life support training in the recent year, (c) those who had performed cardiac resuscitation at least 10 times, and (d) those who had used PPE at least 10 times and were currently eligible for

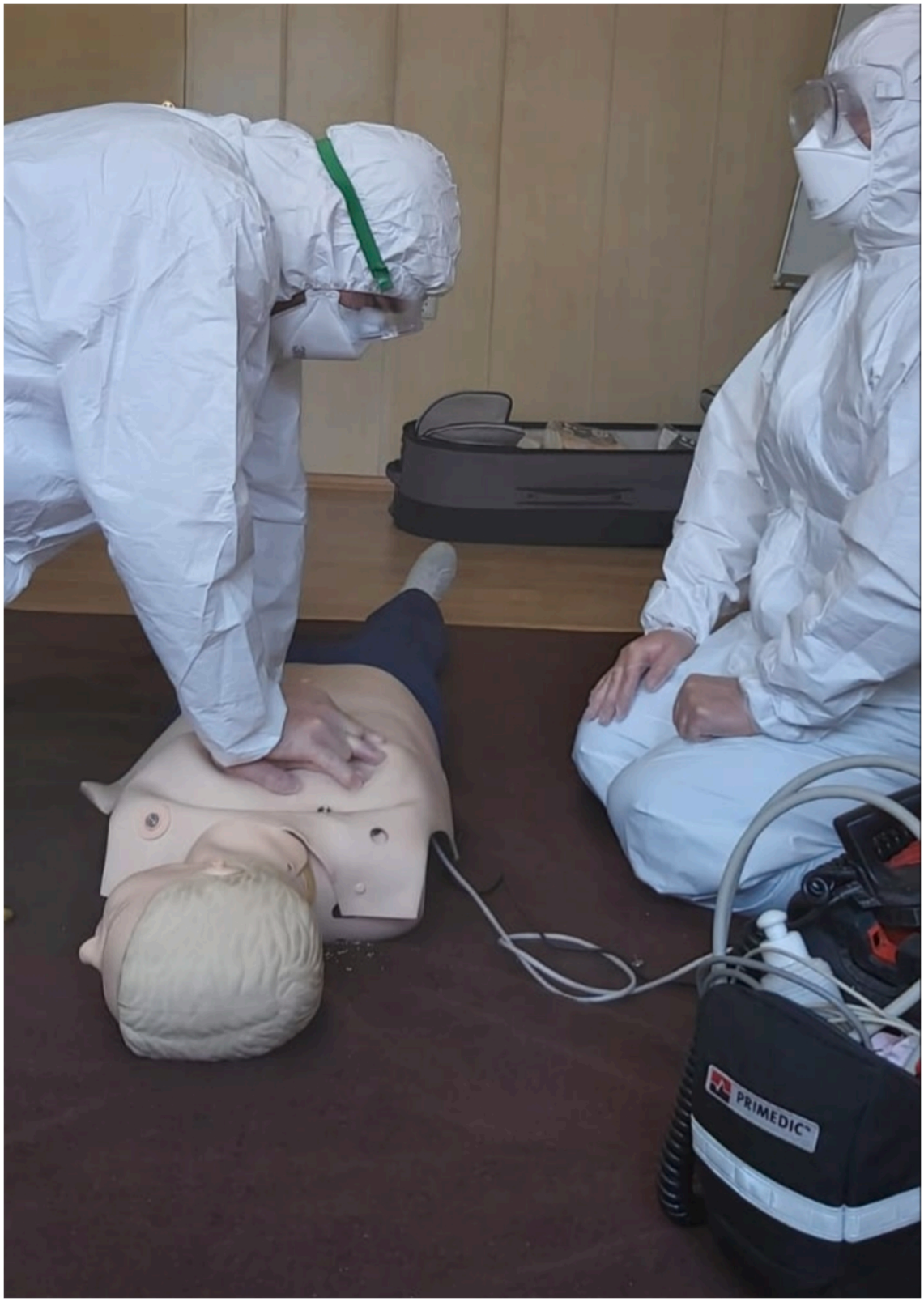


**Fig. 1.** A participant performing CPR with PPE.

PPE usage were included in this study. The participants provided written informed consent and were not paid any compensation.

The study focused on the efficiency of the participants to perform cardiac compression with and without using PPE. Participants were numbered in accordance with the consent time order, and 38 teams consisting of two participants in each team were established. All participants completed both sessions with the same teammate to ensure standardization. The study was completed in eight days (four days with PPE and four days without PPE) in the same training room, which had an automatic air conditioning at a constant temperature of 24 °C. Participants were reminded that the compression rate should be 100–120/min and depth should be at least 5 cm or 1/3rd the depth of the chest, in line with the recommendations provided by the American Heart Association [7]. The manikin used in the study (Resusci Anne QCPR Manikin, LaerdalMedical, Orpington, UK) was positioned on the floor simulating prehospital conditions. To ensure standardization, the cardiac rhythm was considered asystole and neither was endotracheal intubation or ventilation performed nor was any medication administered. A metronome program (provided by Google for Android devices) adjusted at 110 pulse/min was used along with compression.

Each team was asked to perform cardiac compression for 20 min with a switching provider every 2 min. A device attached to the manikin (Simpad Plus with Skill Reporter, Laerdal Medical, Orpington, UK) recorded the number of compressions per minute, mean compression depth, adequate depth rate, fully released compression rate, correct hand positioning, and mean compression score. Mean arterial blood pressure (MAP), heart rate (HR), and oxygen saturation ($SpO_2$) parameters of participants were measured before and after sessions with and without PPE. Participants were asked to rate their degree of fatigue after compression between 0 (no tiredness) and 10 (exhausted). Furthermore, participants were asked to state what they considered as the most disturbing feature of PPE during compression.

PPE utilised in this study included a respiratory mask (a disposable FFP3 mask, without valve, 3M Company, Minnesota, USA), goggles (Baymax S-1551, Bayem Group Company, Istanbul, Turkey), a coverall (Safetouch TP63 5/6 classic disposable protective coverall, Safetouch Ltd., Istanbul, Turkey), and a nonsterile pair of gloves (examination gloves without powder, Beybi AŞ, Istanbul, Turkey), which are currently being used by prehospital HCPs (Fig. 1).

Data obtained from the manikin, measured physiological values, fatigue levels, personal opinions, age, sex, occupation, and body mass index (BMI) of participants were recorded. The measured physiological values, fatigue levels, age, and BMI values were recorded as the mean value of two participants in each team.

Data were analysed using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA). Visual (histogram and probability graphs) and analytical methods (Kolmogorov–Smirnov or Shapiro–Wilks tests) were used to determine distribution normality. Descriptive statistical data for normally distributed variables were expressed as mean ± standard deviation values, whereas categorical variables were expressed as frequency and percentages.

Cardiac compression data and physiological values were compared between the standard uniform and PPE groups using the paired-sample *t*-test. The relationship among age, BMI, and differences in compression and fatigue scores were analysed using Pearson's and Spearman's correlation test. A p-value of <0.05 was considered to be statistically significant.

## Results

A total of 76 (38 compression team members) prehospital HCPs participated in the study. All participants completed both sessions. Their characteristics are summarised in Table 1. The mean participant age was 30.07 ± 4.2 years, and a majority were males (55.3%, n = 42).

Table 2 presents the main results of this study. The mean compression rate was 117.71 ± 8.27/min without PPE and 115.58 ± 9.02/min with PPE (p = 0.191). The overall compression score was 86.95 ± 4.39 without PPE and 61.89 ± 14.43 with PPE (p < 0.001).

There was no significant difference in the MAP, HR, and $SpO_2$ values measured before both sessions (p = 0.693, p = 0.663, and p = 0.600, respectively). MAP, HR, and $SpO_2$ values measured after sessions were significantly different compared from the values measured before sessions (p < 0.001, p < 0.001, and p < 0.05, respectively). The physiological values measured before and after both cardiac compression sessions are summarised in Table 3.

Post-cardiac compression fatigue score was 4.42 ± 0.5 when HCPs used standard uniform and 7.74 ± 0.92 when HCPs used PPE (p < 0.001). The overall difference in compression scores between the two conditions was 25.05 ± 11.74, and the difference in fatigue score was 3.31 ± 0.98. There was a statistically significant correlation between mean compression score difference, fatigue score difference and BMI (Table 4). The most common disturbing factor while performing cardiac compression using PPE was breathing difficulty (n = 27, 35.5%),

**Table 1**
Demographic characteristics of study participants.

| | |
|---|---|
| Age, years, mean ± SD | 30.07 ± 4.2 |
| Male gender, n (%) | 42 (55.3) |
| Body mass index, kg/m$^2$, mean ± SD | 25.83 ± 2.3 |
| Physician, n (%) | 26 (34.2) |
| Nurse, n (%) | 18 (23.7) |
| Paramedic, n (%) | 32 (42.1) |

**Table 2**
Comparison of standard uniform and personal protective equipment.

| | Standard uniform | PPE | p value |
|---|---|---|---|
| Overall compression score, mean ± SD | 86.95 ± 4.39 | 61.89 ± 14.43 | <0.001 |
| Correct hand position, mean ± SD | 94.03 ± 4.20 | 93.76 ± 4.35 | 0.773 |
| Fully released compressions, mean ± SD | 88.11 ± 5.40 | 64.71 ± 11.15 | <0.001 |
| Deep enough compressions, mean ± SD | 69.26 ± 8.36 | 60.21 ± 9.60 | <0.001 |
| Mean rate, mean ± SD | 117.71 ± 8.27 | 115.58 ± 9.02 | 0.191 |
| Fatigue score, mean ± SD | 4.42 ± 0.5 | 7.74 ± 0.92 | <0.001 |

PPE, personal protective equipment.

**Table 3**
Comparison of physiologic variables before and after each compression session.

| | MAP, mm Hg, mean ± SD | p value | HR, per minute, mean ± SD | p value | $SpO_2$, %, mean ± SD | p value |
|---|---|---|---|---|---|---|
| Standard uniform | | <0.001 | | <0.001 | | <0.001 |
| Pre-CC | 92.28 ± 2.2* | | 81.5 ± 2.6^ | | 98.5 ± 0.9& | |
| Post-CC | 94.86 ± 2.6° | | 101.23 ± 2.9° | | 97.63 ± 1.3§ | |
| PPE | | <0.001 | | <0.001 | | <0.001 |
| Pre-CC | 92.34 ± 2.2* | | 81.71 ± 4.6^ | | 98.55 ± 0.9& | |
| Post-CC | 99.36 ± 2.8° | | 109.21 ± 5.9° | | 97.36 ± 1§ | |

CC, chest compression; HR, heart rate; MAP, mean arterial blood pressure; $SpO_2$, oxygen saturation; PPE, personal protective equipment; $SpO_2$, oxygen saturation.
* p = 0.693.
^ p = 0.663.
& p = 0.600.
° p < 0.001.
§ p = 0.039.

**Table 4**
Correlations between age, BMI, overall compression score difference and fatigue score difference.

| | Correlation coefficient | p value |
|---|---|---|
| Age – overall compression score difference | 0.410 | <0.05 |
| Age – fatigue score difference | 0.478 | <0.01 |
| BMI – overall compression score difference | 0.552 | <0.001 |
| BMI – fatigue score difference | 0.884 | <0.001 |
| Gender – overall compression score difference | −0.141 | 0.398 |
| Gender – fatigue score difference | 0.190 | 0.252 |
| Overall compression score difference – fatigue score difference | 0.566 | <0.001 |

BMI, body mass index.

followed by sweating (n = 19, 25%) and fogging (n = 15, 19.7%).

## Discussion

This study suggests that PPE usage reduces compression depth, adequate depth rate, fully released compression rate, and mean compression quality, whereas compression speed remains unaffected.

Previously published studies have investigated the effects of PPE usage on CPR quality [4,5]. The compression sessions performed by 40 anesthesiologists were limited to only 2 min in the study conducted by Chen et al. [4]. In another study conducted with paediatric size manikins, compression sessions lasted for 5 min [5]. Kienbacher et al. determined the CPR time as 12 min in their study [10]. The duration of compression sessions in these studies were considerably shorter than the actual CPR duration. Kim et al. analysed 41,054 out-of-hospital cardiac arrest cases and found that while 21.2% of the patients were transferred to a hospital within eight to 12 min, the transfer of 21.9% patients took greater than or equal to 12 min. Regions with more rural populations will probably have longer transfer times [11]. A study conducted in Turkey reported that the mean hospital arrival time for traumatic cardiac arrest cases was 19 min [12]. We determined the duration of compression sessions to be 20 min, which is similar to actual cardiac arrest cases, and revealed the effects of PPE more accurately.

Chen et al. reported that PPE usage reduces the parameters of compression rate, compression depth, and fully released compression rate [4]. In another study, it has been reported that the quality of CPR decreases with improved mask quality [13]. Donoghue et al. reported that there was no deterioration in CPR quality relevant to PPE usage in their study involving paediatric manikins [5]. In a recent study, Kienbacher et al. demonstrated that the use of PPE did not cause any deterioration in compression quality [10]. Shekhar et al. reported that compared with the return of spontaneous circulation (ROSC) rates three years ago, the ROSC rates were lower in out-of-hospital cardiac arrest cases during the pandemic (49% to 42.9%, respectively). The reasons for this worsening may be the anxiety of transmission to prehospital HCPs and the impact of PPE usage on CPR quality [14]. Our results support this hypothesis. In our study, we noticed deteriorations in the mean compression depth, adequate depth rate, fully released compressions, and mean compression quality associated with PPE usage. These results may contribute to the low ROSC rates in prehospital cardiac arrest cases. In hospitals, the decline in CPR quality can be prevented by the participation of more than two rescuers in chest compression. By increasing the number of prehospital HCPs who are capable of performing CPR, the decline in CPR quality can be prevented.

Personal protective equipment usage is required for preventing transmission to HCPs and thereby ensuring uninterrupted medical care during pandemic [3]. On the other hand, prolonged PPE usage can cause tiredness and reduce physical capacity. Fikenzer et al. indicated remarkable negative impacts of surgical masks and more featured masks on the cardiopulmonary capacity of healthy volunteers [15]. Body temperature, heart rate, respiratory rate, and partial carbon dioxide pressure have been reported to increase with the use of N95 masks [16–19]. Waterproof isolation clothes cause discomfort to users [20]. In recent studies, it was reported that 66% of HCPs developed new-onset symptoms associated with PPE and the most common symptom was a headache [6,7]. In our study, participants had a significantly higher MAP and HR levels and significantly lower $SpO_2$ levels after performing cardiac compression while using PPE than without using PPE. Although the values measured after PPE sessions seem physiologically acceptable, they might be the cause of participants' complaints such as breathing difficulty.

In a study conducted using paediatric manikins, subjective fatigue levels of participants significantly increased on using PPE; however, this fatigue did not influence compression quality [5]. The resistance against cardiac compression could be lesser on paediatric manikins compared to that on adult manikins. In a recent study, subjective fatigue levels were higher with PPE sessions, but did not deteriorate compression quality [10]. In our study, fatigue levels increased while compression quality decreased concomitantly in the compression sessions when PPE was used. Moreover, compression quality and fatigue levels had a correlation with age and BMI. Considering the transfer time for prehospital arrest cases and the fact that these teams involve only two rescuers, fatigue would be excessive, which would thereby affect compression quality.

Mechanical compression devices could be an alternative option to prevent any alterations in the compression quality caused by fatigue. Because of technological advancement, new devices are being developed which take up more frequently utilised in daily clinical practice. It has been shown that the use of mechanical compression devices for in-hospital cardiac arrests increases 30-day survival [21]. American Heart Association announced an update after the COVID-19 pandemic and recommended minimizing personnel numbers and using mechanic compression devices during CPR [9]. Similarly, we believe that the decline in compression quality and increase in rescuer fatigue could be prevented with mechanic compression devices and recommend the use of these devices for resuscitations that require HCPs to use PPE.

The most important limitation of this study is simulation-based structure. The manikin utilised in this trial has standard sizes, dimensions, and anatomy, whereas real patients may have different physical features. In addition, our study was conducted in a room with only participants and observers present. Intervention to the manikin would likely cause less emotional distress compared with intervention in a traveling ambulance or in an environment with members of the public. Another limitation is that participants were not asked to undertake airway or pharmaceutical intervention during the study. Difficulties encountered with airway management and medication may lead to unintended interruptions or delayed provider rotation.

Performing CPR with PPE causes much increased fatigue and decreased compression quality when compared to CPR with standard uniform. During the pandemic, increasing the number of CPR capable HCPs in prehospital teams may prevent the decline in CPR quality. Routine use of mechanical compression devices should be considered for cardiac arrests especially during prehospital or inter-hospital transfer circumstances in which an extra rescuer is not available.

## Dissemination of results

Results from this study were shared with authors only. The results were not published.

## Authorship contribution statement

Authors contributed as follow to the conception or design of the work; the acquisition, analysis, or interpretation of data for the work; and drafting the work or revising it critically for important intellectual content: MH contributed 45%; AÇ 40%; and İK, BÖ and KÖ contributed 5% each. All authors approved the version to be published and agreed to be accountable for all aspects of the work.

## Declaration of competing interest

The authors declare no conflict of interest.

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