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ORIGINAL RESEARCH **CPR / LIFE SUPPORT**

A mannequin based comparative study of quality of chest compression with or without personal protective equipment (PPE)

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Abstract

Background & Objective: The use of Personal Protective Equipment (PPE) is highly recommended during chest compression in COVID-19 patients, as it can generate aerosols. It was thought that quality of chest compression might be affected by the use of PPE. We compared the quality of chest compression with or without PPE using a mannequin to formulate practical recommendations.

Methodology: This observational analytical study used randomised crossover design, and was carried out in Cipto Mangunkusumo National General Hospital from December 2020 to July 2021. After a thorough assessment, a total of 92 samples fulfilled the inclusion and exclusion criteria. The chosen participants were postgraduate residents, and they were asked to do chest compression on a mannequin with (Group-I) and without PPE (Group-II) and with breaks in between. The quality of CPR was measured using feedback tool CPR R Series® Monitor (Zoll Inc., USA). After a break the groups were crossed over and re-evaluated.

Results: Sixty-five (35.3%) non-PPE participants did quality compression, but only 16 (8.7%) did quality compression when using PPE ($P < 0.001$). Effective compression was done by 80 (43.5%) of the non-PPE participants, compared to 61 (33.2%) participants doing the compression effectively when using PPE ($P = 0.002$). Eighty-two (44.6%) non-PPE participants did adequate compressions compared to 61 (33.2%) participants when using PPE ($P < 0.001$). Meanwhile, the post-compression fatigue level was 7 (6.00-9.00) when using PPE compared to 5 (3.00-7.00) when not using PPE ($P < 0.001$).

Conclusion: The use of PPE during chest compressions can reduce the quality of compression and increase the level of post-compression fatigue compared to performing chest compressions without PPE. PPE use was also associated with low levels of effectiveness, and adequacy of the chest compression.

Abbreviations: PPE - Personal Protective Equipment; CPR – Cardiopulmonary resuscitation; AHA - American Heart Association; ERC - European Resuscitation Council

Key words: Cardiopulmonary Resuscitation / methods; Clinical Competence; Compression; COVID-19; Emergency Service, Hospital; Feedback; Heart Massage / methods; Humans; Out-of-Hospital Cardiac Arrest / therapy; PPE; resuscitation, post-compression fatigue; Treatment Outcome

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1. Introduction

In a tertiary hospital based retrospective study from Wuhan, China, it was shown that among 136 patients with cardiac arrest who underwent cardiopulmonary resuscitation (CPR), 87.5% of the subjects suffered from cardiac arrest due to respiratory problems.[1] Another study included 138 hospitalized COVID-19 patients, out of which 16.7% patients had arrhythmias and 7.2% had acute cardiac injury.[2] Cardiac arrest survival rates depend upon the early recognition, prompt activation of the emergency system and the quality of CPR. A poor-quality CPR provides 10-30% of blood flow to the heart and 30- 40% blood flow to the brain, despite the procedure being performed according to the guidelines. According to American Heart Association (AHA), a high-quality CPR is identified to include (1) chest compression rate of 100-120 times per min; (2) depth of chest compressions by 5 to 6 cm; (3) chest recoiling after each compression; and (4) adequate ventilation.[3]

For CPR of a suspected or confirmed COVID-19 patient, personal protective equipment (PPE) level III (includes coverall jumpsuit, face shield, goggles, N95 mask, surgical mask, boot, scrub, and two layered gloves) is required, as this procedure generates aerosols. Airborne transmission can occur during aerosol procedures, such as intubation, bagging, tracheostomy, cardiac and pulmonary resuscitation. For this reason, the European Resuscitation Council (ERC) recommended the use of PPE for preventive measures to prevent the occurrence of airborne transmission when performing chest compressions in these patients.[4] Several studies have found that healthcare workers (HCW) who wore full PPE (level III) resulted with a poor-quality chest compression. Research done by Kim et al. and Chen et al. showed the use of PPE resulted in less effective and inadequate chest compression. The group using PPE revealed higher heart rates, mean arterial pressures (MAP), and subjective fatigue scores.[5]

Both AHA and ERC guidelines stress the avoidance of delay in starting chest compressions, but to keep the safety of individual in view.[6] The use of PPE may cause delay, and affect quality effectiveness, and adequacy of the chest compressions, thus impacting the patient survival.[7]

We compared the quality of chest compression, regarding the quality, effectiveness and adequacy of chest compression in mannequins, performed with or without PPE to create practical recommendation.

2. Methodology

This observational analytical study, used a randomized crossover model, and compared the quality of chest compression on mannequins with and without PPE. The research was approved by Faculty of Medicine Universitas Indonesia - Cipto Mangunkusumo National General Hospital Research Ethics Committee (Approval Number KET-33/UN2.F1/ETIK/PPM.00.02/2021). All research subjects were given detailed description of the study and were asked to sign an informed consent.

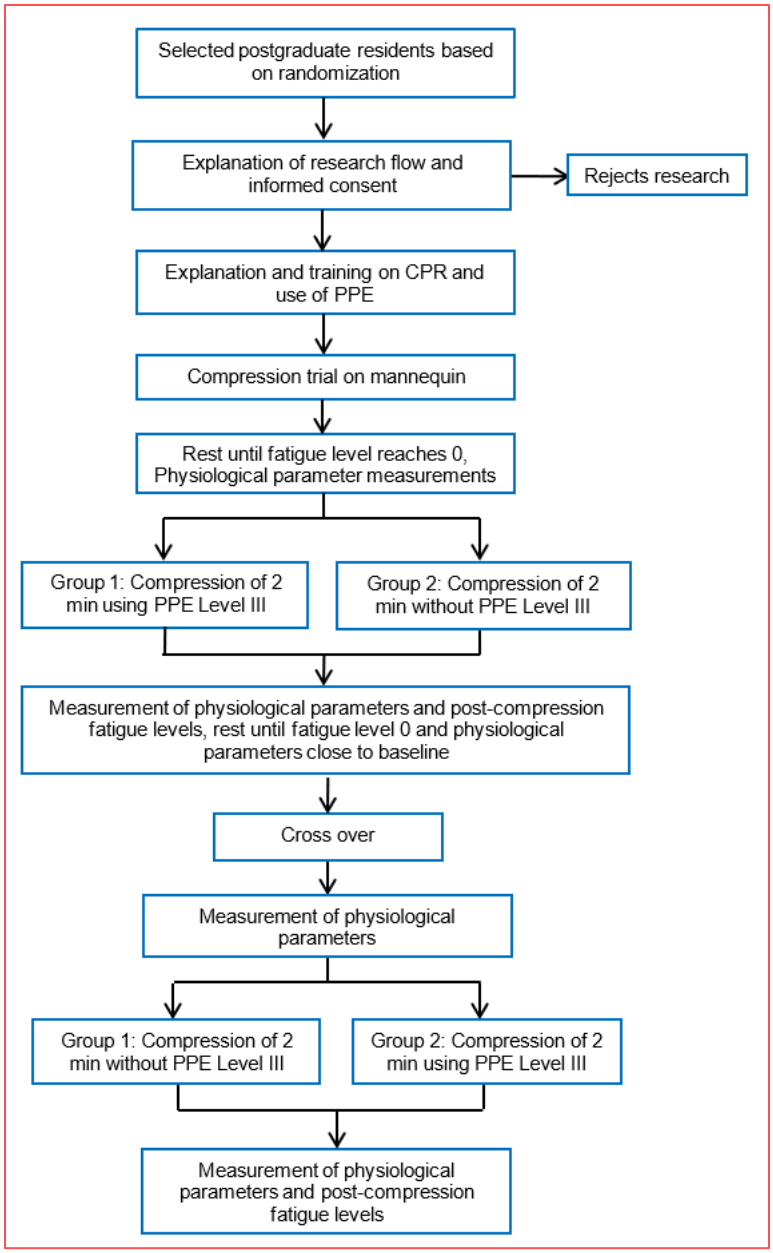
The research was conducted from December 2020 to July 2021, at Cipto Mangunkusumo National General Hospital. Postgraduate residents of the hospital, who met the inclusion and exclusion criteria were recruited for this study. Inclusion criteria consisted of all postgraduate residents who had passed the CPR exam, and exclusion criterion was refusal to participate in the study.

Considering the viability and the minimum potential harm towards subjects, convenient sampling was carried out, and all residents who had passed the CPR examination, were enrolled in the study, resulting a total of 92 participants for 2 groups. The samples obtained were randomly allocated into two groups. The PPE group of this study included the subjects who used PPE, while the control group included those who performed without PPE. For data collection, calibration was carried out on the R Series® Monitor/Defibrillator device (Zoll inc., USA) connected to the CPR mannequin placed on the floor. Measurement of physiological parameters were carried out in the form of non-invasive blood pressure, pulse rate, respiratory rate, oxygen saturation, and fatigue level.

Subjects were divided into two groups, Group-I performed chest compression for 2 min using PPE level III, while the Group-II performed chest compression without using PPE. Both groups were subjected to certification and briefed regarding the procedure. Physiological parameters were evaluated for every participant. The chest compressions were performed on the floor in a kneeling position. After chest compressions for 2 min, physiological parameters and fatigue levels were re-evaluated. The level of fatigue was assessed according to the subjective assessment using the VAS (0 to 10). Subjects were asked to rest until fatigue level reached 0 and the physiological parameters were re-evaluated. After the fatigue level reached 0, the groups were crossed over; the first group performed chest compression without using PPE, while the second group performed chest compression using PPE level III for 2 min (Figure 1). After chest compressions for 2 min, physiological parameters and fatigue levels were re-evaluated. The level of fatigue was assessed according to the subjective assessment using the VAS (0 to 10).

Statistical analysis

Data from CPR R Series® Monitor/Defibrillator (Zoll inc, USA) was transferred to a computer followed by analysis of results.



Data were collected and analyzed using SPSS version 20. Data characteristics were presented in the form of descriptive distribution of the proportion of each characteristic. Research results were presented through tables and graphs. For each variable, bivariate analysis was carried out using chi-square test.

3. Results

Ninety-two subjects were randomized and allocated into two groups, with or without PPE Level III. The age range of the subjects was 26 to 40 y. Other characteristics of subjects are presented in Table 1.

A significant difference was found between the use of PPE and the quality of compression, effectiveness of compression, and adequacy of compression. The results are shown in Table 2. Paired bivariate analysis was done with chi-square test to determine the difference between the use of PPE and the quality of compression. Compared to the group using PPE, the outcome depicts statistically significant results between quality of compression, adequacy of compression, and effectiveness of compression when PPE was not used.

here was a significant difference in average level of post-compression fatigue in both groups ($P < 0.001$) with a tendency of a higher-level fatigue in the group using PPE (Table 3).

Additionally, chi-square test was used to compare the quality of compression of two groups. Mann Whitney U test was used to analyze and compare the fatigue level of both crossover groups. Results show that there was a significant difference between the quality of compression and post-compression fatigue levels in both groups (Table 4).

In this study, the subjects were given time to rest, at 0 fatigue level, before performing compression. This was considering the possible differences in activity before carrying out the research flow and eliminating learning bias and previous post-compression fatigue. This study showed that the difference in physiological parameters of pre-chest compression between the two groups, with and without PPE, was negligible as the entire study sample had rested to 0 before compression. The description of pre-compression physiological parameters when using PPE and without PPE can be seen in Table 5.

Results depict a difference in systolic blood pressure, pulse rate, respiratory rate, oxygen saturation, and level of fatigue during compression between the two groups (Table 5).

4. Discussion

This study compared the use of PPE in HCW when performing chest compressions on mannequin. Data have shown a higher number of male subjects compared to female subjects. A study by Rodriguez M et al. compared the physiological tolerance on gender basis using PPE during cardiac resuscitation.[8] The author concluded that no correlation was found between the gender and physiological tolerance. Anthropometric

Table 1. Characteristics of subjects

Variable		N (%)
Age (y)	26-30	48 (52.2)
	31-35	37 (40.2)
	36-40	7 (7.6)
Gender	Male	60 (65.2)
	Female	32 (34.8)
Level	Preparation	24 (26.1)
	Internship	26 (28.3)
	Independent	42 (45.7)
BMI (kg/m^2)	< 18.5	3 (3.3)
	18.5-24.9	47 (51.1)
	25-29.9	36 (39.1)
	≥ 30	6 (6.5)

Table 2: Comparison of quality, effectiveness, and adequacy of compression of subjects with or without PPE level III

Parameter		Without PPE	With PPE	P-value
Compression quality	Low	27 (14.7)	76 (41.3)	< 0.001*
	High	65 (35.3)	16 (8.7)	
Effectiveness	No	65 (35.3)	31 (16.8)	0.002*
	Yes	80 (43.5)	61 (33.2)	
Adequacy	Non-Adequate	10 (5.4)	31 (16.8)	< 0.001*
	Adequate	82 (44.6)	61 (33.2)	

Data presented as n (%)

Table 3: Comparing fatigue levels of both groups with and without PPE

Participants	Post-compression level of fatigue	P-value
Non-PPE, n (%)	5.00 (3.00-7.00)	< 0.001
PPE. n (%)	7.00 (6.00-9.00)	

Data presented as n (%)

parameters play an important role when facing with physiological body stress. An increased physical activity to move more energy was required, leading to an increase in muscle mass and a decrease in body fat.[9] The increase in energy demand will affect the body's physiological parameters such as blood pressure, pulse rate, frequency breath, body temperature, and oxygen saturation.

To perform high-quality chest compressions, it is required to have a minimum compression depth of 51 mm and a rate of 100 compressions per min. A significant difference was found in the quality of compression when using PPE, and it resulted a lower percentage of depth compression. Due to the sample size, the p-values of the median chest compression rate and depth between the 2 groups were not calculated. Although the median value of the average compression rate in both the PPE and non-PPE groups were similar, the speed range was wider in the PPE group with a rate of less than 100 compressions per min.

In addition, several other factors may affect medical personnel when performing CPR. An increase in body temperature while performing CPR can cause the face shield to become cloudy and impairs vision, affecting speed and depth of compression. The decrease in auditory and visual sensation in the use of PPE may affect the quality of CPR to recall and maintain a proper CPR timing. Furthermore, studies have shown that physical exercise can reduce the incidence of decreased CPR efficiency by increasing the individual's physical capacity.[8] Resuscitation using PPE includes strenuous physical exercise, which increases blood pressure. At the end of physical exercise, the occurrence of vasodilation causes the body to experience redistribution of blood and lowers blood pressure. After 5-6 min of post-exercise, blood pressure will drop below the initial baseline and last up to 5-6 h.[10] These variations can occur due to the release of catecholamines when the body undergoes intense physical exercise, resulting in vasoconstriction and blood redistribution.[11] Towards the end of the measurement, individuals with decreased blood pressure, pulse rate, lactic acid, and body temperature, increased perfusion index and hemoglobin levels, have high physical exercise tolerance.[12] The HCW who use PPE also experience changes in thermoregulatory mechanisms. Due to the waterproof nature of PPE, HCW will sweat with no evaporation mechanism. The increase in blood flow to the skin (peripheral vasodilation) leads to an increase in heat dissipation outside the body. Continuous occurrence of strenuous physical activity will cause discomfort and eventually reduce HCW's attention and responsiveness.[13]

A short duration of high intensity physical exercise causes a relative lack of oxygen but produces more metabolic products, causing an increase in lactic acid

Table 4: Comparing quality of compression and level of post-compression fatigue level between group with and without PPE

Quality of compression (n = 92)	Group 1 (n = 46)	Group 2 (n = 46)	P-value
Quality of Compression, n (%)			
Low-quality compression	38 (41.3)	38 (41.3)	1.000*
High-quality compression	8 (8.7)	8 (8.7)	
Adequacy of compression, n (%)			
Non-adequate compression	16 (17.4)	15 (16.3)	1.000*
Adequate compression	30 (32.6)	31 (33.7)	
Effectivity of Compression, n (%)			
Average of non-effective compression	13 (14.1)	18 (19.6)	0.122*
Average of effective compression	33 (35.9)	28 (30.4)	
Post-compression fatigue level**	8.00 (7.00-9.00)	7.00 (6.00-9.00)	0.775

Group 1: Subjects without using PPE followed by a rest and continued compression using PPE.
Group 2: Subjects using PPE followed by a rest and continue compression without using PPE.
**Chi-square test. P < 0.05 was significant. **Average (Range)*

Table 5: Physiological parameters of pre and post compression of subjects with or without PPE

Physiological parameters	Pre-chest compression		Post-chest compression	
	PPE (n = 92)	Non-PPE (n = 92)	PPE (n = 92)	Non-PPE (n = 92)
SBP (mmHg)	119.00 (99.00-139.00)	119.00 (98.00-178.00)	149.00 (104.00-164.00)	140.00 (100.00-160.00)
DBP (mmHg)	77.50 (50.00-94.00)	71.00 (50.00-92.00)	90.00 (50.00-100.00)	90.00 (67.00-99.00)
HR (Beats/min)	80.50 (55.00-105.00)	80.00 (55.00-120.00)	110.00 (84.00-200.00)	100.00 (75.00-150.00)
RR (Breaths/min)	18.00 (16.00-22.00)	18.00 (16.00-22.00)	24.00 (18.00-28.00)	22.00 (18.00-26.00)
SpO_2 (%)	99.00 (94.00-99.00)	99.00 (97.00-99.00)	-	-

Data given as Median (Range); SBP: systolic blood pressure; DBP: Systolic blood pressure; HR: heart rate; RR: respiratory rate; SpO2: Oxygen saturation.

from glycolytic metabolism. Increased levels of lactic acid can reduce the body's ability to produce energy and muscle capacity, as fatigue can occur faster. Individuals that are trained with strenuous physical activity have higher threshold; hence, level of fatigue can be influenced by the habits of physical activity and lifestyle of HCW.[14-18]

The study identified a significant higher low-quality compression ratio when using PPE. Further analysis concluded a significant difference in the effectiveness of the compression. Subjects using PPE had the least effective compressions. Similarly, there was a significant difference in compression adequacy, in which the non-PPE group resulted in a higher proportion of adequate compressions. Lastly, a significant difference was found between the level of post-compression fatigue and the use of PPE, where the median fatigue levels were higher in the group using PPE.

The author used a crossover study design to minimize the risk of confounding factors, as all interventions were measure on the same subjects. This was an advantage as the required number of subjects was smaller compared to the standard parallel RCTs. Through a thorough analysis of results, there were subjects who did not perform adequate chest compression even without the use of PPE. Before the study was conducted, these subjects were screened out. The screening was to evaluate whether each participant have passed the CPR exam using a mannequin and feedback device that had been calibrated. Due to the time gap between passing the exam and the execution of study, several subjects did not perform adequate chest compressions. A longer intermediate period leads to a decrease in CPR skill; hence, each subject needs to be re-tested.

5. Limitations

There were some limitations in this study. First, this study focused on the effect of level III PPE as whole, not per component of PPE that may affect mobility, comfort and fatigue in different proportions. Second, we considered only the parameters of chest compressions, but not of ventilation. Performing simulated cardiac arrest on mannequins as an evaluation of the quality of chest compressions is still a controversial issue. The use of mannequin differs from the "real-life" situations where conditions such as apnea, unconsciousness, pulselessness cannot be perfectly portrayed. In these conditions, there is no sense of urgency that exists in the real setting. In "real-life" conditions, the subject may have worn PPE for longer durations. It is suggested to conduct a study with chest compression above 2 min in a "real-life" environment, which includes calculating the time required by healthcare worker to use PPE, patient intubation, administering medication, recording the resuscitation cycle, and others. Post-compression severe fatigue was found in subjects using PPE; thus, a minimum of 2 to 3 rescuers is recommended for a rapid switch over of compression and to allow sufficient rest time to maintain the quality of the next phase of compression.

6. Conclusion

The use of PPE during chest compressions can reduce the quality, effectiveness, and adequacy of the chest compression and increase the level of post-compression fatigue.

7. Acknowledgement

None.

8. Competing Interest

There are no competing interests for any authors.

9. Funding

No funding, either internal or external, was involved in this study.

10. Data availability

Numerical data are available on request.

11. Authors' contribution

SY and RF conceived the concept, planned the study. SY conducted study survey. AS and SY processed and analysed study data. RF and AS supervised the study. AS developed the theoretical framework. SY, RF and AS wrote the manuscript. All authors discussed the results and commented on the manuscript. SY submitted the study. SY, RF and AS revised the manuscript. RF and AS are the guarantors of the study.

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