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Clinical paper

# Effects of personal protective equipment on cardiopulmonary resuscitation quality and outcomes: A systematic review

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**Abstract**

**Background**: The impact of wearing personal protective equipment (PPE) during cardiopulmonary resuscitation (CPR) on CPR quality and patient outcomes is unclear. This systematic review aimed to examine whether wearing PPE during resuscitation affects patient outcomes, CPR quality and rescuer fatigue.

**Methods**: In this review registered in PROSPERO (CRD42022347746), we searched Medline, EMBASE and Cochrane library between 2000 and 2022. The inclusion criteria were studies: in actual or simulated cardiac arrest; comparing PPE with no PPE; and randomised controlled trials and observational studies with a English abstract. Risk of bias was assessed using Cochrane's Risk of Bias-2 and ROBINS-I tools and outcomes assessed with GRADE. We conducted a meta-analysis according to the study design. Quantitative data synthesis was done using a random-effect model incorporating the potential heterogeneity.

**Results**: A total of 17 simulation-based studies and 1 clinical study were included. All outcomes were judged to be very low certainty of evidence, subject to high risk of bias. The clinical study showed no difference in survival comparing enhanced and conventional PPE. Meta-analysis of 11 RCTs and 6 observational studies found no difference in CPR quality in rescuers wearing PPE compared with no PPE. Pooled rescuer fatigue was significantly worse in the PPE group (mean difference, 2.7 VAS score out of 10; 95% CI, 1.4–4.0).

**Conclusions**: PPE was not associated with reduced CPR quality or lower cardiac arrest survival. Rescuers wearing PPE may report more fatigue. This finding was mainly derived from simulation studies, additional clinical studies are needed.

**Keywords**: Cardiopulmonary resuscitation, Chest compression, Personal protective equipment

## Introduction

Cardiopulmonary resuscitation (CPR) may lead to aerosol generation, which is associated with a risk of transmission of some infections to rescuers. Studies report the transmission of diseases such as severe acute respiratory syndrome (SARS) and middle east respiratory syndrome (MERS) during CPR.[1,2] Therefore, international guidelines recommend that providers should wear appropriate PPE, including a gown and mask, when performing CPR.[3]

Two conflicting published systematic reviews investigate PPE's impact on CPR quality. One review suggests PPE significantly compromises the quality of chest compression during CPR,[4] while the other showed that using PPE was not associated with a reduced rate or depth of chest compressions.[5] Several studies have been pub-

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lished following these systematic reviews including outcomes such as fatigue.

The purpose of this systematic review was to compare CPR by rescuers wearing PPE with not wearing PPE or wearing an alternative strategy of PPE on CPR outcomes such as CPR quality, time to the procedure of interest, rescuer fatigue, and survival in any setting of cardiac arrest.

## Methods

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement[6] and the Cochrane handbook guidelines were followed during the design and implementation of the study. The study protocol was registered in PROSPERO (CRD42022347746). There were two discrepancies with the PROSPERO registration: the database search period and statistical test methods.

### *Search strategy*

The search strategy was developed by an information specialist and approved by the authors. Three databases (Medline, EMBASE and Cochrane library) were searched and the final database search was conducted on July 31, 2022. The key terms and search strategies used in the databases are presented in detail in Supplementary material A. The publication year was restricted from Jan 2000 to July 2022. Study selection was performed by 4 independent investigators (SC, ZN, NJ, AL) by reviewing the titles and abstracts of the studies using the Rayyan software.[7] Relevant publications subsequently underwent full-text independent review by authors and selected papers underwent data abstraction. All disagreements were resolved by discussion and consensus.

### *Study selection*

All studies on the association between CPR and PPE were included in this systematic review. PPE is equipment worn to minimize exposure to hazards that cause serious workplace injuries and illnesses.[8] In case of resuscitation, PPE mainly refers to equipment used by healthcare workers to reduce the transmission risk of suspected infection (e.g. COVID-19), such as masks, goggles, gowns, and powered air-purifying respirators (PAPR).

The inclusion criteria were: (1) studies addressing any setting of cardiac arrest performing CPR regardless of actual or simulated cardiac arrest, (2) studies comparing any rescuers donning PPE with no PPE or other types of PPE, (3) randomised controlled trials and observational studies (non-randomised controlled trials, interrupted time series, controlled before-and-after studies, cohort studies) and, (4) an English language abstract.

We excluded studies comparing the COVID-19 pandemic period to the period prior because there were many factors affecting survival and CPR quality other than wearing PPE. Studies investigating the protective effect of PPE and comparing CPR methods such as mechanical chest compression devices and rescuer change time while wearing PPE were excluded. Other publication types not providing a comparison of PPE, such as guidelines and review articles, were excluded.

### *Data extraction*

Data extraction was conducted by two independent authors (SC, ZN). If disagreement occurred, it was resolved by consensus. We extracted data regarding study information, study design, patient and rescuer characteristics, PPE used, comparison, outcome measures, and findings. Outcomes were rated by importance: survival to 1-month and return of spontaneous circulation (ROSC) was rated as critical; CPR quality, time to start CPR, rescuer fatigue, and neuropsychologic performance such as concentration and dexterity were regarded as important outcomes. The time to procedure outcomes was limited to basic life support interventions.

### *Risk of bias and certainty of evidence*

Two reviewers independently assessed the risk of bias for each study, and disagreements were resolved by consensus. The risk of bias of the randomised trials was assessed by Cochrane's Risk of Bias–2 tool,[9] and that of non-randomized studies was assessed by the Risk of Bias in Non-randomised Studies of Interventions (ROBINS-I) tool.[10] The level of certainty for the generated evidence was determined by the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) methodology using the GRADEpro GDT online open-access tool.

### *Data synthesis with meta-analysis*

Among the studies comparing PPE and no PPE, we conducted a meta-analysis when two or more studies reported the same outcome. Differences in outcomes between groups with and without the use of PPE were separately evaluated according to study design (RCT or observational study) via mean difference (MD) and their 95% confidence interval (CI). We used the $I^2$-statistic to detect heterogeneity. When the $I^2 > 60\%$ reflected significant heterogeneity. Pooled analyses were calculated using a random effect model because this method incorporates the influence of potential heterogeneity and retrieves a more generalized result. Publication bias was evaluated by visual inspection of funnel plots and the Egger's test. $P$-values <0.05 were considered statistically significant. RevMan (Version 5.4; Cochrane Collaboration, Oxford, UK) and the meta package in the R 4.03 software (The R Foundation for Statistical Computing, Vienna, Austria) were applied for meta-analysis and statistical analyses.

## Results

### *Search results*

Our search strategy identified 5,203 unique articles of which 26 were selected for full-text review. Of these, one clinical study[11] and 17 simulation studies (11 RCTs[12–22] and 6 non-RCTs[11,23–28]) were included (Table 1). In the case of studies comparing different types of PPE, meta-analysis was not performed because the types of PPE varied widely between studies. Meta-analysis was performed when two or more studies reported the same outcome, with 10 simulation studies (6 RCTs[15–17,19–21] and 4 non-RCTs[24-27]) comparing PPE to no PPE included (Fig. 1).

### *Characteristics of included studies*

The included studies were conducted from 10 countries including Austria,[17,18] Canada,[28] China,[15,22] Hungary,[12] Italy,[14,20,21] Korea,[11,19,27] Spain,[13,16] Sweden,[23] Turkey,[25,26] and USA.[24] Studies were published between January 2015 and May 2022. Various types of PPE were used during CPR; Level-B/C PPE in one study[24], Level-C in 4 studies,[15,19,20,27] Level-D in 5 studies.[11,16–18,25] PAPR was used in one study,[11] and 3 studies used only face masks.[12,22,26]

**Table 1 – Summary of included studies.**

| Author, year | Design | PPE | Patient | Rescuer, n | Comparison | Outcomes | Findings |
|---|---|---|---|---|---|---|---|
| Abelsson 2018 | Non-randomised, parallel | No accurate description | Adult manikin | Firefighter, 80 | PPE + self-contained breathing apparatus vs no PPE | Correctly performed ventilations, compression (%) | No difference |
| Bánfai 2022 | RCT, parallel | Mask only | Adult manikin | College student, 216 | Cloth mask vs surgical mask | CC depth, rate; fatigue: vital signs, subjective scale | Effectiveness of CC decreased significantly in both groups |
| Barcala-Fuelos 2021 | RCT, crossover | Glove, mask, glasses, apron | Adult manikin | Lifeguard, 14 | Full PPE vs basic PPE + plastic blanket (on-boat) | time to start CPR; CPR quality; perceived fatigue | Basic-PPE is significantly faster than Full-PPE, equally good quality |
| Cavallin 2022 | RCT, crossover | Gown, FP2 mask, gloves, hat, eye protection, shoe covers | Infant manikin | NICU consultant, pediatric resident and nurse; 48 | PPE vs no PPE | Time to start ventilation and compression | Using PPE delayed neonatal resuscitation procedures |
| Chen 2016 | RCT, crossover | Level C | Adult manikin | Anesthesiologist, 80 | PPE vs no PPE | Depth, rate, fatigue | PPE led to poorer quality CPR metrics and higher fatigue |
| Donoghue 2020 | Non-randomised, crossover | Level B (prehospital) or level C (hospital) | Pediatric manikin | EMS personnel, nurse, physician; 108 | Baseline vs PPE session up to 5 min | Depth, rate, release velocity, fatigue | No difference |
| Fernández-Méndez 2021 | RCT, crossover | Level D (coverall, face shield, goggles, surgical mask, KN95 mask, nitrile gloves and boot swabs) | Adult manikin | Nurse, physiotherapist, physician and EMT; 20 | PPE vs no PPE | % compressions at target depth, recoil and rate; % ventilations at target volume; physiologic response | No difference |
| Hacımustafaoğlu 2021 | Non-randomised, crossover | Level D | Adult manikin | Physician, nurse, paramedic; 76 | PPE vs no PPE | Depth, rate, recoil, fatigue score, physiologic variables | PPE associated with poorer CPR quality and higher fatigue rates |
| Kienbacher 2021 | RCT, crossover | Level D, with and without mask valve | Adult manikin | EMT, 48 (24 teams) | (a) no PPE, (b) PPE including a FFP2 mask with an expiration valve, (c) PPE including an FFP1 mask without an expiration valve | Depth, effective CC, hands-off time, fatigue | Despite a subjective increase in physical strain, the actual quality of CPR remains unchanged |
| Kienbacher 2022 | RCT, crossover | Level D, with and without mask valve | Adult manikin | EMT, 48 (24 teams) | Same as above | Concentration (d2 test), psychomotor strain (nine-hole peg test) | Attention and dexterity are not inferior when wearing PPE, including FFP2 masks |
| Kim 2016 | RCT, crossover | Level C | Adult manikin | EMT, 20 | PPE vs no PPE | Depth, rate, no flow time | PPE significantly increased hands-off time but increase adequate proportion of CC rate |
| Ko 2021 | Retrospective (before after) | Level D + PAPR | OHCA patients ($n$ = 130) | ED professional, 67 | Conventional PPE vs enhanced PPE (including PAPR) | ROSC, 1-month survival, perceptions to PPE use | Use of enhanced PPE did not alter patient outcomes |
| Mormando 2021 | RCT, parallel | Level C CBRNe PPE | Adult manikin | Senior resident, 36 | PPE vs no PPE | Depth, rate, release | No difference |

(*continued on next page*)

**Table 1 (continued)**

| Author, year | Design | PPE | Patient | Rescuer, n | Comparison | Outcomes | Findings |
|---|---|---|---|---|---|---|---|
| Rauch 2021 | RCT, crossover | FFP3 mask, safety glasses, gloves and gown | Adult manikin | EMT, 34 | PPE vs no PPE | Depth, rate, release, and number of effective chest compressions | No difference |
| Serin 2021 | Non-randomised, crossover | Mask only | Adult manikin | Physician, paramedic; 48 | No mask, surgical, FFR (filtering face-piece respirator), half-face mask | Depth, rate, effectiveness and fatigue | Masks other than surgical masks increase rescuer fatigue and negatively affect the quality of chest compression |
| Shin 2015 | Non-randomised, crossover | Level C | Adult manikin | EMT, 20 | PPE vs no PPE | Depth, rate | No difference |
| Tian 2020 | RCT, parallel | Mask only | Adult manikin | Doctor, nurse; 80 | N95 mask vs surgical mask | Depth, rate, chest recoil, fatigue | N95 mask increases fatigue and decreases CPR quality |
| Watson 2008 | Non-randomised, parallel | Gloves, N95 respirator, eyewear, gown | Adult manikin | Firefighter instructor, 58 | No gown vs standard gown vs modified gown | Time to vetilation and compression | Gown modification (pre-tied neck straps and longer waist ties that tie in front) reduce the time delay of standard gown in chest compression and ventilation |

CBRNe: chemical, biological, radiological, nuclear, and high yield explosives, CC: chest compression, CPR: cardiopulmonary resuscitation, ED: emergency department, EMT: emergency medical technician, FFP: filtering facepiece, Level B: Highest level of respiratory protection with a lower level of skin protection, Level C: Same level of skin protection as Level B with a lower level of respiratory protection, Level D: No respiratory protection and only minimal skin protection, OHCA: out-of-hospital cardiac arrest, PAPR: powered air purifying respirator, PPE: personal protective equipment, RCT: randomised controlled trial.

Most studies used adult manikins for CPR simulation, although pediatric[24] and infant[14] manikins were used in two studies. In addition, there were 13 studies comparing PPE to no PPE,[14–21,23–27] and 5 studies comparing effects between PPE types.[11–13,22,28] CPR providers also varied and included students,[12] lifeguards,[13] firefighters,[23,28] EMTs,[19,27] and in-hospital healthcare professionals.[11,14–16,20,22] Many studies used crossover design, while some used parallel comparison.[12,20,22,23,28] Simulated CPR length was varied from 2 min, 4 min,[19,27] 5 min,[24] 12 min,[17,18] and 20 min.[16,21,25] Standard CPR with ventilation was usually performed but some studies[12,15,22,24,25] simulated compression only CPR. A total of 22 outcomes were extracted from the included studies. The Supplementary material B shows the details of the risk of bias assessment. The outcomes included in the meta-analysis were evaluated as having very low certainty of evidence according to the GRADEpro tool (Supplementary material C).

### Findings of studies

Survival was reported in a before-after observational study[11] comparing conventional PPE ($n$ = 73, surgical mask, glove and gown) and enhanced PPE ($n$ = 57, complete bodysuit, boots, N95 respirator, and powered air-purifying respirator) in the emergency department. This study reported no difference in 1-month survival (conventional PPE 8.2% vs enhanced PPE 3.5%, adjusted OR = 0.38, 95% CI: 0.07–2.10; $P$ = 0.27) or ROSC (49.3% vs 43.8%, adjusted OR = 0.79, 95% CI: 0.38–1.67; $P$ = 0.54).

Among 15 simulation studies reporting various CPR quality measures, 8 studies[13,16,17,20,21,23,24,27] reported no difference in CPR quality by PPE group. Among the 6 studies[12,15,17,22,25,26] that reported rescuer fatigue, all but 1 study[12] reported an increase in fatigue in the PPE group. The time to starting compressions and ventilations was reported to be delayed with PPE in all of 3 studies.[13,14,28] Concentration and dexterity were measured in 1 study and were not inferior when wearing PPE.[18]

### Meta-analysis

Meta-analysis was performed for the following 7 outcomes (Fig. 2): chest compression depth (mm),[15,17,19–21,24–27] compression rate (per min),[15,17,19–21,24–27] percentage of appropriate compression depth,[15,16,19,21] appropriate compression rate,[15,16,19] appropriate chest recoil,[16,20] hands-off time,[16,19] and rescuer fatigue.[25,26]

There was no difference in key measures of CPR quality in rescuers wearing PPE compared with no PPE. However, pooled rescuer fatigue measured using the visual analogue scale in 2 observational studies was significantly worse in the PPE group (mean difference 2.7 VAS score out of 10; 95% CI, 1.4 to 4.0).[25,26] Among these outcomes, the appropriate percentage of chest recoil was higher in the PPE group by combining 2 studies. However, both studies showed no significant difference in chest recoil between groups.[16,20] This discrepancy resulted from the conversion process of median (IQR) values of the study to mean (SD).[20] A funnel plot showed no evidence of visual asymmetry in the plotted studies reporting compression depth and rate (Supplementary material D), and this was confirmed by Egger's test ($P$ = 0.65).

## Discussion

In this review and meta-analysis, we identified very low certainty evidence that wearing PPE does not impact survival and quality of CPR

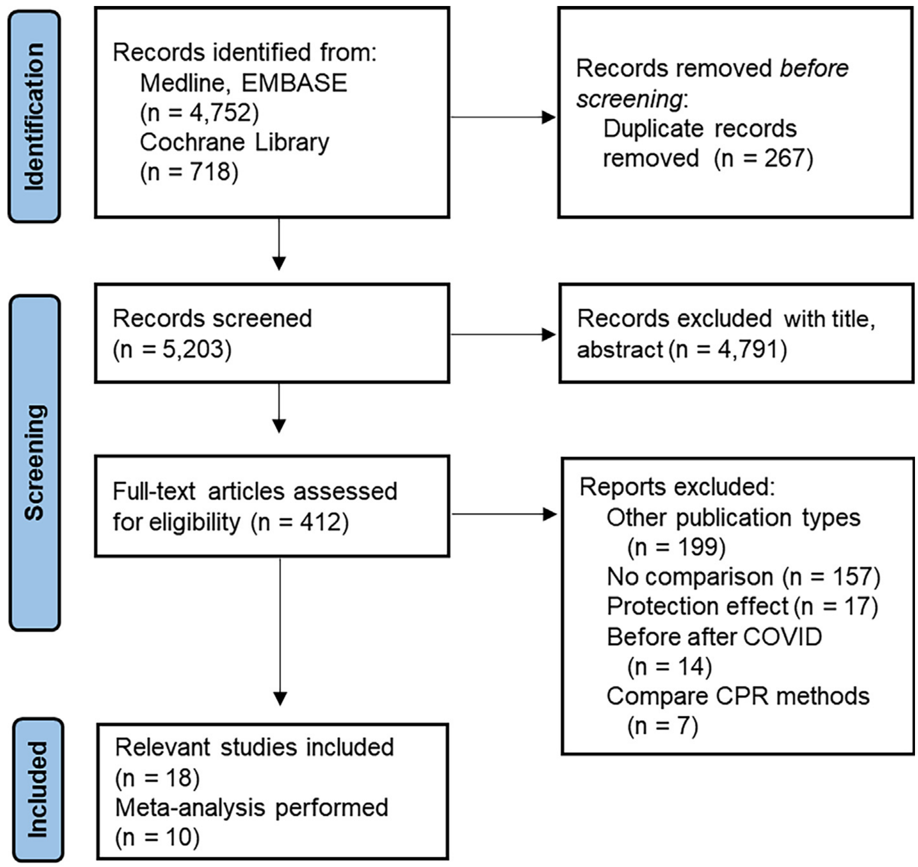


**Fig. 1 – PRISMA diagram for study selection.**

despite increasing rescuer fatigue. We compared several metrics of CPR quality, including compression depth and rate, appropriate compression depth and rate, hands-off time, and appropriate chest recoil, and found no difference in comparing rescuers wearing PPE and those without PPE.

Wearing PPE significantly increased rescuer fatigue. In addition to the 2 studies included in the meta-analysis, 4 more studies assessed rescuer fatigue during CPR. However, the study design, types of PPE used, and outcome measures were too varied to combine. For example, some studies reported fatigue using the Borg scale[29] ranging from "6" (no exertion) to "20" (maximal exertion), while other studies used the VAS scale. Five out of 6 studies showed an increase in fatigue in the PPE group. Rescuers wearing PPE may have more significant fatigue.

The delivery of chest compressions is physically tiring. The two studies included a meta-analysis reporting greater fatigue in the groups wearing PPE. CPR was performed in pairs, and the person performing chest compressions was changed every 2 minutes.[25,26] Although both studies reported worse CPR quality with PPE, the overall results of our meta-analysis show no effect on CPR quality. Furthermore, there is a lack of clinical studies examining the impact of PPE on patient outcomes. Some authors suggested an option to shorten CPR cycles while wearing PPE[30,31] by changing the rescuer every 1 minute. However, there is no evidence to support this change from international recommendations, we found no evidence that PPE influenced CPR quality and a shorter CPR cycle may also increase the hands-off time.[32] An ILCOR systematic review in 2019 also suggested against pausing chest compressions at intervals other than every 2 minutes to assess the cardiac rhythm.[33]

The studies included in this review were predominately simulation manikin-based studies and varied in the type of PPE, the design of simulated scenarios, the duration of CPR performed, and the measures of CPR quality used. We used a random effect model for pooled analyses because this method incorporates the influence of potential heterogeneity and retrieves a more generalized result.[34] A previous systematic review by Sahu et al.[4] which suggested that PPE significantly compromised CPR quality used fixed effect models, while another systematic review by Cui et al.[5] using random effect models reported no statistical difference in CPR quality according to PPE. As such, results should be interpreted carefully and may not be generalizable to the clinical setting.

Current knowledge gaps are as follows: the effect of PPE on patient outcomes; the impact of PPE on CPR quality in actual resuscitation; the relationship between PPE use, CPR duration, and rescuer fatigue; and the best type of PPE or appropriate modification strategies to mitigate rescuer fatigue. Since PPE is essential for infection prevention during CPR, future research should be focused on developing PPE that reduces transmission of infection, causes less fatigue for rescuers, and does not worsen CPR quality.

There are several limitations in this review. First, critical outcomes such as patient survival were identified in only one very low certainty study with only 130 patients. Second, we planned multiple subgroup analyses such as PPE types, adult vs pediatric, out-of-hospital vs in-hospital cardiac arrest, and CPR duration. However,

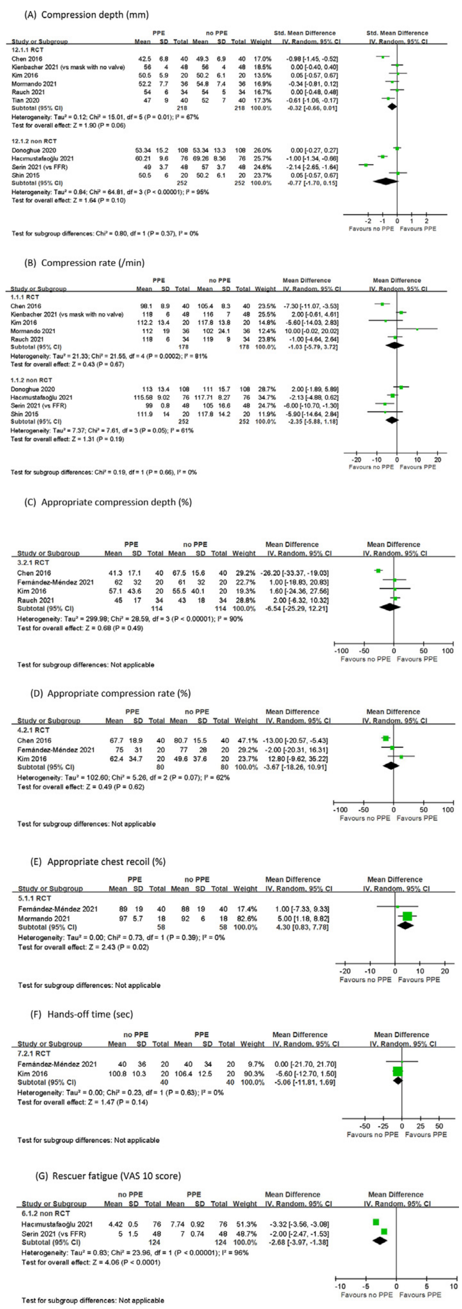


**Fig. 2 – Forest plots of CPR quality.**

due to the low number of studies, subgroup analyses were unable to be performed. Finally, the studies included in this review were predominately simulation manikin-based studies and varied significantly in the procedures used, including the type of PPE, the design of simulated scenarios, the duration of CPR performed, and the measures of CPR quality used. As such, results should be interpreted carefully and may not be generalisable to the clinical setting.

## Conclusion

In this review, using PPE was not associated with reduced CPR quality in simulation studies. At this time, there is insufficient data in the clinical setting, particularly on the time to interventions and patient outcomes. Although rescuers wearing PPE may fatigue more quickly with PPE, this finding was mainly derived from simulation studies, and requires confirmation in clinical studies. Increased vigilance of fatigue during CPR with PPE may be necessary.

## CRediT authorship contribution statement

**Sung Phil Chung:** Conceptualization, Formal analysis, Writing – original draft. **Ziad Nehme:** Data curation, Validation, Writing – review & editing. **Nicholas J. Johnson:** Investigation, Writing – review & editing. **Anthony Lagina:** Software, Validation, Writing – review & editing. **Janet Bray:** Supervision.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. JB is an Associate Editor of Resuscitation Plus.

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## Appendix A

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## Appendix B. Supplementary material

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## REFERENCES


1. Christian MD, Loutfy M, McDonald LC, et al. Possible SARS coronavirus transmission during cardiopulmonary resuscitation. Emerg Infect Dis 2004;10:287–93.
2. Nam HS, Yeon MY, Park JW, Hong JY, Son JW. Healthcare worker infected with Middle East Respiratory Syndrome during cardiopulmonary resuscitation in Korea, 2015. Epidemiol Health 2017;39:e2017052.
3. Perkins GD, Morley PT, Nolan JP, et al. International Liaison Committee on Resuscitation: COVID-19 consensus on science, treatment recommendations and task force insights. Resuscitation 2020;151:145–7.
4. Sahu AK, Suresh S, Mathew R, Aggarwal P, Nayer J. Impact of personal protective equipment on the effectiveness of chest compression - A systematic review and meta-analysis. Am J Emerg Med 2021;39:190–6.
5. Cui Y, Jiang S. Influence of Personal Protective Equipment on the Quality of Chest Compressions: A Meta-Analysis of Randomized Controlled Trials. Front Med (Lausanne) 2021;8 733724.
6. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372 n71.
7. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan-a web and mobile app for systematic reviews. Syst Rev 2016;5:210.
8. Occupational Safety Health Administration. Safety and Health Topics, Personal Protective Equipment. (Accessed 14 Feb, 2023 at https://www.osha.gov/personal-protective-equipment).
9. Sterne JAC, Savović J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ 2019;366 l4898.
10. Sterne JA, Hernán MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ 2016;355 i4919.
11. Ko HY, Park JE, Jeong DU, et al. Impact of Personal Protective Equipment on Out-of-Hospital Cardiac Arrest Resuscitation in Coronavirus Pandemic. Medicina (Kaunas) 2021;57.
12. Bánfai B, Musch J, Betlehem J, et al. How effective are chest compressions when wearing mask? A randomised simulation study among first-year health care students during the COVID-19 pandemic. BMC Emergency Medicine 2022;22.
13. Barcala-Furelos R, Abelairas-Gómez C, Alonso-Calvete A, et al. Safe On-Boat Resuscitation by Lifeguards in COVID-19 Era: A Pilot Study Comparing Three Sets of Personal Protective Equipment. Prehosp Disaster Med 2021;36:163–9.
14. Cavallin F, Lupi F, Bua B, Bellutti M, Staffler A, Trevisanuto D. Impact of personal protective equipment on neonatal resuscitation procedures: a randomised, cross-over, simulation study. Arch Dis Child Fetal Neonatal Ed 2022;107:211–5.
15. Chen J, Lu KZ, Yi B, Chen Y. Chest Compression With Personal Protective Equipment During Cardiopulmonary Resuscitation: a Randomized Crossover Simulation Study. Medicine 2016;95:e3262.
16. Fernández-Méndez M, Otero-Agra M, Fernández-Méndez F, et al. Analysis of Physiological Response during Cardiopulmonary Resuscitation with Personal Protective Equipment: A Randomized Crossover Study. Int J Environ Res Public Health 2021;18.
17. Kienbacher CL, Grafeneder J, Tscherny K, et al. The use of personal protection equipment does not impair the quality of cardiopulmonary resuscitation: A prospective triple-cross over randomised controlled non-inferiority trial. Resuscitation 2021;160:79–83.
18. Kienbacher CL, Grafeneder J, Tscherny K, et al. The use of personal protection equipment does not negatively affect paramedics' attention and dexterity: a prospective triple-cross over randomized controlled non-inferiority trial. Scand J Trauma Resusc Emerg Med 2022;30:2.
19. Kim T, Kim C, Shin S, Haam S. Influence of personal protective equipment on the performance of life-saving interventions by emergency medical service personnel. Simulation 2016;92:893–8.
20. Mormando G, Paganini M, Alexopoulos C, et al. Life-Saving Procedures Performed While Wearing CBRNe Personal Protective Equipment: A Mannequin Randomized Trial. Simul Healthc 2021;16:e200–5.
21. Rauch S, van Veelen MJ, Oberhammer R, et al. Effect of wearing personal protective equipment (Ppe) on cpr quality in times of the covid-19 pandemic—a simulation, randomised crossover trial. J Clin Med 2021;10.
22. Tian Y, Tu X, Zhou X, et al. Wearing a N95 mask increases rescuer's fatigue and decreases chest compression quality in simulated cardiopulmonary resuscitation. Am J Emerg Med 2021;44:434–8.
23. Abelsson A, Lundberg L. Cardiopulmonary resuscitation quality during CPR practice versus during a simulated life-saving event. Int J Occup Saf Ergon 2018;24:652–5.
24. Donoghue AJ, Donoghue AJ, Henretig FM, et al. Impact of personal protective equipment on pediatric cardiopulmonary resuscitation performance: A controlled trial. Pediatr Emerg Care 2020;36:267–73.
25. Hacımustafaoğlu M, Çağlar A, Öztürk B, Kaçer İ, Öztürk K. The effect of personal protective equipment on cardiac compression quality. Afr J Emerg Med 2021;11:385–9.
26. Serin S, Caglar B. The Effect of Different Personal Protective Equipment Masks on Health Care Workers' Cardiopulmonary Resuscitation Performance During the Covid-19 Pandemic. J Emerg Med 2021;60:292–8.
27. Shin D, Kim S, Shin S, et al. Effect of wearing personal protective equipment on cardiopulmonary resuscitation: Focusing on 119 emergency medical technicians. Korean J Emerg Med Serv 2015;19:19–32.
28. Watson L, Sault W, Gwyn R, Verbeek PR. The "delay effect" of donning a gown during cardiopulmonary resuscitation in a simulation model. Can J Emerg Med 2008;10:333–8.
29. Lopes TR, Pereira HM, Silva BM. Perceived Exertion: Revisiting the History and Updating the Neurophysiology and the Practical Applications. Int J Environ Res Public Health 2022;19.
30. Cekmen B, Bildik B, Bozan O, et al. Chest compression quality during CPR of potential contagious patients wearing personal protection equipment. Am J Emerg Med 2022;52:128–31.
31. Malysz M, Dabrowski M, Böttiger BW, et al. Resuscitation of the patient with suspected/confirmed COVID-19 when wearing personal protective equipment: a randomized multicenter crossover simulation trial. Cardiol J 2020;27:497–506.
32. Jo CH, Cho GC, Ahn JH, Park YS, Lee CH. Rescuer-limited cardiopulmonary resuscitation as an alternative to 2-min switched CPR in the setting of inhospital cardiac arrest: a randomised cross-over study. Emerg Med J 2015;32:539–43.
33. Olasveengen TM, Mancini ME, Perkins GD, et al. Adult Basic Life Support: International Consensus on Cardiopulmonary Resuscitation and Emergency Cardiovascular Care Science With Treatment Recommendations. Resuscitation 2020;156:A35–79.
34. Tufanaru C, Munn Z, Stephenson M, Aromataris E. Fixed or random effects meta-analysis? Common methodological issues in systematic reviews of effectiveness. Int J Evid Based Healthc 2015;13:196–207.