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Review

# The optimal surface for delivery of CPR: An updated systematic review and meta-analysis

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## Abstract

**Aim**: To determine the effect of CPR delivery surface (e.g. firm mattress, floor, backboard) on patient outcomes and CPR delivery.

**Methods**: We searched MEDLINE, Embase, Web of Science and the Cochrane Central Register of Controlled Trials for studies published since 2019 that evaluated the effect of CPR delivery surface in adults and children on patient outcomes and CPR depth (PROSPERO CRD42023467583). We included manikin studies due to a lack of human studies. We identified pre-2019 studies from the 2020 ILCOR evaluation of this topic. Two reviewers independently screened titles/abstracts and full-text papers, extracted data and assessed risk of bias. Evidence certainty for each outcome was evaluated using GRADE methodology. Where appropriate, we pooled data in a meta-analysis, using a random-effects model.

**Results**: Database searches identified 489 citations. We included six studies published since 2019. We analysed these studies together with the eleven studies included in the previous ILCOR review. All included studies were manikin randomised controlled trials. Certainty of evidence was low. Interventions including placing the patient on the floor or the use of backboard had minimal impact on achieving greater compression depth. Meta-analyses of floor versus firm hospital mattress or firm home mattress found a mean difference of 5.36 mm (95% CI −1.59 to 12.32) and 2.11 mm (95% CI −3.23 to 7.45) respectively.

**Conclusion**: The use of a backboard led to a small 2 mm increase in chest compression depth in meta-analysis of multiple mannikin trials. Use of a firm mattress or transitioning to the floor did not affect chest compression depth.

**Keywords**: Cardiac arrest, Systematic review, Chest Compressions, Backboard, Mattress

## Introduction

Cardiopulmonary resuscitation (CPR) is considered a crucial first step in managing a cardiac arrest as chest compressions play a vital role in maintaining hemoperfusion to the brain, heart and other vital organs. The International Liaison Committee on Resuscitation (ILCOR) and its member organisations emphasise high-quality chest compressions as part of the cardiac arrest chain of survival with current guidelines recommending chest compression depth of 5–6 cm in children and adults.[1–3]

Performing adequate chest compressions on soft surfaces, such as a mattress, poses challenges as it can compress both the chest and surface itself. In manikin studies, up to 57% of the compression force may be absorbed by the mattress resulting in insufficient compression depth and increased provider fatigue.[4–6] The need for additional force to counteract the mattress's absorption may further exacerbate provider fatigue. The insertion of backboards, the use of CPR mode on hospital beds or the movement of patients to the floor have been proposed to counter the impact of soft surfaces. However, these methods may cause delays in starting CPR[7] or in the case of movement place the provider at risk.

In 2020, the International Liaison Committee on Resuscitation (ILCOR) reviewed the evidence in a systematic review with a subsequent treatment recommendation to perform chest compressions on a firm surface when possible (weak recommendation, very low-certainty evidence).[1] As part of the ongoing ILCOR review process,

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we now aim to update the 2020 systematic review regarding CPR delivery on firm surfaces.

## Methods

The systematic review for this update to the 2020 systematic review[8] was published on the International Prospective Register of Systematic Reviews (PROSPERO CRD42023467583), and complies with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting framework.[9] The ILCOR evidence evaluation process for systematic reviews was followed.[10] As an update to the 2020 systematic review[8] this review focused only on CPR compression depth as the sole measure of CPR quality due to limited evidence for other CPR quality metrics (including chest compression rate and chest compression fraction). For completion, there is a summary of the data for additional CPR quality metrics in Supplemental Materials.

### *Information sources and search strategy*

We searched the following electronic databases on the February 4, 2024: MEDLINE, Embase, Web of Science and the Cochrane Central Register of Controlled Trials (CENTRAL) databases for studies published since September 1, 2019. The search strategy was the same used to update the 2020 ILCOR worksheet (Detailed search strategy available in Supplemental Materials). Studies published prior to 2019 that were included in the 2020 ILCOR systematic review were included in the present review. The reference lists of included studies were interrogated for additional relevant papers not identified in the search.

### *Eligibility criteria*

Studies were included if they involved adults or children in cardiac arrest on a bed or other soft surface in any setting (in-hospital or out-of-hospital), who received CPR on a hard surface (e.g. backboard, floor, deflatable or specialist mattress) compared to CPR on a regular mattress. Randomized controlled trials (RCTs) and non-randomized studies (non-randomized controlled trials, interrupted time series, controlled before-and-after studies, cohort studies) were included. Randomised manikin/simulation/cadaver studies were included due to insufficient identification of human studies. Studies were excluded if they were unpublished (e.g., conference abstracts, trial protocols), non-randomized manikin/simulation/cadaver studies, narrative reviews, editorials, or opinion pieces with no primary data. Finally, all languages were included if there was an English abstract available.

### *Selection and outcome measures*

Citations were uploaded into Endnote 20.0 and duplicates removed. Using a pre-defined screening criteria, MD and ES independently screened the title and abstracts, followed by the full-text articles of selected studies using the Rayyan software program. Conflicts were resolved by a third reviewer (JB).

The primary outcome measure was survival with a favourable neurological outcome at hospital discharge/30-days measured using the cerebral performance category, the modified Rankin Score, or an equivalent neurological score. Additional outcomes included survival to hospital discharge/30-days, event survival (survival to hospital), return of spontaneous circulation, and CPR depth. Evidence certainty for each outcome was evaluated using GRADE methodology (See Supplemental Tables 1–3).

### *Data extraction*

A standardized data extraction form was used to extract study design, study population, and outcome measures. Relevant statistical information was extracted (ES) and where possible, missing values (e.g. standard deviation) were calculated from the available data (*p*-values, *t*-values, confidence intervals or standard errors). Extraction was ratified by another author (JB) and conflicts were resolved through group discussion.

### *Risk of bias*

Two authors (MD and GP) independently assessed each study for risk of bias. Risk of bias was assessed using the Cochrane Risk of Bias 2.0 (RoB 2.0) tool was used to assess randomized control trials (RCTs).[11] Any discrepancies were discussed and resolved.

### *Synthesis of findings*

STATA (Version 17) was used for data analysis, data synthesis and creating forest plots. We have reported continuous outcomes as mean differences with 95% CIs. Heterogeneity was assessed by visual inspection of the forest plot, by using the $Chi^2$-test (significant if $p < 0.10$) and the $I^2$ statistic (heterogeneity considered significant if $I^2 > 60\%$). Meta-analysis was performed using the random effects model. The Mantel-Haenszel method for dichotomous outcomes was used and the Inverse Variance method was used for continuous outcomes. A *p*-value <0.05 was considered significant.

A narrative synthesis was conducted of outcomes where the heterogeneity (i.e. clinical, methodological, and statistical) was deemed too substantial across studies to allow for meaningful meta-analyses. Evidence certainty for each outcome was evaluated using GRADE methodology.

## Results

### *Study selection*

Through the electronic database searches, 489 publications were identified which after the removal of duplicates was reduced to 455 publications. Of these, 42 publications were considered for full text review. Eleven publications from the 2020 ILCOR review were also included[8] (Fig. 1).

We did not identify any eligible clinical studies, so we included manikin studies. Six new manikin studies were included. One randomised manikin study examined chest compression depth with a backboard versus a firm hospital mattress[12] and another examined chest compression depth on the floor versus a firm home mattress.[13] Three papers examined alternate surfaces including sports matting,[14] dental chairs,[15] and dynamic overlay mattresses.[16] The final one focused specifically on kneeling on different surfaces and provider fatigue[17] (Table 1).

### *Risk of bias*

All but one included study was assessed as being at an overall low risk of bias or some concerns (Table 2).

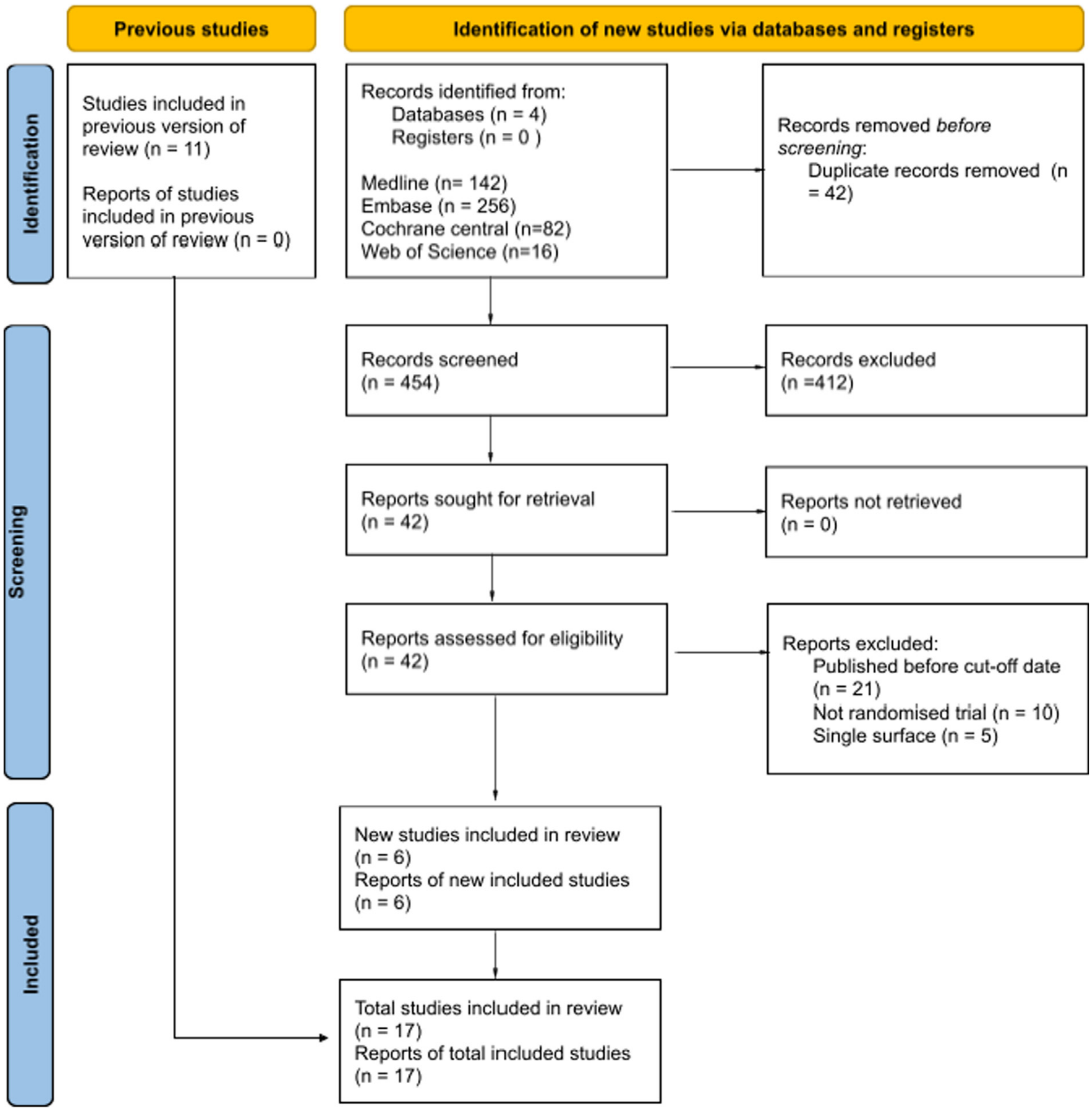


**Fig. 1 – PRISMA Flow Diagram.**

### *Study characteristics*

*Floor versus firm hospital mattress*

No clinical studies were identified. No new manikin studies were identified.

Low certainty evidence (downgraded for serious indirectness) from 2 RCTs from the systematic review in 2020[18,19] showed no difference (5.36 mm (95% CI −1.59 to 12.32)) in chest compression depth when CPR was performed on a manikin placed on the floor compared to a bed (Fig. 2).[18,19] These two studies examined the impact on chest compression depth when chest compressions were performed on the floor versus a firm hospital mattress in the bed frame.

*Backboard versus hospital mattress*

No clinical studies were identified. One new randomized manikin study was identified.[12] Following self-learning to retrain, nurses were allocated to backboard or control group and performed two minutes of chest compressions. There was no significant difference in performance with or without a backboard, and an older age (≥51 year old) of the rescuer was associated with decreased performance for chest recoil.

For the outcome of compression depth, we identified low certainty evidence (downgraded for serious indirectness) from seven randomized manikin studies, one new and six from the 2020 systematic review. Meta-analysis of seven studies,[6,12,20–24] showed a 2.16 mm (95% CI 0.52–3.81) improvement in chest compression depth associated with backboard use when CPR was performed on a manikin placed on a hospital mattress (Fig. 3).

*Floor versus firm home mattress*

No clinical studies were identified. Low certainty evidence from one new randomized manikin study[13] was added to a prior study from

**Table 1 – Summary of Studies.**

| Author | Type of Study | Subjects | Surfaces Tested | Task | Outcomes |
|---|---|---|---|---|---|
| Missel 2023 | Manikin, randomized single-blind crossover design | Lay/Untrained Providers | Firm home mattress versus the floor. | Two minutes of compression on each surface (order randomized) with five minute break. | Depth Rate |
| Cuvelier 2022 | Manikin, superiority randomized control trial | Trained Providers (ALS Trained Healthcare Workers) | Backboard on firm hospital mattress versus no backboard on firm hospital mattress. | Two minutes of compression on floor as a self-learning station followed by two mins CPR on randomized surface | Depth Rate Complete Release |
| Torsy 2022 | Manikin, single-blinded randomized control trial | Trained Providers (BLS Trained Students) | Foam mattress versus dynamic overlay mattress on top of foam mattress | Two minutes of compressions on inflated dynamic overlay mattress on top of foam mattress versus foam mattress alone. | Depth Rate Hand Positioning |
| Kingston 2021 | Manikin, randomized, single-blind, crossover design | Trained Providers (ALS Trained Healthcare Workers) | Floor, Low-Compliance Matting, Low-Compliance Matting with backboard, High-Compliance Matting, High-Compliance Matting with Backboard | Two minutes of compression on each surface (order randomized) with five minute break. | Depth Rate Physical Exertion |
| Shimizu 2021 | Manikin, randomized control trial | Trained Providers (BLS Trained Students) | Two dental chair configurations versus the floor | One minute of compressions on first randomized surface followed by a two-hour break and then a second one minute of CPR on second randomized surface. | Depth Rate Anterior Chest Wall Motion |
| Hasegawa 2020 | Manikin, randomised, cross-over trial | Trained Providers (BLS Trained Students) | Floor versus bed | Two minutes of compressions on randomised surface with thirty minute break, followed by two minutes of compression on other surface. | Depth Provider Heart Rate Provider Muscle Activity Provider Visual Analog Scale |

**Table 2 – Risk of bias table.**

| Study | Randomization process | Deviations from intended interventions | Missing outcome data | Measurement of outcome | Selection of reported results | Overall risk of bias |
|---|---|---|---|---|---|---|
| Missel 2023 | Low | Low | Low | Low | Low | Low |
| Cuvelier 2022 | Low | Low | Low | Low | Low | Low |
| Torsy 2022 | Low | Low | Low | Low | Low | Low |
| Kingston 2021 | Low | Some Concerns | High | Low | Low | High |
| Shimizu 2021 | Some Concerns | Low | Low | Low | Low | Some concerns |
| Hasegawa 2020 | Some Concerns | Low | Low | Low | Low | Some concerns |

the 2020 systematic review. Using a randomized cross-over trial of bystander chest compression quality on manikins in the bed versus on the floor, Missel et al found chest compression below guideline targets on both surfaces with no statistically significant difference in unadjusted performance.

Meta-analysis of these two studies showed no difference (2.11 mm (95% CI −3.23 to 7.45)) in chest compression depth when CPR was performed on a manikin placed on the floor compared to a bed (Fig. 4). These two studies examined the impact on chest compression depth when chest compressions were performed on the floor versus a firm home mattress.

### *Other surface types*

No clinical studies were identified.

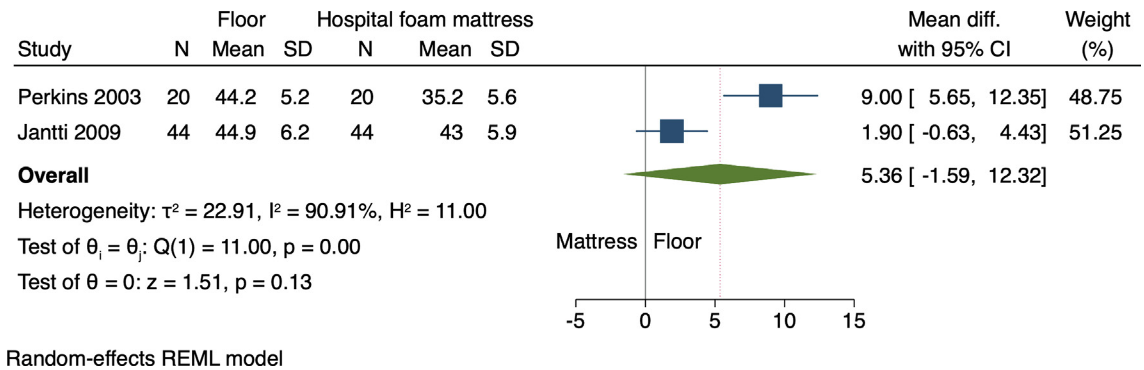


**Fig. 2 – Meta-analysis of compression depth between floor and hospital mattress.**

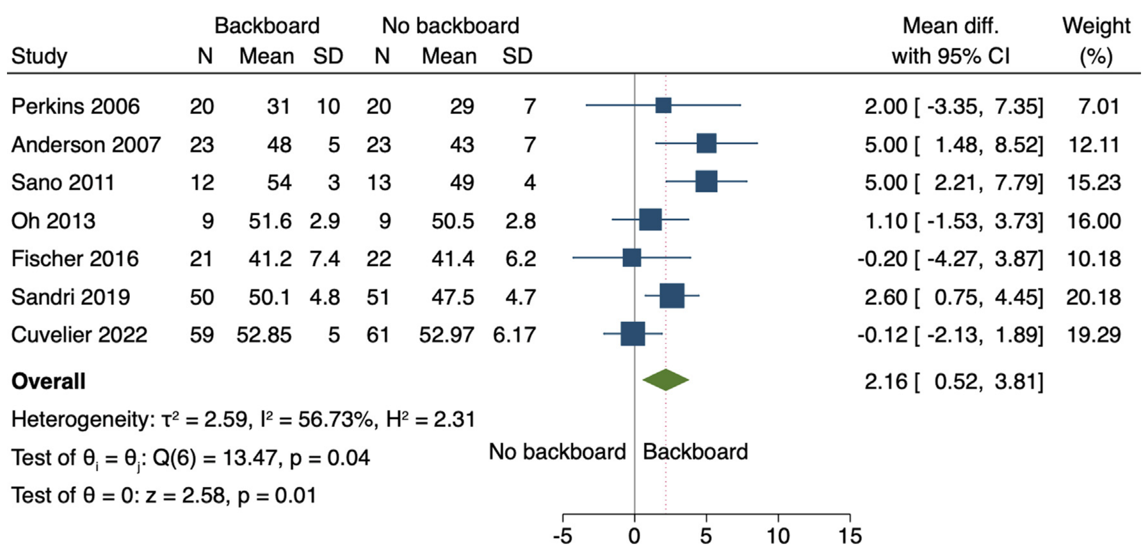


**Fig. 3 – Meta-analysis of compression depth between backboard and no backboard.**

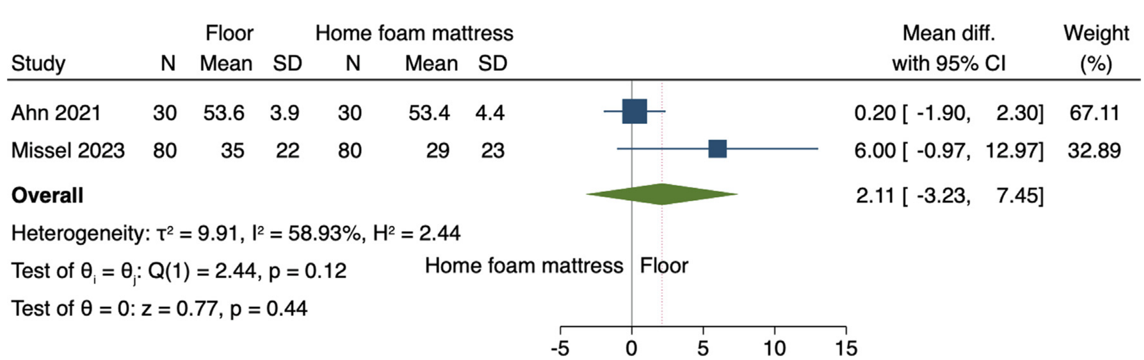


**Fig. 4 – Meta-analysis of compression depth between floor and firm home mattress.**

For the outcome of compression depth, we identified low certainty evidence (downgraded for serious indirectness and one for high risk of bias[14] from two RCTs when CPR was performed on resuscitation manikins with different surface types including sports matting[14] and dental chairs.[15] Heterogeneity between surface types precluded a meta-analysis. The first study compared CPR quality including compression depth and rate and rescuer fatigue including perceived exertion and heart rate on three surfaces the floor, low compliance safety sports matting, high compliance safety sports matting with and without a backboard.[14] For CPR quality metrics, high compliance matting with and without a backboard had a significantly lower compression rate and compression depth compared to floor or low compliance matting with or without backboard. This study had high risk of bias for missing data as five participants were excluded for failure to reach predetermined depth on the solid floor, all of which were female participants. The second study, evaluated chest compression rate and depth in two different dental chairs versus the floor.[15] The percentage of chest compressions ≥5 cm was significantly lower in both dental chairs as compared with the floor.

### *Certainty of evidence across studies*

The certainty of evidence was rated as low for all studies on CPR quality. Certainty of evidence was downgraded due to risk of bias, inconsistencies with study design and outcomes, and significant indirectness as there were only manikin studies available and no clinical studies.

## Discussion

This systematic review updates a prior review by Holt et al.[8] and adds findings from six additional randomised manikin studies. No new clinical studies were identified. All outcomes were rated as very low certainty of evidence due to the indirectness of manikin studies.

Overall, these studies reinforced that chest compression depth is overall inadequate with few studies reaching the targeted depth of >50 mm (mm). While there was statistically significant improvement in a few studies with use of the interventions studied (either use of backboard, floor, or specialty surface), the very small mean differences, all less than 10 mm, do not substantially improve depth compliance. However, it is known that a 5 mm increase in chest compression depth can lead to a two-fold improvement in shock success, despite the mean depth not meeting guideline compliance.[25] Therefore, these small differences in compression depth with CPR performed on firm surfaces may be clinically meaningful to patients.

Meta-analyses of the floor versus either firm hospital mattress or firm home mattress found a mean difference of 5.36 mm (95% CI −1.59 to 12.32) and 2.11 mm (95% CI −3.23 to 7.45) respectively, but this was not statistically significant. For the floor versus firm hospital mattress, one study found a statistically significant improvement in compression depth by placing the patient on the floor with trained rescuers,[19] but neither of the firm home mattress studies found a statistically significant improvement in depth with movement of the patient to the floor when CPR was performed by lay or trained rescuers. Given that as many as a quarter of bystanders for OHCA have barriers to transferring a patient to the floor, and these barriers have been associated with a reduced rate of telecommunicator-directed bystander CPR and a longer time to first compression,[7] the practice of routine recommendation of transfer to the floor or another firm surface for bystanders needs to be re-evaluated.

Examining the use of backboards versus no backboard strategy, there was a small overall mean difference of 2.16 mm (95% CI 0.52–3.81) that was statistically significant, with two of the seven studies showing a mean difference of 5 mm.[20,24] This was a decrease in the mean difference with the addition of one new study from the prior meta-analysis.[8] The heterogeneity in rescuers and impact of rescuer factors like age, weight, and gender may explain the significant discrepancies in the seven studies provided. For example, the new study added evaluates the CPR performance of in-hospital nurses,[26] whereas prior studies included medical students[22,23] or trainees,[21] hospital orderlies,[20] or physicians only.[24] Not to mention substantial age, gender, height, and BMI differences in rescuers which are known significant predictors of CPR quality.[13,26–29]

Rescuer fatigue was measured in two studies.[14,17] The findings of increased fatigue, less effective CPR, and decreased stability on the bed versus the floor, as well as, a higher rate of perceived exertion when chest compressions were done on high compliant surfaces, even with a backboard, raises questions around the impact that firm surface can have on rescuer's exertion and fatigue. This topic requires further study, with standard outcomes to derive conclusions and impact guidelines.

## Limitations

All studies had a low certainty of evidence due to risk of bias, inconsistency, and significant indirectness. Study populations only included manikins for both lay and trained rescuers, and did not assess any clinical outcomes including ROSC, survival and neurological outcomes.

## Conclusion

This updated systematic review added to the evidence that CPR depth is sub-optimal on all surfaces. Interventions including placing the patient on the floor or the use of backboard had minimal impact on achieving greater compression depth. Future research should include clinical studies, as well as the logistical impact of moving patients to the floor or the deployment of a backboard.

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## CRediT authorship contribution statement

**Maya Dewan:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Ethan Schachna:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis. **Kathryn Eastwood:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Gavin Perkins:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Janet Bray:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Conceptualization.

## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: 'GDP is an Editor of Resuscitation and Editor-in-Chief of Resuscitation Plus. JB is an Editor of Resuscitation Plus and an Editorial Board Member of Resuscitation. GDP is supported by the National Institute for Health Research (NIHR) Applied Research Collaboration (ARC) West Midlands. The views expressed are those of the author(s) and not necessarily those of the NIHR or the Department of Health and Social Care.'.

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## Appendix A. Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.resplu.2024.100718.

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