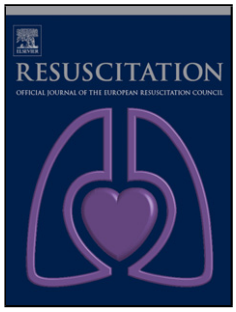
# Journal Pre-proof




The optimal surface for delivery of CPR: a systematic review and meta-analysis

Josephine Holt (Conceptualization) (Methodology) (Investigation) (Writing - original draft) (Writing - review and editing), Abigail Ward (Conceptualization) (Methodology) (Investigation) (Writing - original draft) (Writing - review and editing), Tay-Yibah Mohamed (Conceptualization) (Methodology) (Investigation) (Writing - original draft) (Writing - review and editing), Priya Chukowry (Conceptualization) (Methodology) (Investigation) (Writing - original draft) (Writing - review and editing), Natalia Grolmusova (Conceptualization) (Methodology) (Investigation) (Writing - original draft) (Writing - review and editing), Keith Couper (Conceptualization) (Methodology) (Investigation) (Writing - review and editing) (Supervision), Peter Morley (Conceptualization) (Methodology) (Writing - review and editing) (Supervision), Gavin D. Perkins (Conceptualization) (Methodology) (Investigation) (Formal analysis) (Writing - review and editing) (Supervision)

PII: S0300-9572(20)30297-5

DOI: https://doi.org/10.1016/j.resuscitation.2020.07.020

Reference: RESUS 8633

To appear in: *Resuscitation*

Received Date: 1 June 2020

Revised Date: 29 June 2020

Accepted Date: 16 July 2020

Please cite this article as: Holt J, Ward A, Mohamed T-Yibah, Chukowry P, Grolmusova N, Couper K, Morley P, Perkins GD, The optimal surface for delivery of CPR: a systematic review and meta-analysis, *Resuscitation* (2020),

doi: https://doi.org/10.1016/j.resuscitation.2020.07.020

**The optimal surface for delivery of CPR: a systematic review and meta-analysis**

Josephine Holt (1), Abigail Ward (1), Tay-Yibah Mohamed (1), Priya Chukowry (1), Natalia Grolmusova (1), Keith Couper (1,2), Peter Morley (3), Gavin D Perkins (1,2)

1) University Hospitals Birmingham NHS Foundation Trust, Birmingham, UK
2) Warwick Clinical Trials Unit, Warwick Medical School, University of Warwick, Coventry, CV4 7AL
3) The Royal Melbourne Hospital, RMH, Victoria 3050, Australia

Corresponding author: Gavin D Perkins, Warwick Clinical Trials Unit, Warwick Medical School, University of Warwick, Coventry, CV4 7AL
Email: g.d.perkins@warwick.ac.uk; Tel: 024 76 150925

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, Cochrane Library and Web of Science for studies published since 2009 that evaluated the effect of CPR delivery surface in adults and children on patient outcomes and quality of CPR. We included randomised controlled trials only. We identified pre-2010 studies from the 2010 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 2701 citations. We included seven studies published since 2009. We analysed these studies together with the four studies included in the previous ILCOR review. All included studies were randomised controlled trials in manikins. Certainty of evidence was very low. Increasing mattress stiffness or moving the manikin from the bed to the floor did not improve compression depth. Use of a backboard marginally improved compression depth (mean difference 3mm (95% CI 1 to 4).

Conclusion The use of a backboard led to a small increase in chest compression depth in manikin trials. Different mattress types or delivery of CPR on the floor did not affect chest compression depth.

PROSPERO CRD42019154791

Introduction

Chest compressions have a crucial role in cardiopulmonary resuscitation (CPR) by maintaining perfusion to the heart, brain and other vital organs. The International Liaison Committee on

Resuscitation (ILCOR) and its member organisations have emphasized high quality chest compressions as a critical component of the cardiac arrest chain of survival.[1, 2] Rate, depth, and chest recoil are key determinants of effective chest compressions.[3] Observational studies have shown an association between compression depth, survival and neurological outcomes.[4] The greater the chest compression depth, the better the outcomes, up to a plateau of approximately 5-6 cm.[5]

Delivery of chest compressions on a soft surface, such as a mattress, compressed both the patient's chest and underlying mattress. Manikin studies and mathematical models show that soft surfaces absorb 12-57% of the delivered compression depth, with softer mattresses absorbing a greater proportion of compression force.[6-9] Failure to recognise and compensate for mattress compression may lead to under compression of the chest.[10] Increasing compression force to overcome the effects of mattress compression requires greater effort from the CPR provider, risking fatigue.

On this basis, moving a patient in cardiac arrest to a firmer surface (e.g. backboard, mattress with increased stiffness, moved to the floor) might optimize compression delivery. These processes risk potential harm to both the patient (e.g. through chest compression interruption and dislodgement of indwelling devices) and rescuer (e.g. additional manual handling processes). Given these potential risks, there is a need to quantify the potential benefits of CPR delivery on a firm surface. The aim of this systematic review is to update the 2010 ILCOR review, and describe current evidence regarding CPR delivery on firm surfaces.[11]

## Methods

This systematic review was prospectively registered with the International Prospective Register of Systematic Reviews (PROSPERO registration- CRD42019154791). It is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting framework.

### *Information sources and search strategy*

We searched the following electronic bibliographic databases on 16th September 2019: Medline, pre-medline, Cochrane reviews, Cochrane CENTRAL, and Web of Science for studies published since 2009. This literature search was the same as that used for updating the 2010 ILCOR worksheet. For studies published prior to 2009, we included relevant studies included in the 2010 ILCOR review.[11] We additionally reviewed the reference list of included studies for potential additional articles. The search strategies for each database are provided in the supplementary contents.

### *Eligibility criteria*

We used the PICO (Population, Intervention, Comparison, Outcome) format to frame the review question: Among adults and children with cardiac arrest on a bed in any setting (out-of-hospital or in-hospital) (P), does the performance of CPR on a hard surface (backboard, floor, deflatable

or specialist mattress) (I), compared with the performance of CPR on a regular mattress (C), improve survival, survival with a favourable neurological outcome, ROSC, CPR quality (O)?

The ILCOR Basic Life Support Task Force prioritised outcome importance using the GRADE system.[12] Survival with a favourable neurological outcome, survival and return of spontaneous circulation were classified as critical outcomes. CPR quality (e.g. compression depth, compression fraction) was classified as an important outcome.

We defined a backboard as any rigid board placed under a patient's back during the administration of chest compressions. A deflatable mattress was defined as a mattress whose mechanical properties can be changed from soft to firm to increase rigidity and facilitate chest compressions.

Randomised controlled trials (RCTs) and non-randomized studies (non-randomized controlled trials, interrupted time series, controlled before-and-after studies, cohort studies) were eligible for inclusion. We planned to include randomised controlled trials of manikin and cadaver studies only if insufficient human studies were identified. Unpublished studies (such as conference abstracts, trial protocols) were excluded as well as non-randomised cadaver studies, narrative reviews, editorials, opinions with no primary data, animal studies, experimental / lab models and mathematical models. Papers included in the 2010 systematic review and any new papers identified from 2009 onwards were included.  There were no language restrictions applied.

*Study selection and data extraction*

Two reviewers [JH, NG], using pre-defined screening criteria, independently screened all titles and abstracts retrieved from database searches. Reviewers then looked at the full text-reports of

all potentially relevant publications passing the first level of screening. Reviewers extracted data using a pre-defined, standardised data extraction form. At each stage, disagreements were resolved through discussion or referral to a third reviewer.

*Risk of bias in individual studies and across studies*

Each included study was independently assessed for risk of bias by two of the authors and checked by KC. Risk of bias was assessed by the GRADE (Grading of Recommendations, Assessment, Development and Evaluation) handbook tool for randomised controlled trials.[12] In the advice provided by the GRADE handbook, risk of bias is assessed within specified domains, including (1) lack of allocation concealment, (2) lack of blinding, (3) incomplete accounting of patients and outcome events and (4) selective outcome reporting. For each category the bias risk was allocated the label “high, “unclear” or “low”. Disagreements were resolved via discussion between the investigators.[13]

*Certainty of evidence across studies*

We used the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach to assess the overall certainty of evidence for each intervention and outcome. Evidence certainty was categorised as very low, low, moderate or high.

*Data synthesis*

Studies were assessed for methodological, clinical and statistical heterogeneity. When appropriate meta-analyses were performed using fixed or random-effects models, depending on

the heterogeneity of the data. We describe statistical heterogeneity in meta-analyses using the $I^2$ statistic.[14] We planned to report binary outcomes as relative risk (RR) and 95% confidence interval. Continuous outcomes are described as mean difference and 95% confidence interval. Analysis was undertaken using Review Manager (Cochrane, version 5.3). Where meta-analysis was not appropriate, we undertook a narrative synthesis.

## Results

### *Study selection*

2701 publications were identified through database searches, which after the removal of duplicate papers came down to 1532 publications. Of these, 26 papers were considered potentially relevant based on a review of title and abstract and the full text articles were reviewed. 4 papers from the 2010 ILCOR review were also included. No new studies were identified from bibliography review of included studies. See figure 1.

We identified no eligible clinical studies so we included manikin studies. Eleven manikin studies were retained.[8, 15-24] Three randomized manikin studies examined increasing mattress stiffness on compression depth.[8, 16, 20] Four randomized manikin studies examined compression depth when CPR was undertaken on the floor rather than a bed.[16, 17, 19, 20] Seven randomized manikin studies examined the effect of backboards on compression depth.[8, 15, 18, 21-24] One of the studies used visual feedback of chest compressions which was visible to the participant during the course of the study.[8]

### *Risk of bias*

All included studies were assessed as being at an overall moderate or low risk of bias (table 1).

*Increasing mattress stiffness*

No clinical studies were identified.

Three randomised controlled trials on resuscitation manikins were identified which examined the influence of mattress stiffness on compression depth.[8, 16, 20] A single randomized manikin trial compared a compressed foam mattress with a standard mattress. The study involved 9 subjects and found similar compression depths (compressed mattress 51 mm, standard mattress 51 mm).[8]

A further randomized cross over trial involving 20 subjects compared a standard foam mattress (compression depth 35 mm) with an inflated pressure relieving mattress (compression depth 37 mm) and deflated pressure relieving mattress (compression depth 39 mm).[20] An additional, small (n=4) randomized cross over trial reported only small differences between a foam mattress (mean depth 38 mm) and 3 different pressure relieving mattresses (range 33-39 mm).[13]

*Floor versus bed*

No clinical studies were identified.

Four randomised controlled trials on resuscitation manikins were identified.[16, 17, 19, 20] The studies examined the influence on chest compression depth when undertaking CPR on the floor versus on a mattress/bed. The mattresses examined were all foam of various stiffnesses: two studies weighted the manikins to simulate human weight:[16, 20], CPR was performed with the

mattress placed on a hospital bed in three studies[16, 19, 20] whilst the fourth study sought to simulate out-of-hospital cardiac arrest and placed the mattresses on the floor.[17]

Meta-analysis of the 2 studies undertaken with a mattress on a hospital bed[19, 20] showed no difference (4 mm (95% CI -1 to 9)) in chest compression depth when CPR was performed on a manikin placed on the floor compared to a bed. See figure 2.

The study which examined different foam mattresses placed on the floor reported no difference in chest compression depth when CPR was performed directly on the floor median 54 mm (IQR 51–56) on a bed with a hard foam mattress 54 mm (IQR 50–56), medium foam mattress 53 mm (48–57) or soft foam mattress 53mm (46–54) (P=0.3).[17]

An additional, small (n=4) randomised cross over trial reported only small differences between CPR performed on the floor (mean depth 43 mm) versus a foam mattress on a bed (mean depth 37.5mm) and 3 different pressure relieving mattresses (range 33mm-39mm).[16]

None of the studies examined the effect on quality of CPR whilst moving the manikin from a bed to the floor. The act of moving the body or manikin to the floor also creates a delay or pause in chest compressions and this delay may have unintended negative consequences as a delay in more than 10 seconds of CPR can reduce the chance of a successful shock.[2]

*Backboard*

No clinical studies were identified.

Seven randomised controlled manikin trials which examined the effect of backboards on compression depth were identified.[8, 15, 18, 21-24] The studies reported the influence of backboards placed on various mattresses located on a standard hospital bed[8, 15, 21, 22] emergency department stretcher[18, 23] or operating table[24] and examined the effect on

compression depth. Mattress types were foam[8, 15, 18, 21, 23] or air-filled[22, 24]. Backboard sizes were reported in one study (45cm width, 60cm length and 1 cm depth)[8] and orientation in one (longitudinal).[18]

Quantitative meta-analysis of 6 similar studies[8, 15, 18, 21, 23, 24] is shown in figure 3. This identified increased chest compression depth in patients treated on a backboard, compared with a mattress/ bed (mean difference 3mm (95% CI 1-4)). The high heterogeneity looks to be mainly driven by the Perkins 2006 study. None of the studies reviewed looked at the time taken to place a backboard under the manikin so this is a knowledge gap.

*Certainty of evidence across studies*

The certainty of evidence was rated as very low across all comparisons. Certainty of evidence was downgraded due to serious risk of bias (due to unclear allocation concealment and absence of blinding), inconsistency and very serious risk of indirectness, reflecting the fact that only manikin studies were available for evaluation. The possibility of publication bias was considered but deemed not to be appropriate as less than 10 studies were quantitatively analysed.

Discussion

This systematic review summarises findings from 11 manikin studies that compared chest compression quality on various surfaces. No studies were identified which reported any clinical outcomes. All papers that were included were randomised controlled trials, nine of which included a cross-over design. The evidence available was of very low certainty and provided indirect evidence from randomised manikin studies.

Across almost all studies, chest compression depth was inadequate when CPR was performed in a bed. None of the interventions studied (either use of backboard, deflate or floor) substantially improved compression depth. Meta-analysis of two studies found 4 mm difference in chest compression depth in favour of the floor compared to a bed but the confidence interval crossed one.[19, 20] One study found no significant difference in chest compression depth between the floor and mattresses of varying firmness.[17] Results from 8 studies looking at compression depth on using a backboard were inconsistent. Six RCTs demonstrated a small increase in chest compression depth on manikins using a backboard[15, 18, 19, 21, 23, 24] whilst two demonstrated no significant difference.[8, 22] Various types of mattress surfaces were also studied. Heterogeneity between mattress types precluded meaningful analysis.[8, 16, 20] The overall certainty of evidence was very low for all outcomes.

It has long been known that adequate chest compression depth is linearly associated with vital organ perfusion.[25] It is also associated with improved survival and functional outcomes.[26] A 5mm increase in chest compression depth is associated with a two fold increase in shock success during resuscitation of patients with either in or out of hospital cardiac arrest. This in turn translates to a higher survival to hospital discharge rate (9% versus 0%, $p = 0.21$) for patients with first-shock success.[27] The location of the cardiac arrest is important as most OHCA take place on the floor and IHCA take place on hospital beds.[19] Irrespective of the surface, confounding factors such as participant's position when performing CPR plays a significant role in CC depth.[28]

There is concern that the force used in performing CPR may be dissipated on a soft surface leading to worse outcomes due to energy spent on mattress displacement and slow rebound from a softer surface.[17] Three studies which used manikin models indicate the amount of mattress compression ranges between 12-57% of total compression depth, with softer mattresses being compressed the most. This can lead to reduced spinal-sternal displacement and a reduction in effective chest compression depth. Furthermore, this can lead to increased physical effort and perceived fatigue.[17]

Real-time feedback was provided in one of the studies included. It found no significant difference between compression depth on the surfaces when feedback was not given.[8] Single accelerometers placed on the chest overestimate chest compression depth on a soft surface as it is measuring total compression depth i.e. mattress displacement + chest compression depth. Inaccurate feedback can lead to decreased chest compression depth.[29]

A more accurate measurement of effective chest compression depth can be measured using two accelerometers: one accelerometer placed on top of the sternum and one placed on the posterior surface directly below the compression point. This then calculates accurate sternal to spine displacement which can provide feedback to the CPR provider who in turn delivers more effective chest compressions.[30] This may overcome limitations in performing CPR on a soft surface.

Limitations

Certainty of data was considered to be very low due to serious risk of bias, inconsistency and very serious indirectness. All study populations included manikins and did not assess critical

outcomes: neurological outcomes, ROSC and survival. Some manikins were weighted whilst others were not. The potential of possible harm from interventions was not fully assessed. For example in transferring the patient to the floor there is a risk of injury to the patient displacing medical equipment. Long term assessment of harm may be needed (for example mattress types and prevention of pressure sores)[7]. Studies looking at mattress types primarily considered the most common type of hospital bed in their locality. This then led to difficulty in comparing data and creating a meaningful analysis given the variety of mattresses included in the study. Future research should address the need for clinical studies and the logistical aspects of backboard deployment.

## Conclusion

This systematic review found very low certainty evidence from manikin studies that cardiopulmonary resuscitation performed in a hospital bed is sub-optimal. Placing the patient on the floor, the use of a backboard or emergency mattress deflation had minimal effect on improving compression depth.

## Credit author statement

Josephine Holt conception, methodology, investigation, writing original draft, review and editing,
Abigail Ward conception, methodology, investigation, writing original draft, review and editing,
Tay-Yibah Mohamed conception, methodology, investigation, writing original draft, review and editing,
Priya Chukowry conception, methodology, investigation, writing original draft, review and editing,
Natalia Grolmusova conception, methodology, investigation, , writing original draft, review and editing,
Keith Couper conception, methodology, investigation, writing review and editing, supervision

Peter Morley conception, methodology, writing review and editing, supervision
Gavin D Perkins conception, methodology, investigation, analysis, writing review and editing, supervision

Conflict of interest:

GDP co-authored 3 papers in this review. The decision to include these papers and data extraction activities were undertaken by other authors. GDP is co-chair of ILCOR and Editor of Resuscitation. KC is a Domain lead for ILCOR. No other conflicts to declare.

Conflict of interest statement:
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Funding: GDP is supported as a NIHR Senior Investigator.

Acknowledgement: This systematic review was supported by the International Liaison Committee on Resuscitation and member Councils.

The authors acknowledge the expert input from the ILCOR BLS Task Force Avis S, Castren M, Considine J, Chung S, Escalante R, Hatanaka T, Hung K, Kudenchuk P, Mancini MB, Nishiyama C, Ristagno G, Semeraro F, Smith C, Smyth M, Morley P, Olasveengen T, Vaillancourt C. We would also like to thank Samantha Johnson, Information Specialist, University of Warwick for designing and running the search strategy for this review.

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Figures

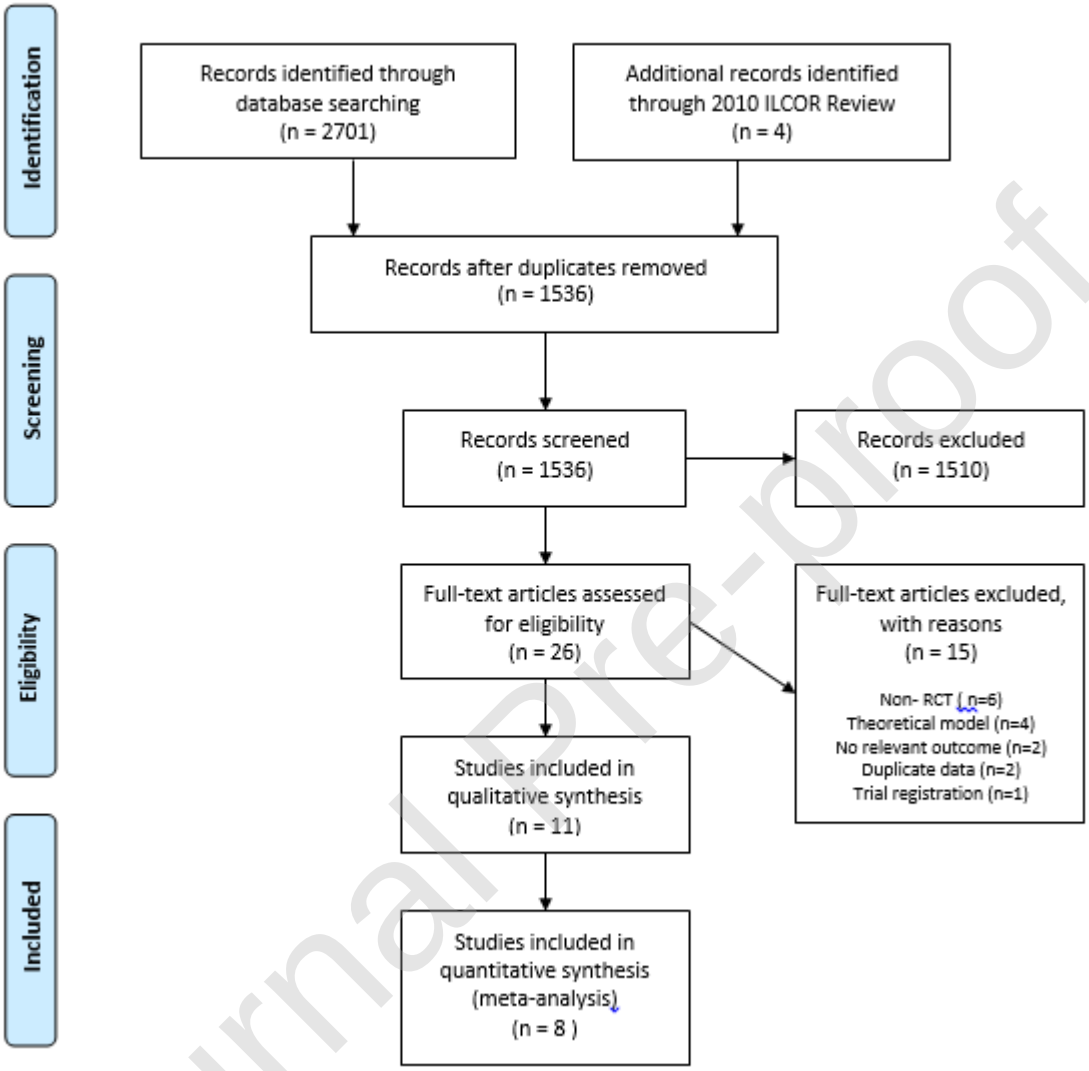


Figure 1: PRISMA diagram

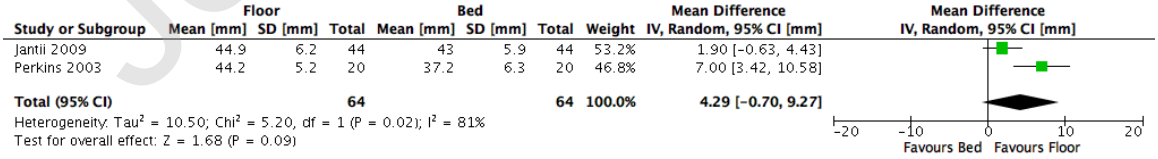


Figure 2: Meta-analysis of compression depth between the floor and bed

| Study or Subgroup | Backboard Mean [mm] | Backboard SD [mm] | Backboard Total | No backboard Mean [mm] | No backboard SD [mm] | No backboard Total | Weight | Mean Difference IV, Random, 95% CI [mm] |
|---|---|---|---|---|---|---|---|---|
| Andersen 2007 | 48 | 5 | 23 | 43 | 7 | 23 | 13.8% | 5.00 [1.48, 8.52] |
| Fischer 2016 | 41.2 | 7.4 | 21 | 41.4 | 6.2 | 22 | 11.0% | -0.20 [-4.29, 3.89] |
| Perkins 2006 | 31 | 10 | 20 | 29 | 7 | 20 | 7.1% | 2.00 [-3.35, 7.35] |
| Sanri 2019 | 50.1 | 4.8 | 50 | 47.5 | 4.7 | 51 | 28.7% | 2.60 [0.75, 4.45] |
| Sato 2011 | 54 | 3 | 12 | 49 | 4 | 13 | 19.1% | 5.00 [2.24, 7.76] |
| Song 2013 | 51.6 | 2.9 | 9 | 50.5 | 2.8 | 9 | 20.2% | 1.10 [-1.53, 3.73] |
| **Total (95% CI)** | | | **135** | | | **138** | **100.0%** | **2.74 [1.19, 4.28]** |

Heterogeneity: Tau² = 1.27; Chi² = 7.74, df = 5 (P = 0.17); I² = 35%
Test for overall effect: Z = 3.47 (P = 0.0005)

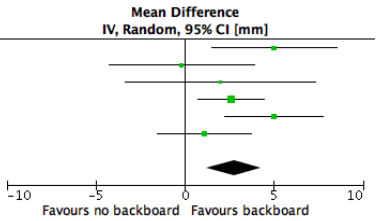


Figure 3: Meta-analysis of chest compression depth with and without backboard

Table

| *Paper* | *Allocation concealment* | *Blinding* | *Incomplete outcomes* | *Selective outcome reporting* | *Overall risk* |
|---|---|---|---|---|---|
| Mattress | | | | | |
| **Oh 2013** | Unclear | High | Low | Low | Moderate |
| **Perkins 2003** | Unclear | High | Low | Low | Moderate |
| **Tweed 2001** | High | Unclear | Low | Low | Moderate |
| FLOOR | | | | | |
| **Ahn 2019** | Unclear | High | Low | Low | Moderate |
| **Jantil 2009** | Unclear | High | Low | Low | Moderate |
| **Perkins 2003** | Unclear | High | Low | Low | Moderate |
| **Tweed 2001** | High | Unclear | Low | Low | Moderate |
| BACKBOARD | | | | | |
| **Anderson 2017** | Unclear | High | Low | Low | Moderate |
| **Fisher 2018** | Unclear | High | Low | Low | Moderate |
| **Oh 2013** | Unclear | High | Low | Low | Moderate |
| **Perkins 2006** | Unclear | Low | Unclear | Unclear | Moderate |
| **Putzer 2016** | Unclear | High | Low | Low | Moderate |
| **Sanri 2019** | Unclear | Low | Low | Low | Low |
| **Sato 2011** | Unclear | High | Low | Low | Moderate |