Effect of a backboard on chest compression quality during in-hospital adult cardiopulmonary resuscitation: a randomised, single-blind, controlled trial using a manikin model.

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KEYWORDS
Backboard; Basic Life Support; Cardiopulmonary Resuscitation; Resuscitation Skills; Training Quality.

WORD COUNT PAPER: 2998
WORD COUNT ABSTRACT: 239

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Brecht Serraes: Conceptualization, Methodology, Validation, Formal analysis, Resources, Writing – Review & Editing, Supervision
Carl Haentjens: Conceptualization, Methodology, Validation, Resources, Writing – Review & Editing, Supervision
Stijn Blot: Conceptualization, Methodology, Validation, Formal analysis, Resources, Writing – Review & Editing, Supervision
Nicolas Mpotos: Conceptualization, Methodology, Software, Validation, Formal analysis, Resources, Writing – Review & Editing, Supervision

Acknowledgements
The authors offer great appreciation to all participants for participating as well as all head nurses, volunteers and the ICT department of the hospital for facilitating and assisting during data collection.

Role of the Funding Source: None

Conflicts of Interest
The authors received no research grant of a funder. Nicolas Mpotos (NM) developed a training strategy to acquire and retrain CPR skills in a self-learning
station. NM is owner of Pinga Group bv., a company providing CPR self-learning. Data acquisition was not conducted by NM.

**Clinical Trial registration number:** B670201941133
Abstract

Introduction

Chest compression quality during in-hospital resuscitation is often suboptimal on a soft surface. Scientific evidence regarding the effectiveness of a backboard is scarce. This single-blinded manikin study evaluated the effect of a backboard on compression depth, rate and chest recoil performed by nurses. Sex, BMI, age and clinical department were considered as potential predictors.

Methods

Using self-learning, nurses were retrained to achieve a minimal combined compression score at baseline. This combined score consisted of ≥70% compressions with depth 50-60mm, ≥70% compressions with complete release (≤5mm) and a mean compression rate of 100-120bpm. Subsequently, nurses were allocated to a backboard or control group and performed a two-minute cardiopulmonary resuscitation test. The main outcome measure was the difference in proportion of participants achieving a combined compression score of ≥70%.

Results

In total 278 nurses were retrained, 158 nurses dropped out and 120 were allocated to the backboard (n=61) or control group (n=59). The proportion of participants achieving a combined compression score of ≥70% was not significantly different (p=0.475) and suboptimal in both groups: backboard group 47.5% (backboard) versus 41.0% (control). Older age (≥51 years) was associated with a lower probability of achieving a combined compression score >70% [OR = 0.133; 95% confidence interval (CI), 0.037-0.479; p=0.002].

Conclusion

Using a backboard did not significantly improve compression quality in our study. Important decay of compression skills was observed in both groups, highlighting the importance of frequent retraining, particularly in some age groups.
Implications for Clinical Practice

- Interruption of chest compressions is not recommended to place a backboard. However, CPR teams should carefully assess whether placing a backboard is justified for the type of mattresses used in their hospital.
- Frequent chest compression skill retraining is recommended, particularly in nurses 51≥ years. Compression skills already decayed within a maximum period of fourteen weeks after training.
- Successful chest compressions during manikin CPR training on the floor do not guarantee successful chest compressions during manikin CPR in bed.

Introduction

High-quality cardiopulmonary resuscitation (CPR), specifically chest compressions, is essential to increase the likelihood of survival and enhance neurological outcome (Considine et al., 2020; Kleinman et al., 2015; Perkins et al. 2015). International guidelines of the European Resuscitation Council (ERC) for adult basic life support (BLS) recommend performing CPR on a firm surface when possible (Perkins et al., 2015).

However, in-hospital cardiac arrests (IHCA) usually occur in patients lying in bed (i.e. no firm surface). Transferring a patient to the floor cannot always be done safely and promptly during IHCA (Handley et al., 2012) and is not recommended (Perkins et al., 2019). Moreover, chest compression quality during in-hospital CPR is often suboptimal on a soft surface (Monsieurs et al., 2015). Performing CPR on a mattress in bed results in mattress and bedframe deflection and negatively influences compression depth on the sternum during manikin CPR (Lin et al., 2017; Nishisaki et al., 2012; Oh et al., 2016; Ruiz de Gauna et al., 2016; Sainio et al., 2014). Other factors that might influence compression quality are bed height (Perkins et al., 2003; Perkins et al., 2006), sex (Amacher et al., 2017; Jaafar et al., 2015) and body mass index (BMI) (Jaafar et al., 2015; Krikscionaitiene et al. 2013).
Focusing on mattress compression, a backboard can be placed between the patient and mattress to reduce its unfavourable effect on chest compression quality. Overall, a lack of evidence exists on the use and effectiveness of a backboard during in-hospital CPR. A recent manikin study observed an increase in compression quality (Sanri and Karacabey, 2019), while other manikin studies reported no improvement in compression quality when using a backboard during CPR on a mattress (Fischer et al., 2016, Perkins et al., 2006, Putzer et al., 2016, Schober et al., 2014). Some authors described a decrease in mattress compressibility but emphasised that it is not eliminated (Lin et al., 2017, Noordergraaf et al., 2009, Oh et al., 2016). Furthermore, backboard placement during in-hospital CPR interrupts the resuscitation cycle (Perkins et al., 2015).

The aim of this study was to evaluate the effect of a backboard on chest compression depth, rate and chest recoil during in-hospital CPR by nurses on an adult-sized manikin.
Methods

A prospective, non-crossover, superiority randomised controlled trial (RCT) was conducted between mid-October 2019 and February 2020. This trial hypothesised that backboard use could enhance compression depth, rate and chest recoil. The study protocol was approved by the Ethics committee (trial registration B670201941133). Digital and/or written informed consent was obtained from every participant.

Data collection

In a Belgian general hospital with 810 beds a consecutive sample of registered nurses working in adult critical or non-critical care was selected. Minimal work experience or recent CPR qualification was not required. Participants were invited to participate by poster, mail, telephone, face-to-face contact on the ward and through their head nurses. CPR training (phase one: six weeks) was scheduled prior to the intervention (phase two: nine weeks).

Phase one

CPR training was provided with an automated CPR self-learning station (CPRTEST®, Pinga Group, Belgium) using a repetitive formative test strategy to minimize performance bias (Mpotos et al., 2012, Mpotos et al., 2013, Mpotos et al., 2015). Participants were not familiar with automated self-learning and assessment of CPR skills. Therefore, a non-obstructive researcher was present to solve technological difficulties without providing feedback. The mobile station consisted of a laptop connected to a new adult-sized manikin torso (15.75kg, Resusci Anne®, Laerdal, Norway) available for all wards. The manikin was equipped with a validated and patented internal CPRTEST® sensor (EP 3370220, Pinga Group, Belgium) to record chest compression depth, rate, chest recoil and ventilation volume.

In order to succeed training, participants had to achieve a predefined combined score of ≥70% consisting of ≥70% chest compressions with depth 50-60mm and ≥70% chest compressions with complete release (≤5mm) and a mean compression rate of 100-120bpm and ≥70% ventilations with visible chest rise (volume 200-800ml) during a two-minute formative test (Mpotos et al., 2012,
Mpotos et al., 2013, Mpotos et al., 2015). Past research recommended clinical competence to be assured by passing a predefined competence level (Wass et al., 2015). The threshold of 70% was in accordance with previous research (Mpotos et al., 2013, Mpotos et al., 2015). A two-minute period was chosen to minimise fatigue (Perkins et al., 2015).

Training in phase one was executed on the floor. Compressions always had to be performed by participants. A researcher performed head tilt-chin lift and held a bag-valve-mask in place so the participant could control ventilation volume. During the formative test there was no audio-visual feedback. Participants only saw a timer. After the test the software automatically provided feedback to every participant and when the pass criteria were not achieved feedforward was given to improve performance. There was no limitation to the number of training efforts needed for succeeding training. Every new effort started with previous test feedback.

Phase two

To minimise bias from an unequal baseline CPR skill level, only nurses who obtained a combined score $\geq 70\%$ in phase one were alphabetically listed by surname by two researchers and after similar listing randomised once (block size = 10, allocation ratio 1:1) into two groups by an online randomisation tool (Sealed Envelope Ltd): a backboard or a control group.

Phase two was conducted in a hospital room with two hospital beds (Evolution™ LI-156E0, Hill-Rom®, The Netherlands) separated by a screen. On each bedframe a new memory foam mattress (200 x 90 x 14 cm, VISCOSAM85®, Sampli, Belgium) was placed with a density of 80-85kg/m³ (top layer, 4 cm) and 50-55kg/m³ (bottom layer, 10 cm). A manikin torso (15.75kg, Resusci Anne®, Laerdal, Norway), as used in phase one, was placed on each mattress. Both manikins were identical and equipped with a CPRTEST® sensor (Pinga Group, Belgium).

Both beds were placed in the lowest position. In the backboard group, a backboard (59 x 44 x 5 cm, 2kg, CPR board, Bound Tree Medical, Dublin, OH, USA) was longitudinally placed between the manikin and the mattress. The mattress and backboard (if present) were covered with a non-translucent white
sheet. A non-obstructive researcher was present throughout phase two. None of the participants were informed about the use and evaluation of a backboard.

To test the study hypothesis, a new test (two minutes, 30:2 CPR) was performed similar as in phase one. After the test, participants were given digital feedback and completed the data collection process. Demographics and time since last CPR training were registered. A successful CPR test was achieved when participants reached a combined compression score of ≥70%: ≥70% chest compressions with depth 50-60mm and ≥70% chest compressions with complete release (≤5mm) and a mean compression rate of 100-120bpm.

Outcome measures and covariates

The primary outcome was defined as the difference in proportion of participants reaching a ≥70% combined compression score between both study groups. Secondary outcomes were defined as the difference in median (i) chest compression depth, (ii) compression rate and (iii) number of compressions with complete release between both study groups. The covariates considered were sex, age (21-30, 31-40, 41-50, ≥51 years), clinical department (critical, non-critical care) and BMI (<25, 25-30, >30 kg/m²).

Sample size calculation

A 10% difference in the primary outcome between both groups was predefined as clinically relevant. With SAS® Power and Sample Size (Version 9.4, SAS Institute Inc., Cary, NC, USA) a required sample size of 250 participants per group was calculated considering 85% of the backboard group and 75% of the control group would achieve the threshold of 70% (β=0.80, α=0.05). High success rates were expected since CPR skills deteriorate within three to six months after training (Greif et al., 2015). The maximum time interval between both study phases was expected to be two months. The total sample size was doubled (n=1000) considering a 50% dropout between both phases was anticipated. Since it seemed unlikely that the desired sample size would be achieved during the predefined study period, a *post-hoc* power calculation was anticipated.
Statistical analysis

Compression quality is the major determinant for survival (Considine et al., 2020; Kleinman et al., 2015; Perkins et al. 2015). Therefore, researcher assisted ventilations were not included in data-analysis in phase two. A two-sided p-value set at α<0.05 was considered statistically significant. To assess the effect of a backboard on compression quality, Chi-square and Fisher’s exact tests were used in categorical variables and Mann-Whitney U tests in non-normally distributed continuous variables.

Multiple logistic regression analyses were executed to assess independent relationships with the primary outcome and its three individual compression components. Independent variables in these analyses included BMI, age, sex and clinical department. The ‘Enter’ method was used and covariates with p>0.15 were stepwise removed from the model. The Hosmer-Lemeshow test was performed to determine the goodness-of-fit of the regression models (Hosmer and Lemeshow, 2013). Since there was no difference in primary outcome between participants in the first three age categories, the covariate was recoded into two categories (21-50 and ≥51 years) and analysed using IBM® SPSS® Statistics (Version 25.0, IBM Corporation, New York, NY, USA).

Participant recruitment, online randomisation, data collection and analysis were performed by the same two non-blinded researchers.

Results

The study sample in phase one consisted of 278 participants (82.1% female and 17.9% male) of whom 134 (44.1%) worked in the critical care. Ten out of the 49 nurses that dropped out during phase one (Fig. 1) belonged to the age category of ≥51 years. The largest group that dropped out (n=25) was 21-31 years. The median number of attempts to succeed in phase one was two.

Hundred and twenty participants achieved a combined score ≥70% and were randomised into a backboard group (n=59) or control group (n=61). They performed a new CPR test (phase two). During this period 47.6% (109/229) total drop-out rate was observed (Fig. 1). Both study groups had no significant differences in baseline characteristics (Table 1).
**Effect of a backboard**

No significant difference was found between both groups in achieving a combined compression score of ≥70% in phase two (Table 2). In total, only 53 participants reached this predefined threshold. Out of the 24 nurses with an age of ≥51 years in phase two, only four passed the test. Between both study groups, no difference was observed regarding compression depth, rate and chest recoil (Table 2, Fig. 2).

With a sample size of 59 (backboard group) and 61 (control group) and a proportion of participants reaching the threshold of ≥70% combined compression score in phase two of respectively 47.5% and 41.0% (α=0.05), the post-hoc power calculation was 0.083.

Comparing the median chest compression depth, rate and chest recoil between both groups no statistically significant difference was found (Table 3).

**Influence of age, sex, BMI and clinical department**

A multiple binary logistic regression analysis was performed to assess independent relationships with combined compression score (Table 4). The Hosmer and Lemeshow statistic indicated no significant difference between the observed and expected values (p=0.925). Only age (participants ≥51 years) was a significant predictor to less likely achieve the combined compression score compared to younger participants.

The logistic regression model could not identify any independent predictors for the individual score component ‘chest compression depth’. As for chest recoil, only participants ≥51 years performed significantly lower than their younger colleagues. Regarding chest compression rate, non-critical care nurses were a significant predictor for poor chest compression rate. No other variables reached statistical significance (including backboard) (Table 4).
Discussion

This study evaluated the effect of a backboard on chest compression quality during in-hospital CPR on an adult-sized manikin. No significant differences in chest compression depth, rate and chest recoil were found when CPR-certified nurses performed compressions with or without a backboard on a memory foam mattress. The logistic regression model confirmed this by showing that a backboard was not a significant predictor for any of the four dependent variables.

This current manikin study confirms the lack of evidence on backboard effectiveness during in-hospital adult CPR. Moreover, existing evidence only consists of manikin studies, limiting extrapolation of study results to humans (Perkins et al., 2019). Numerous methodological differences such as mattress type and thickness, sample size and composition, CPR duration, manikin weight, backboard size/orientation, participant CPR position, target compression depth/recoil/rate and whether or not participants were blinded or given feedback during CPR complicate the comparison of those results. Previous manikin studies were generally focused on mean chest compression depth, while compression quality is determined by chest compression depth, rate and chest recoil (Perkins et al., 2015).

The study of Sanri and Karacabey, investigating the effect of a backboard on all three compression parameters (compression depth, rate and chest recoil), was methodologically closest to this RCT (Sanri and Karacabey, 2019). In their manikin study 101 medical students performed CPR on a stretcher with an 8 cm foam mattress. In the backboard group a significant improvement was observed for every individual compression parameter. The proportion of compressions with all three sub-parameters being successful increased from 38.0% to 66.7% (Sanri and Karacabey, 2019). When compared to our study, those better results might be attributed to differences in mattress thickness or a bias in baseline skills. In the Sanri and Karacabey study all participants received CPR training during their emergency medicine clerkship (Sanri and Karacabey, 2019). However, no measurement of their actual competence level is reported after training. An unequal baseline skill level might have biased the chest compression quality in favour of the backboard group. Current RCT used a 14 cm thick memory foam
mattress, which could have induced a higher compressibility, faster fatiguing and therefore more shallow chest compressions.

The effectiveness of a backboard is influenced by mattress stiffness (Perkins et al., 2019) and mainly described in soft mattresses, not in relatively hard hospital mattresses (i.e. emergency stretcher mattresses, operating room mattresses and more dense standard hospital mattresses) (Andersen et al., 2007; Cloete et al., 2011; Fischer et al., 2016; Nishisaki et al., 2012; Oh et al., 2013; Perkins et al.; 2009; Sanri and Karacabey, 2019). This can be explained by a higher amount of mattress compressibility in soft mattresses and therefore a greater opportunity for chest compression optimisation when using a backboard. However, three manikin studies with foam and/or pressure relieving mattresses did not support backboard use during CPR (Perkins et al., 2006; Putzer et al., 2016; Schober et al., 2014) and are similar to the findings in this RCT.

The continuing existence of mattress compression despite backboard placement might be another possible explanation for the findings in this study. Three manikin studies observed reduced mattress compression using a backboard, but emphasise that it is not eliminated (Lin et al., 2017; Noordergraaf et al., 2009; Oh et al., 2016). One trial attributed this to backboard shifting during compressions decreasing the contact area with the underlying mattress, resulting in poorer compression quality (Perkins et al., 2009).

To assess the effect of a backboard on compression quality, the proportion of participants who achieved a combined compression score of ≥70% was reported. Reporting a combined competence score acknowledges more comprehensive reporting of the total CPR quality than individual reporting of each CPR skill (Mpotos et al., 2015). In both groups more than 50% of participants reached the 70% threshold for compression depth, rate and chest recoil. However, despite recent CPR training less than 50% of participants obtained a combined compression score ≥70%. This could be explained by the fact that CPR skills already deteriorate within three to six months after training (Greif et al., 2015) and the interval between both study phases could maximum have reached 3.5 months. In addition, phase one results were obtained performing CPR on the floor whilst in phase two the manikin was laying on a mattress in bed. This different
CPR position (kneeling on a stable floor vs. standing next to or kneeling in a less stable bed) and the potential unfavourable influence of mattress deflection on compression depth during CPR in bed might also explain the lower success rates in phase two (Hasegawa et al., 2020; Lin et al., 2017; Nishisaki et al., 2009; Nishisaki et al., 2012; Noordergraaf et al., 2009; Oh et al., 2016; Ruiz et al., 2016; Sainio et al., 2014).

Results in this current trial showed that only age predicted a higher chance not to achieve the ≥70% combined compression score. For the individual score components (depth, rate and chest recoil) only age ≥51 years was a significant predictor for not achieving ≥70% sufficient chest recoil. However, the age group of ≥51 years did show a trend to significance to predict a mean compression rate of 100-120bpm. This is in line with the findings of Peberdy and colleagues where individuals of ≥51 years achieved a lower mean chest compression depth and a higher percentage of suboptimal chest compressions than younger individuals (Peberdy et al., 2009). Loss of muscle mass and strength with ageing could be explanations. This current study confirms the need for frequent CPR retraining as recommended by the ERC and suggests more frequent CPR training for nurses ≥51 years. Yearly retraining may be insufficient since CPR skills already decay within months after training (Greif et al., 2015).

With regard to sex and BMI, this trial could not demonstrate an impact on achieving a combined compression score of ≥70%. Yet, other studies suggested that sex (Amacher et al., 2017; Jaafar et al., 2015; Peberdy et al., 2009) and BMI (Gianotto-Oliveira et al., 2010; Jaafar et al., 2015; Sayee and McCluskey, 2012) are significant predictors for adequate chest compression quality. Two studies stated that males performed better than females on CPR quality (Amacher et al., 2017; Peberdy et al., 2009). Jaafar, Abdulwahab and Al-Hashemi reported that participants with a mean BMI of <26 performed better than those with a mean BMI of >26 (Jaafar et al., 2015), whereas other studies stated that healthcare providers with a higher BMI were associated with better CPR quality (Gianotto-Oliveira et al., 2010; Sayee and McCluskey, 2012).
Focusing on clinical department, critical care nurses showed a trend to significance to predict a combined compression score of ≥70%. However, there is no evidence supporting the assumption that critical care nurses tend to perform chest compressions more correctly than non-critical care nurses.

Since CPR using a backboard is not significantly superior to CPR without a backboard, this manikin study suggests against the interruption of chest compressions to place a backboard. However, the generalizability of this result is limited. CPR teams should carefully assess whether placing a backboard is justified for the mattress types used in their hospital. Further well-designed, multicentre RCT’s on all three compression parameters (depth, recoil and rate) are necessary using other types of bed frames, mattresses, backboards or backboard positions.

Limitations
This study has a number of limitations. Since the calculated sample size was not reached, it became improbable to demonstrate a significant difference between the groups. However, a post-hoc power calculation revealed a β=0.08 indicating unlikeliness of finding significant differences even when the anticipated sample size would have been achieved. Mattress compressibility was not measured since the effectiveness of CPR results from achieving adequate compression depth rather than reducing the amount of mattress compression. Considering this trial was conducted with manikins, extrapolation of the results to patients remains limited. In addition, only one type of manikin, bed frame, mattress and backboard were tested.

Conclusion
Using a backboard did not significantly improve compression quality (compression depth, rate and chest recoil) during in-hospital CPR on an adult-sized manikin. Nurses ≥51 years were less likely to achieve the combined compression score of ≥70%. Important decay of compression skills was observed in both groups, highlighting the importance of frequent retraining, particularly in some age groups.
References


**Legends to figures and tables**

Fig. 1: Participant flow chart

Fig. 2: Graphical representation of successful participants for the combined compression score, chest compression depth, chest recoil and chest compression rate

Table 1: Participants demographics after phase two

Table 2: Proportions of successful participants

Table 3: Median of chest compression parameters

Table 4: Predictors for successful chest compression quality
Fig. 1: Participant Flow Chart

Phase 1  
Assessed for eligibility and trained in CPR (n=278)  
Excluded (n=49)  
Combined CPR score <70%

Phase 2  
Randomized after combined CPR score >70% (n=229)

Backboard group (n=114)  
2 min CPR intervention with backboard  
Dropouts (n=55)  
Unknown reason, did not respond to the invitation  
Analysed (n=59)

Control group (n=115)  
2 min CPR intervention without backboard  
Dropouts (n=54)  
Unknown reason, did not respond to the invitation  
Analysed (n=61)

Fig. 2: Graphical representation of successful participants for the combined compression score, chest compression depth, chest recoil and chest compression rate

Legend  ■ Control Group (n=63)  □ Backboard Group (n=59)  CC = Chest Compression
Table 1: Participants demographics after phase two

<table>
<thead>
<tr>
<th>Variable</th>
<th>Backboard Group (^a) (n=59)</th>
<th>Control group (^b) (n=61)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median (IQR) / n (%)</td>
<td>Median (IQR) / n (%)</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>37.00 (28.00-45.00)</td>
<td>35.00 (27.00-48.00)</td>
<td>0.737 (^d)</td>
</tr>
<tr>
<td>Critical care department</td>
<td>26 (44.1)</td>
<td>27 (44.3)</td>
<td>0.983 (^c)</td>
</tr>
<tr>
<td>Non-critical care department</td>
<td>33 (55.9)</td>
<td>34 (55.7)</td>
<td></td>
</tr>
<tr>
<td>Sex (male)</td>
<td>15 (25.4)</td>
<td>12 (19.7)</td>
<td>0.451 (^c)</td>
</tr>
<tr>
<td>BMI</td>
<td>23.03 (20.93-25.88)</td>
<td>23.83 (21.31-28.07)</td>
<td>0.265 (^d)</td>
</tr>
</tbody>
</table>

\(^a\) Intervention: With backboard

\(^b\) Control: Without backboard

\(^c\) Chi-square test.

\(^d\) Mann-Whitney u test.
Table 2: Proportions of successful participants

<table>
<thead>
<tr>
<th>Variable</th>
<th>Backboard Group&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Control group&lt;sup&gt;b&lt;/sup&gt;</th>
<th>p-value&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n/N (%) [95% CI]</td>
<td>n/N (%) [95% CI]</td>
<td></td>
</tr>
<tr>
<td>≥70% compressions with depth 50-60 mm</td>
<td>37/59 (62.7) [50.0-75.0]</td>
<td>31/61 (50.8) [38.0-64.0]</td>
<td>0.189</td>
</tr>
<tr>
<td>≥70% compressions with complete release (≤5 mm)</td>
<td>57/59 (96.6) [92.0-100.0]</td>
<td>57/61 (93.4) [87.0-100.0]</td>
<td>0.426</td>
</tr>
<tr>
<td>Mean compression rate 100–120 min&lt;sup&gt;−1&lt;/sup&gt;</td>
<td>44/59 (74.6) [63.0-86.0]</td>
<td>49/61 (80.3) [70.0-91.0]</td>
<td>0.451</td>
</tr>
<tr>
<td>≥70% combined compression score&lt;sup&gt;d&lt;/sup&gt;</td>
<td>28/59 (47.5) [34.0-61.0]</td>
<td>25/61 (41.0) [28.0-54.0]</td>
<td>0.475</td>
</tr>
</tbody>
</table>

<sup>a</sup> Intervention: With backboard

<sup>b</sup> Control: Without backboard

<sup>c</sup> Chi-square test.

<sup>d</sup> ≥70% combined compression score: ≥70% of all compressions 50-60mm and ≥70% of all compressions with complete release (≤5mm) and compression rate of 100-120 min<sup>−1</sup>. 
<table>
<thead>
<tr>
<th>Variable</th>
<th>Backboard Group\textsuperscript{a} (n=59)</th>
<th>Control group\textsuperscript{b} (n=61)</th>
<th>p-value\textsuperscript{c}</th>
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<tbody>
<tr>
<td>Compression depth (mm)</td>
<td>52.82 (49.57-56.16)</td>
<td>52.86 (48.95-57.08)</td>
<td>0.815</td>
</tr>
<tr>
<td>Median number of compressions with complete release</td>
<td>163.49 (150.50-180.00)</td>
<td>162.93 (159.50-180.00)</td>
<td>0.778</td>
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<tr>
<td>Compression rate (bpm)</td>
<td>107.86 (102.00-117.00)</td>
<td>108.28 (102.50-116.00)</td>
<td>0.866</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Intervention: With backboard

\textsuperscript{b} Control: Without backboard

\textsuperscript{c} Mann-Whitney U test.
Table 4: Predictors for successful chest compression quality

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Predictor</th>
<th>p-value</th>
<th>Odds Ratio</th>
<th>95% C.I. Lower</th>
<th>95% C.I. Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined compression score</td>
<td>Backboard, yes</td>
<td>0.522</td>
<td>1.288</td>
<td>0.593</td>
<td>2.800</td>
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<td>Department, critical care</td>
<td>0.076</td>
<td>2.038</td>
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<td></td>
<td>Age, ≥51</td>
<td>0.002</td>
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<td></td>
<td>Sex, male</td>
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<td>Hosmer and Lemeshow test: p = 0.925</td>
<td>MCS</td>
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<tr>
<td>Chest compression depth</td>
<td>Backboard, yes</td>
<td>0.215</td>
<td>1.589</td>
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<tr>
<td></td>
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<td>0.268</td>
<td>1.666</td>
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<td>Hosmer and Lemeshow test: p = 0.481</td>
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<td>Chest recoil</td>
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<td>Hosmer and Lemeshow test: p = 0.770</td>
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<tr>
<td>Chest compression rate</td>
<td>Backboard, yes</td>
<td>0.470</td>
<td>0.719</td>
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<td>Hosmer and Lemeshow test: p = 0.102</td>
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Predictors with p>0.15 were stepwise removed from the model (except "backboard") as long as at least two predictors per dependent variable remained in the final model.

Analysis is based on logistic regression. P-values <0.05 are considered statistically significant. P-values with range of 0.05-0.10 are considered a trend to significance.

Number of participants included in analysis: n= 120.
Statement of Authorship

Title: Effect of a backboard on chest compression quality during in-hospital adult cardiopulmonary resuscitation: a randomised, single-blind, controlled trial using a manikin model.

Study design: A prospective, non-crossover, single-blind, randomised controlled trial (superiority design) was designed using a manikin model.

First author: Zara Cuvelier RN, BSc MSc, Graduate, Department of Public Health and Primary Care, Faculty of Medicine and Health Sciences, Ghent University, Corneel Heymanslaan 10, 9000 Ghent, Belgium.
Contribution to the paper: (1) Contribution to the conception and design of the study (2) acquisition of data (3) analysis and interpretation of data, (4) drafting the article (5) revising it critically for important intellectual content, (6) final approval of the version to be submitted.

Second author: Ruben Houthooft RN, BSc MSc, Graduate, Department of Public Health and Primary Care, Faculty of Medicine and Health Sciences, Ghent University, Corneel Heymanslaan 10, 9000 Ghent, Belgium.
Contribution to the paper: (1) Contribution to the conception and design of the study (2) acquisition of data (3) analysis and interpretation of data, (4) final approval of the version to be submitted.

Third author: Brecht Serraes RN, BSc MSc, Critical Care Nurse, Staff member Nursing and Paramedical Department, AZ Nikolaas (General Hospital), Moerlandstraat 1, 9100 Sint-Niklaas, Belgium.
Contribution to the paper: (1) Contribution to the conception and design of the study (2) acquisition of data (3) analysis and interpretation of data, (4) revising it critically for important intellectual content, (6) final approval of the version to be submitted.

Fourth author: Carl Haentjens, RN, BSc MSc, Critical Care Nurse, Emergency Department, AZ Nikolaas (General Hospital), Moerlandstraat 1, 9100 Sint-Niklaas, Belgium.
Contribution to the paper: (1) Contribution to the conception and design of the study (2) acquisition of data (3) revising it critically for important intellectual content, (4) final approval of the version to be submitted.

Fifth author: Stijn Blot RN, BSc MSc, PhD, Professor, Department of Internal Medicine and Pediatrics, Faculty of Medicine and Health Sciences, Ghent University, Corneel Heymanslaan 10, 9000 Ghent, Belgium; Burns, Trauma, and Critical Care Research Centre, Faculty of Medicine, The University of Queensland, Australia.
Contribution to the paper: (1) Contribution to the conception and design of the study (2) analysis and interpretation of data, (3) drafting the article (4)
revising it critically for important intellectual content, (5) final approval of the version to be submitted

**Sixth author:** Nicolas Mpotos MD, BSc MSc, PhD, Emergency Physician, Emergency Department, St. Lucas general hospital, Groenebriel 1, 9000 Ghent, Belgium.

**Contribution to the paper:** (1) Contribution to the conception and design of the study (2) analysis and interpretation of data, (3) drafting the article (4) revising it critically for important intellectual content, (5) final approval of the version to be submitted

**Notification of conflicts of Interest and external funding**

‘Conflicts of interest: Nicolas Mpotos (NM) developed a training strategy to acquire and retrain CPR skills in a self-learning station. NM is owner of Pinga Group bv., a company providing CPR self-learning. Data acquisition was not conducted by NM’.

‘External funding: None.’

**Ethical Adherence**

The study protocol was approved by the Ethics Committee of Ghent University Hospital, Ghent, Belgium (trial registration B670201941133). Digital informed consent was obtained from every participant. Written informed consent was additionally obtained from every participant in phase two. All study procedures were performed according to the Good Clinical Practice Guidelines (ICH/GCP) and the ethical guidelines of the Helsinki Declaration (2013 version).

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<tr>
<th>Zara Cuvelier</th>
<th>Ruben Houthoofdt</th>
<th>Brecht Serraes</th>
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