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Comparison of different surfaces in resuscitation quality using a real-time feedback device: A manikin study

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Abstract:

OBJECTIVES: Delivering chest compressions (CCs) at the targeted depth and rate is a crucial aspect of maintaining the quality of cardiopulmonary resuscitation (CPR). Although administering CCs on a firm surface is recommended, it may not always be feasible. This study aimed to determine whether the underlying surface affects CC depth and rate using a real-time feedback device.

METHODS: An observational study was conducted on a manikin (ResusciAnne; Laerdal). 25 volunteer emergency medicine physicians performed 2 min of continuous CCs without feedback on the floor, emergency department stretcher (EDS), and ambulance stretcher (AS). The following day, all participants performed an additional 2 min of CCs while receiving audiovisual real-time feedback (ZOLL M2 series). Compression depths and rates were measured and recorded in a real-time feedback device.

RESULTS: A total of 150 CC intervals were analyzed. The mean values of compression depths and rates on all surfaces are within the targeted range for high-quality CPR, except for the mean depth without feedback on the EDS (mean: 6.37 cm). There were a statistically significant difference, with both AS and EDS were achieved deeper compressions than those on the floor ($P < 0.05$). When examining the mean compression depths on three different surfaces with feedback, no statistically significant difference was observed. However, CCs performed without feedback on both AS and EDS were statistically significantly deeper than those on the floor. The mean compression rates both on the floor and the AS were statistically significantly faster compared to EDS. When examining the mean compression rates during CCs performed on three different surfaces with feedback, no statistically significant difference was observed but in the without feedback compressions, both on AS and floor were found to be statistically significantly faster than EDS.

CONCLUSIONS: CC's depth are influenced by the underlying surface. It appears more feasible to minimize surface-related differences while maintaining appropriate targets for depth using real-time feedback devices. The mean compression rate could be kept within the targeted range regardless of the surface.

Keywords:

Audio feedback, cardiopulmonary resuscitation, compression depth, feedback, manikin, visual feedback

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Introduction

The quality of cardiopulmonary resuscitation (CPR) is the most crucial determinant of survival in cardiac arrest.

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Box-ED section

What is already known on the study topic?

- Delivering optimal chest compression (CC) is believed to be most effective when the victim is positioned on a firm surface
- The depth and rate of CCs can be influenced by the underlying surface
- Using real-time audiovisual feedback devices during resuscitation for optimization of cardiopulmonary resuscitation (CPR) quality may be reasonable.

What is the conflict on the issue? Has it importance for readers?

- Although there are several studies investigating the relationship between different surfaces with compression depth and rate, there are few studies comparing ambulance stretcher (AS), emergency department stretcher (EDS), and floor
- Several studies have shown that using real-time feedback devices can enhance CPR quality and improve survival rates, but some studies have found results that contradict these findings
- Studies are needed to investigate whether real-time feedback can mitigate the impact of different surfaces on CPR depth and rate.

How is this study structured?

- This study was an observational manikin study with 25 emergency medicine physicians.

What does this study tell us?

- CC depth and rate are affected by the underlying surface. It appears more feasible to minimize surface-related differences while maintaining appropriate targets for depth using real-time feedback devices.

Management

- The mean values of compression depths and rates on all surfaces are within the targeted range for high-quality CPR, except for the mean compression depth without feedback on the EDS
- The mean compression depths on three different surfaces with feedback are similar
- The mean compression depths measured on the EDS and AS are deeper in the groups without feedback
- The mean compression rates are similar in the groups with and without feedback on all three surfaces
- The mean compression in target was higher in the real-time feedback groups but, no difference was observed among surfaces.

Several essential components have been outlined for high-quality CPR, which encompass minimizing interruptions in chest compressions (CCs), maintaining a CC fraction of >60%, refraining from leaning on the chest between compressions, avoiding excessive ventilation, and ensuring compressions are delivered at an adequate rate and depth.[1]

Performing high-quality CPR is tiring, and the quality of CPR may vary over time as the practitioner becomes fatigued.[2-4] Instantaneously monitoring the parameters with real-time audiovisual feedback devices may facilitate achieving the target compression rate and depth more easily. Therefore, using feedback devices during CPR for real-time optimization of CPR quality may be reasonable.[1] In addition, CPR feedback devices have been endorsed for use in resuscitation training as they contribute to the acquisition and retention of CPR skills.[5] Several studies have demonstrated that the use of real-time feedback can enhance the quality of CPR and improve survival rates.[6-10] Nevertheless, some studies have produced results contradicting these findings, indicating no positive contributions to CPR quality and no favorable discharge outcomes.[11,12]

Administering resuscitation is generally advised where the victim is found, provided that the delivery of high-quality CPR can be accomplished securely and efficiently.[1] Delivering optimal CC is most effective when the victim is positioned on a firm surface. If high-quality CPR cannot be performed, the patient may be transferred to a suitable surface or a backboard may be added to a soft surface.[13] When reviewing the literature, trials investigating the effects on compression depth present varying results for backboards, patient beds, intensive care beds, different mattresses, and ASs. In some studies, investigating the relationship between surfaces such as hospital beds, floor, and backboards with compression depth, there is no statistically significant difference among compression depths.[3,14,15] However, in different studies, deeper compressions were achieved on the floor.[16,17] Further research is required to identify the optimal surface for high-quality CPR in various scenarios and assess surfaces impact on CPR quality.

The objective of this study was to determine whether CC depth and rate are influenced by the underlying surface. We hypothesized that CC depth and rate would be measured at similar values across all surfaces during CCs performed by emergency physicians using audiovisual feedback devices.

Methods

Study design

We conducted an observational manikin study. The ethical approval of this study was authorized by the University of Health Sciences Hamidiye Clinical Research Ethics Committee with decision number 5/9 on February 2, 2023.

Participants

The participants were recruited from emergency physicians currently serving at a tertiary-level training and research hospital in Istanbul, Turkey, who had undergone advanced cardiac life support training following the American Heart Association's (AHAs) 2020 guidelines within the past year. After being informed about the study, written consent was obtained from participants. The exclusion criteria were defined as follows: not having received CPR training within the past 12 months, or having an inability to physically perform CPR.

Equipment and materials

The CC performance was assessed using pads equipped with accelerometer technology, positioned between the manikin's sternum and the volunteer's hands (Stat-Padz, ZOLL Medical Corporation, Chelmsford, MA, USA). Simultaneously, the performance was measured and recorded using a defibrillator (ZOLL M2 Series, ZOLL Medical Corporation, Chelmsford, MA, USA), which also featured audiovisual real-time feedback functionality. Real-time feedback is provided visually and verbally through the monitor (e.g., "increase compression frequency slightly"). The manufacturer (ZOLL) has predefined the target values following the 2020 AHA guidelines for CPR and emergency cardiovascular care. The target compression depth was set within a range of 5–6 cm, and the goal for compression rate was 100–120/min. The CPR manikin (Resusci Anne Simulator; Laerdal, Stavanger, Norway) was placed on three different surfaces, including the EDS (Multifunctional Emergency Stretcher UT-18, 760 mm × 2200 mm, Rausmann, Turkey, viscoelastic mattress with polyurethane coverage 600 mm × 1850 mm × 100 mm,) AS (ES 100, EMS, Turkey), and floor. We used a footstool with EDS (395 mm × 450 mm × 410 mm).

Intervention

Before the commencement of the study, participants were informed about the defibrillator's real-time feedback technology. On the 1st day, 25 volunteer emergency medicine physicians performed 2 min of continuous CCs without audiovisual real-time feedback on three different surfaces. During compressions performed on the AS, the stretcher was lowered to ground level, and volunteers applied CC while kneeling beside the stretcher. Similarly, on the floor, volunteers completed CC by kneeling beside the manikin. On the EDS, volunteers applied compression while standing on a footstool right next to the stretcher, choosing the height that allowed them to apply pressure most comfortably. The following day, all participants performed an additional 2 min of CCs while receiving audiovisual real-time feedback.

Data collection

Compression performance was measured using the pads, recorded on an internal memory card in the defibrillator, and analyzed using the RescueNet Code Review program (ZOLL Medical Corporation, 2018, version 5.8.1). The compression performance was evaluated following the 2020 resuscitation guidelines of the AHA. The proportion of compressions that simultaneously met both the appropriate rate and depth was calculated and expressed as compression in target (CiT). The data were exported into Microsoft Excel Professional Plus 2016 and subsequently transferred to statistical software (IBM SPSS Statistics 26.0, IBM Corp, Armonk, NY, USA) for further statistical analysis.

Outcomes measures

The primary outcomes of our study were CC depth, CC rate, and CiT. The secondary outcomes were characterized as the differences between the groups in the mean pairwise comparisons of the measurements according to the surfaces and whether feedback was received or not.

Statistical methods

The study had 96% power to produce a significant difference with 25 participants in terms of depth and alpha error of 5%. We used the Shapiro–Wilk test for the normal distribution of data. The results were reported as mean ± standard deviation for normally distributed continuous variables. In the comparison of two groups showing a normal distribution, the paired *t*-test was used for dependent groups, while the independent *t*-test was employed for independent groups. A $P < 0.05$ was accepted as statistically significant. All analyses were performed using IBM SPSS Statistics 26.0 (IBM Corp, Armonk, NY, USA).

Results

A total of 150 CC intervals, each lasting 2 min and conducted by 25 volunteers, were analyzed. Performance data for the groups and box plots graphics are presented in Table 1 and Figure 1. The mean values of compression depths and rates on all surfaces are within the targeted range for high-quality CPR, except for the mean depth of CCs applied without feedback on the EDS (mean: 6.37 cm). The shallowest mean compression depth was achieved on the floor while the deepest was observed during compressions performed on the EDS. In pairwise comparisons between the floor and both EDS and AS, there was a statistically significant difference, with both AS and EDS producing deeper compressions than on the floor ($P = 0.011$, $P = 0.002$) [Table 2]. When examining compression depths during CCs on three different surfaces with feedback, no statistically significant difference was observed [Table 3]. Nonetheless, in CCs performed without feedback, the compression depths on EDS and AS were statistically significantly deeper than on the floor ($P = 0.007$, $P = 0.003$) [Table 4].

Table 1: Comparison of compression parameters with and without feedback at three surfaces

	All CC (SD)	Group	Mean±SD	95% CI mean lower-upper bound	*P*
Depth EDS (cm)	5.85 (1.2)	WOF	6.37±1.51	5.75–6.99	0.002
		WF	5.34±0.36	5.19–5.49	
Depth AS (cm)	5.62 (0.65)	WOF	5.82±0.84	5.47–6.17	0.032
		WF	5.42±0.29	5.30–5.55	
Depth floor (cm)	5.35 (0.49)	WOF	5.34±0.66	5.07–5.62	0.933
		WF	5.36±0.25	5.25–5.46	
Rate EDS (/min)	113.9 (10.81)	WOF	111.80±11.5	107–117	0.172
		WF	116.00±9.84	112–120	
Rate AS (/min)	118.74 (8.61)	WOF	120.24±10.4	0.222	0.222
		WF	117.24±6.18	115–120	
Rate floor (/min)	119.18 (10.26)	WOF	120.12±13.5	115–126	0.523
		WF	118.24±5.55	116–121	
CiT EDS (%)	34.12 (32.34)	WOF	13.20±19.1	5.33–21.1	<0.001
		WF	55.04±29.3	42.9–67.2	
CiT AS (%)	38.88 (31.01)	WOF	17.56±21.7	8.62–26.2	<0.001
		WF	60.20±23.4	50.5–69.9	
CiT floor (%)	43 (33.35)	WOF	25.84±30	13.4–38.2	<0.001
		WF	60.16±27.5	48.8–71.5	

CC: Chest compression, CiT: Compression in target, EDS: Emergency department stretcher, AS: Ambulance stretcher, WOF: Without feedback, WF: With feedback, SD: Standard deviation, CI: Confidence interval

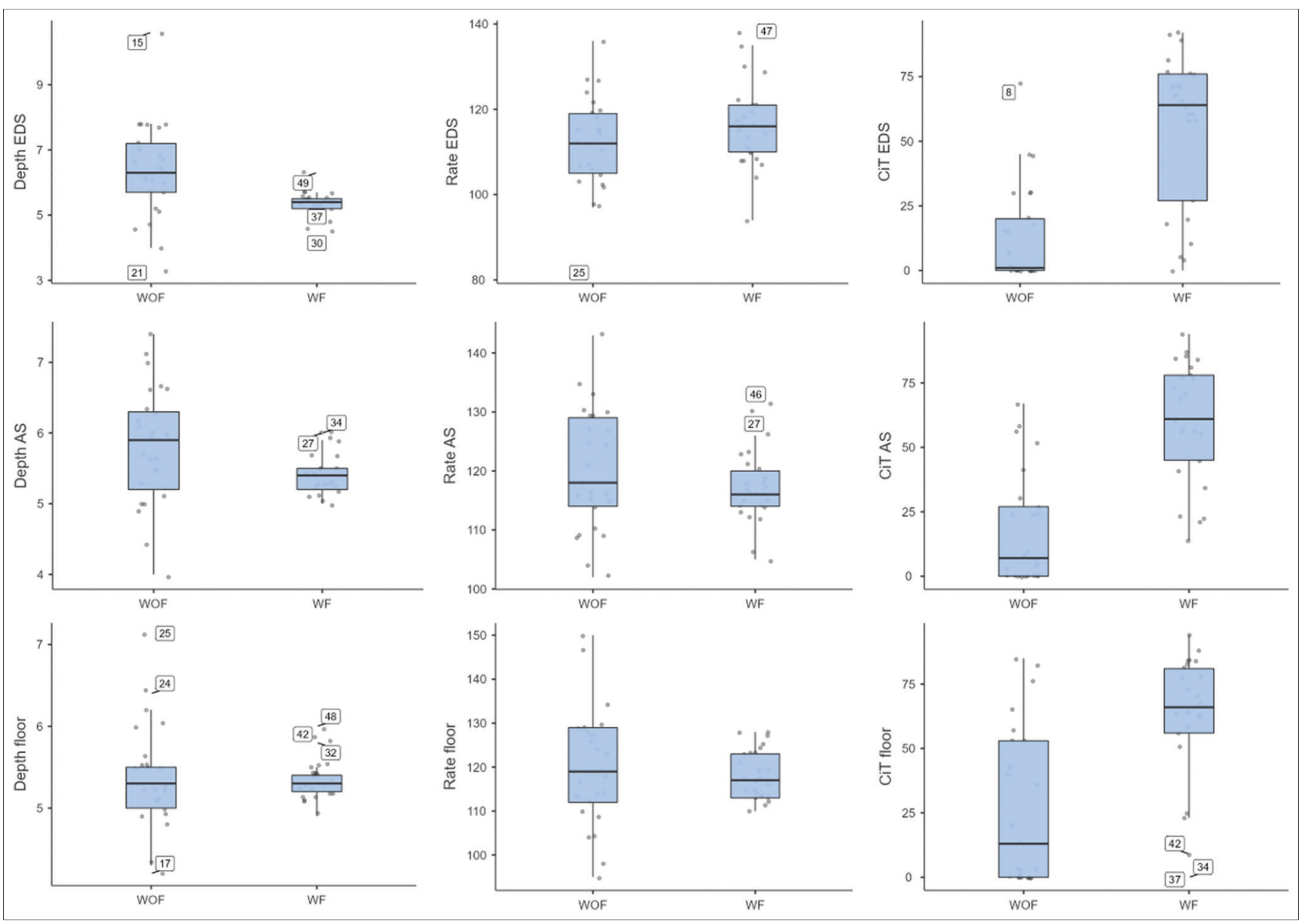

Figure 1: Box plots graphics of compression parameters with and without feedback at three surfaces

When examining the mean compression depths measured during CCs on the EDS and AS based on the feedback status, statistically significant differences were observed between those who received feedback and

Table 2: Pairwise comparison of all chest compression parameters, independent of feedback

	Statistic	*P*	Mean difference	SE difference
CiT floor - CiT AS	1.014	0.315	4.120	4.0617
CiT floor - CiT EDS	1.931	0.059	8.880	4.5981
CiT EDS - CiT AS	−1.093	0.280	−4.760	4.3537
Depth floor - depth AS	−3.326	0.002	−0.272	0.0818
Depth floor - depth EDS	−2.631	0.011	−0.504	0.1916
Depth EDS - depth AS	1.364	0.179	0.232	0.1700
Rate floor - rate AS	0.463	0.645	0.440	0.9503
Rate floor - rate EDS	2.755	0.008	5.280	1.9162
Rate EDS - rate AS	−2.776	0.008	−4.840	1.7434

CiT: Compression in target, EDS: Emergency department stretcher, AS: Ambulance stretcher, SE: Standard error

Table 3: Pairwise comparison of chest compression parameters at with feedback groups

	Statistic	*P*	Mean difference	SE difference
CiT floor - CiT AS	−0.006	0.09	−0.04	6.3
CiT floor - CiT EDS	0.76	0.453	5.12	6.7
CiT EDS - CiT AS	−0.67	0.5	−5.16	7.65
Depth floor - depth AS	0.95	0.34	1.76	1.84
Depth floor - depth EDS	1.01	0.32	1.85	1.83
Depth EDS - depth AS	−0.8	0.42	0.08	0.1
Rate floor - rate AS	0.88	0.38	1	1.13
Rate floor - rate EDS	0.9	0.34	2.24	2.3
Rate EDS - rate AS	−0.59	0.55	−1.24	2.08

CiT: Compression in target, EDS: Emergency department stretcher, AS: Ambulance stretcher, SE: Standard error

Table 4: Pairwise comparison of chest compression parameters at without feedback groups

	Statistic	*P*	Mean difference	SE difference
CiT floor - CiT AS	1.65	0.11	8.28	4.99
CiT floor - CiT EDS	1.99	0.058	12.64	6.34
CiT EDS - CiT AS	−1.007	0.32	−4.36	4.34
Depth floor - depth AS	−3.33	0.003	−0.47	0.14
Depth floor - depth EDS	−2.96	0.007	−1.02	0.34
Depth EDS - depth AS	−1.74	0.09	−0.54	0.31
Rate floor - rate AS	−0.07	0.93	−0.12	1.54
Rate floor - rate EDS	2.78	0.01	8.32	2.98
Rate EDS - rate AS	−3.18	0.004	−8.44	2.64

CiT: Compression in target, EDS: Emergency department stretcher, AS: Ambulance stretcher, SE: Standard error

those who did not ($P = 0.02$, $P = 0.032$). However, there was no statistically significant difference noted in the compressions performed on the floor ($P = 0.933$) [Table 1].

There was no significant difference in the mean compression rate between the groups with and without real-time feedback [Table 1]. Throughout the assessment of compression rates during CCs performed both on the floor and the AS, the mean compression rate was statistically significantly faster compared to EDS ($P = 0.008$, $P = 0.008$) [Table 2]. When examining the mean compression rates during CCs performed on EDS and AS with feedback, no statistically significant difference was observed ($P = 0.55$) [Table 3]. Nonetheless, in CCs performed without feedback, the mean compression rate on AS was found to be statistically significantly faster than EDS ($P = 0.004$). Similarly, the mean compression rate without feedback on the floor also contributed to the statistically significant difference compared to EDS ($P = 0.01$) [Table 4].

The mean CiT was higher in the real-time feedback groups, with a statistically significant difference ($P < 0.001$) [Table 1]. However, when comparing all CCs based on the feedback status, we observed a statistically significantly higher mean CiT in the feedback group (18.86%, 58.46%). In pairwise comparisons, no statistically significant difference was observed among surfaces in terms of CiT.

Discussion

When all CCs with and without audiovisual feedback are evaluated, the mean values of compression depths and compression rates on all surfaces are within the targeted range for high-quality CPR, except for the mean depth of cardiac compressions applied without feedback on the EDS. We attribute this to the fact that our participants consist of emergency medicine physicians who regularly practice CPR. In line with our findings, Lyngeraa *et al*. observed that mean depths and rates were within the targeted range, maintaining the quality of CPR irrespective of feedback in a cohort of trained participants.[11] However, some research has found that CPR administered by health-care professionals may not align with recommended targets, including slower compression rates and shallower compression depths.[18,19]

When examining all CCs in our study through pairwise comparisons, we did not find a statistically significant difference in mean CiT among the surfaces. However, when comparing all CCs based on the feedback status, we observed a statistically significantly higher mean CiT in the feedback group. Similarly, in a recent prospective observational study that assessed the quality of resuscitation in out-of-hospital cardiac arrests without real-time feedback, a CiT of 13% was calculated.[20] In the study conducted by Wattenbarger *et al*. examining the quality of CPR performed on a manikin by health-care providers, statistically significantly higher CiT was found in the group with real-time feedback compared to the group without feedback (31%–79%, $P < 0.001$).[21] In contrast to our study, Lee *et al*. reported that providing feedback did not contribute positively to CiT.[22] The ratio of compressions to all compressions in which the target rate and depth recommended for high-quality

CPR are achieved simultaneously is expressed as CiT. Based on the data obtained from our study, we observed higher CiT values during compressions performed with feedback. Therefore, we conclude that higher quality CPR can be performed when an audiovisual feedback device is used.

When comparing compression depths based on the surfaces where CPR was applied, the deepest compression average was obtained on the EDS, while the shallowest compressions were calculated on the ground. In pairwise comparisons between the floor and both EDS and AS, there was a statistically significant difference, with both EDS and AS producing deeper compressions than on the floor. However, publications indicate that compression depths measured with two different accelerometers tend to be higher on softer surfaces, suggesting that the actual impact of these compressions may be shallower.[23,24] Lee *et al*. found that to achieve a compression depth of 5–6 cm during CCs performed on a hospital bed, the accelerometer reading should be between 6 cm and 7 cm.[25] A study was conducted to investigate the impact of hospital beds, the ground, and two different backboards on compression depth with an accelerometer was placed under the mattress to measure the compression depth of the manikin on all three surfaces. After subtracting the sinking height of the manikin in the bed from the measured compression depth, similar average compression depths were found on all three surfaces, indicating that the bed did not affect the compression depth.[3] Another manikin study examining the effect of the ground and hospital bed on CPR depth calculated a shallower compression depth relative to the target, but no statistically significant difference between the two surfaces.[15] Jäntti *et al*. compared the ground and hospital bed as CPR surfaces, they achieved deeper compressions on the ground, but they did not find a statistically significant difference in compression depths between the surfaces.[26]

In addition to the real-time feedback device, using an accelerometer to measure the depth loss caused by the sinking of the surface where CPR is administered allows for a more accurate measurement of compression depth. However, currently, such a device is not available for clinical use. Participants in our study, who were experienced in CPR, likely sensed that the negative impact of these soft surfaces on compression depth allowed for less CC depth. In response, they attempted to create deeper compressions to overcome this situation. One reason for the deeper mean compression depth observed on the EDS could be that the compressions were performed while participants were standing on a footstool. In contrast, on the floor and on the AS, compressions were performed while participants were in a kneeling position beside the manikin and the stretcher. In the kneeling position, participants might be less able to lean over the manikin, potentially resulting in shallower compressions compared to those performed while standing. Contrary to our findings, the literature indicates that studies comparing CPR positions found no statistically significant difference in compression depths between those performed standing on a footstool and those performed kneeling beside the patient.[27,28]

When analyzing the mean compression depths recorded during CCs on both EDS and AS based on the feedback status, statistically significant differences were noted between the group that received feedback and the one that did not. In the feedback-received group, shallower compression depths were achieved on EMS and AS. Contrary to our study, publications are reporting a statistically significant increase in compression depth with the use of real-time feedback devices.[9,12] We believe this phenomenon, as previously mentioned, may be attributed to the soft surface. Perhaps, if we had not set an upper limit for compression depth, our experienced participants would not have adjusted their compression depths to shallower levels to fit within the suitable range determined by the real-time feedback device.

The mean compression rate remained within the target range in all groups. There was no statistically significant difference in the mean compression rate between the groups with and without real-time feedback for each surface. Similar to ours, in other studies conducted with experienced participants in resuscitation, it has been reported that there is no statistically significant difference in the mean compression rates between groups with and without feedback.[9,10,29] Unlike our study, a manikin trial examining the quality of CPR in participants including lay rescuers and trained rescuers reported a statistically significant difference in the mean compression rates between groups with and without feedback.[30]

In pairwise group comparisons, the mean compression rates during CCs performed both on the floor and AS were statistically significantly faster compared to the EDS. Among these surfaces, we did not observe a statistically significant difference in the mean compression rates during compressions with feedback; the difference was attributed to CCs performed without feedback. There could be two potential reasons why the compression rate on the EDS was slower than on both the AS and the floor. The first reason is the inverse relationship between speed and depth. According to the literature, studies investigating the relationship between CC rate and depth, have reported that an increase in rate is associated with a decrease in depth.[31,32] Our study yielded similar results. This might be due to the participants attempting to increase the speed by performing shallower compressions. Second, this difference might stem from the positions in which CPR is performed. A trial examining CPR parameters in standing and kneeling positions reported that compressions performed in the kneeling position were faster than those performed in the standing position.[28] Our data also showed slower compressions in the EDS, where CC was performed in the standing position.

In accordance with our hypothesis, when examining CCs performed with audiovisual feedback on three different surfaces, pairwise comparisons between surfaces revealed no statistically significant differences in mean compression rate, compression depth, and CiT values. In addition, the mean values were very close to the targeted rate and depth, in all compressions performed on all surfaces, with or without feedback. The clinically significant difference made by the audiovisual feedback device is the notable increase in the percentage of compressions achieved at both the targeted depth and targeted rate, known as CiT. Future clinical studies may help determine whether this increase in CiT positively affects survival, providing more data to support the use of these devices during resuscitation.

Limitations

There are several limitations in this study. First, this is a manikin study, and manikins may not simulate all aspects of human physiology. Second, CPR could be performed on different stretchers besides the stretchers we used in the study, so it would not be accurate to generalize these data for all stretchers. Third, performing CPR in different positions (standing on EDS, kneeling on AS, and on the floor) may have also affected the results. Fourth, in real-life situations, resuscitations can occur in many different scenarios beyond those we simulated.

Conclusions

It can be challenging to achieve the targeted compression depth required for high-quality CPR when performing on soft surfaces like a stretcher. CC depth and rate are affected by the underlying surface. It appears more feasible to minimize surface-related differences while maintaining appropriate targets for depth using real-time feedback devices. On the other hand, the compression rate could be kept within the targeted range regardless of the surface.

Author contribution statement

Hande Asan: Conceptualization, methodology (lead), software (lead), investigation (lead), resources, writing – original draft (lead), writing – reviewing and editing (supporting). Erdem Çevik: Data curation, methodology (supporting), writing – review and editing (lead), supervision (lead). Kemal Yıldırım: Data collection (lead), visualization, investigation (equal), project administration. Aydin Cenk Gungor: Data collection (supporting), software (supporting), reviewing. Abdullah Ilhan: Software (supporting), formal analysis, validation. Dilay Satılmiş: Writing- reviewing and editing (supporting), supervision (supporting).

Conflicts of interest

None Declared.

Ethical approval

The ethical approval of this study was authorized by the University of Health and Science Hamidiye Clinical Research Ethics Committee (Istanbul, Turkey) with decision number 5/9 on February 2, 2023.

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