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ORIGINAL RESEARCH

A backboard makes manual chest compressions more effective on bed mattresses

Aki Otsuka[1,†], Yoshifumi Kawakubo[2], Tomoyuki Tanaka[2], Masanobu Tsurumoto[3,4], Keisuke Hayashi[3], Takunori Shimazaki[2], Mana Kawakubo[5], Takashi Hitosugi[4,*,†], Takesh Yokoyama[4]

[1] Hemodialysis Center, Sugi Hospital, 837-0916 Fukuoka, Japan
[2] Department of Clinical Engineering, Faculty of Health Care Sciences, Jikei University of Health Care Sciences, 532-0003 Osaka, Japan
[3] Department of Clinical Engineering, Faculty of Health and Welfare, Tokushima Bunri University, 769-2193 Kagawa, Japan
[4] Section of Dental Anesthesiology, Division of Maxillofacial Diagnostic & Surgical Sciences, Faculty of Dental Science, Kyushu University, 812-8582 Fukuoka, Japan
[5] Department of Childhood, Faculty of Human Life Sciences, Shikoku University, 771-1151 Tokushima, Japan

***Correspondence**
hitosugi.takashi.724@m.kyushu-u.ac.jp
(Takashi Hitosugi)

† These authors contributed equally.

Abstract

When performing cardiopulmonary resuscitation (CPR) on a patient with cardiopulmonary arrest in bed, it has often been recommended that a backboard be placed behind the patient. However, the effectiveness of the use of a backboard has not yet been adequately studied. As a result, there are differences in the criteria for the use of the backboard in the latest global guidelines. This study tested the usefulness of backboards on five different mattresses and the floor. The depth of manual chest compressions (MCC), the recoil of MCC, MCC success rate, and participant's fatigue were evaluated with and without backboards. The MCC depth was maximum on the floor. On the bed, MCC depths were significantly deeper with backboards inserted than without backboards on all five mattress types. Similarly, MCC recoil depth and success rate, were more effective with the backboard inserted. It is recommended that MCC be performed on the floor only when manpower, environment, time and patient condition permit. However, if MCC must be performed on the bed, it is more effective with backboards placed behind a patient's back on various types of mattresses.

Keywords

Manual chest compressions; Medical mattresses; Cardiopulmonary resuscitation; Backboards

1. Introduction

Cardiopulmonary resuscitation (CPR) is the initiation of manual chest compressions (MCC) and defibrillation as soon as possible [1]. Effective MCC should be delivered by pushing hard and fast, allowing the chest wall to return after each push, and minimizing the time that MCC is interrupted. It is recommended that to maximize the effectiveness of MCC, the patient should be placed in the supine position on a stable, hard surface [1, 2]. When considering a stable, hard surface, it is ideal to lower the patient to the floor and perform MCC on the floor. However, lowering a patient to the floor requires manpower and is difficult in patients undergoing dialysis, in an intensive care unit, for example, where the vessels are routed and connected to medical pieces of equipment. In such cases, MCC is initiated in bed. To provide a stable, hard, flat surface on the bed, there are two options: on a hard medical mattress (hereafter referred to as the mattress) as it is, or with a backboard placed behind the patient's back. It has been reported that MCC is more effective when performed with a backboard [3, 4]. It has also been reported that MCC on a bed is influenced by the firmness of the mattress [5, 6]. However, there are several different types of mattresses, such as pressure distribution, rehabilitation, pressure sore prevention and standard models, each with different firmness, material and thickness, so that the choice can be tailored to the patient's condition. Medical industries have no standards for mattress firmness. These different types of mattresses have not yet been fully researched. Still, the use of backboards remains controversial even in the global guidelines. Only manikin-based studies are available thus human trials are still needed. However, if it is still ethically and technically difficult to start a new study, thus new results as well as past data are important. Because the mattresses on which patients lie have advanced with time, and the conditions of patients in cardiopulmonary arrest are different from those of the past. Therefore, this study tested the need for a backboard and its effects by evaluating the depth of MCC, MCC recoil, and success rates of MCC on five different mattresses of varying firmness, comparing groups where MCC was performed without a backboard, with a backboard, or when MCC was performed on the floor.

2. Materials and methods

2.1 Study design and setting

Five types of Seahonens medical mattresses (Table 1) and Azone backboards® (600 mm × 400 mm × 15 mm, Material: high-density polyethylene) (AS ONE, Osaka, Japan) used on

TABLE 1. List of medical mattresses.

Model	Product name	Thickness (mm)	Material	Mattress Classification Abbreviation name		#Value sunk (mm)
				Without backboard	With backboard	
1	Reversible mattresses (Hard surface)	100	Polyester	M1	M1b	−15.0
2	Fit Tex	80	Urethane foam	M2	M2b	−10.5
3	CoreMattress10 Cloud (Hard surface)	100	Urethane foam	M3	M3b	−29.5
4	CoreMattress10 Motion	100	Urethane foam	M4	M4b	−12.5
5	C-MAX	120	Urethane foam	M5	M5b	−23.0

#Value sunk (mm): The height of a medical mattress and a 10 kg weight are measured. Next, we placed a 10 kg weight on the center of the medical mattress. The height of the top of the weight on the medical mattress.
(Height of the medical mattress in mm + height of the weight in mm) − (Height of the top of the weight when the weight is placed on the medical mattress in mm) = sunken height of the medical mattress in mm.

medical beds were used. The bed was a Paramount A8513® (PARAMOUNT BED CO., LTD., Tokyo, Japan)® and the CPR training manikin was a Resusci Anne® Simulator PLUS (Laerdal, Stavanger, Norway). CPR assist (CPR-1100)® (NIHON KOHDEN, Tokyo, Japan) and QCPR Skill Reporter (QCPR)® systems (Laerdal, Stavanger, Norway) were used for evaluation and analysis of MCC. CPR-1100 measure changes in relation to the height of the device itself were recorded using acceleration sensors. QCPR measures the manikin's chest compression depth. The recoil is an average of the degree of recovery of the manikin's chest compression depth. In the mattress (Width 90 cm, Length 190 cm) evaluation groups, the manikin was placed on a bed with a mattress on which the chest was placed horizontally.

2.2 MCC participants

We recruited volunteer participants in the study to perform MCC and evaluate the results; no patients were included. All MCC participants had previously attended a Basic Life Support (BLS) or general lifesaving course, and have CPR provider or equivalent qualifications and skills. MCC was performed with a target of 100 times per minute for each medical mattress (five types), both with and without a backboard inserted. In addition, 100 MCCs were performed on the floor per person per minute, for a total of 1100 MCCs. The surfaces on which MCC was performed were changed in the following order, with M reporting the mattress type, and Mb the mattress plus board: M5 → M5b → M2 → M2b → M4 → M4b → M3 → M3b → M1 → M1b → F (floor). Compression points were chosen in the middle of the chest and the lower half of the sternum, as recommended by the American Heart Association (AHA) Guidelines for Resuscitation 2020 [1] and the European Resuscitation Council Guidelines for Resuscitation 2021 [7]. The height of the bed was varied for each MCC performer according to the height of the MCC performer. The target depth of the MCC was always between 50 and 60 mm, and the output from the CPR-1100 was displayed on a monitor to confirm that the specified value had been reached. The data were recorded using the LAERDAL's QCPR Skill Reporter (hereafter QCPR) and output to Microsoft Excel.

2.3 Analysis

2.3.1 Evaluation of depth during MCC

The average depth of MCC with and without the use of a backboard was calculated. This statistic was calculated for each mattress. The average depth was also calculated when the manikin was placed directly on the floor.

2.3.2 Evaluation of recoil during MCC

The average values of recoil during MCC were calculated with and without the backboard inserted. This statistic was calculated for each mattress. Mean recoil values were also calculated when the manikin was placed directly on the floor. Recoil is the release of compressions after MCC so that the chest wall returns fully to its original height. Recoil is the concept of taking all of one's weight off of the chest between each compression to allow the chest to fully expand, which creates a negative pressure that draws blood back into the heart [7, 8].

2.3.3 Percentage of successful MCC

The median percentage of successful MCC by implementation condition was calculated. In addition, differences were tested for each mattress or with the manikin placed directly on the floor. The criterion for success was set at 50 mm to 60 mm of MCC target depth, as recommended in the guidelines.

2.3.4 Measure fatigue levels immediately after MCC

Participants performed each MCC with at least 60 minutes of rest in between. The level of fatigue immediately after the MCC was measured by the participant using a visual analog scale (VAS). The scale was set at 0 mm for the best feeling of not being tired at all, and 100 mm for the worst feeling of being so exhausted that they could not continue providing MCC. In addition, for each mattress the median fatigue of the 9 MCC performers was calculated for each of the evaluation groups in which they performed MCC with the backboard inserted, without the backboard inserted, or on the floor.

2.3.5 Statistical analysis

One-way analysis of variance (ANOVA) was used to test the means of multiple groups when the data were normally distributed. Bonferroni's corrected *t*-test was used for multiple comparisons. When the data were not normally distributed, the medians were compared using the Kruskal Wallis test, a nonparametric test, and Bonferroni's corrected Wilcoxon signed-rank test was used for multiple comparisons. Statistical analysis was performed using the programming language R (version 3.4.3; The Comprehensive R Archive Network, USA). The significance level for difference tests was set at $p < 0.05$.

3. Results

3.1 Depth assessment during MCC

The mean depth of the MCC with and without backboard insertion is shown in Table 2 and Fig. 1A. Compared to the case without backboard insertion, M1b had a significantly higher value by 3.1 mm ($p < 0.01$); M2b had a significantly higher value by 1.8 mm than M2 ($p < 0.01$); M3b had a significantly higher value by 6.2 mm than M3 ($p < 0.01$); M4b had a significantly higher value by 5.2 mm than M4. MCC depth was significantly higher in the F group compared to all other conditions ($p < 0.01$). These results indicate that the use of a backboard significantly enhanced MCC depth when combined with the indicated mattresses.

3.2 Evaluation of recoil during MCC

The mean values of recoil with and without backboard insertion are shown in Table 2 and Fig. 1B. The results of the test for the difference between the respective means are also shown in Fig. 1B. Compared to the condition without a backboard, MCC recoil in the M1b group was significantly higher by 4.2 mm ($p < 0.01$); M2b was significantly higher by 1.4 mm ($p < 0.01$); M3b was significantly higher by 5.8 mm ($p < 0.01$); M4b was significantly higher by 4.4 mm ($p < 0.01$); M5b was significantly higher by 2.1 mm ($p < 0.01$). These results indicate that the use of a backboard significantly enhanced MCC recoil efficiency when combined with the indicated mattresses.

3.3 Evaluation of MCC success rates

The median percentage success rate of MCC with and without backboard insertion is shown in Table 2 and Fig. 1C. The results of the test for differences between the respective medians are also shown in Fig. 1C. M3b was significantly higher than M3 without backboard insertion by 57% ($p < 0.05$); M4b was significantly higher than M4 by 53% ($p < 0.05$); F was significantly higher than M3, M4 and M5 ($p < 0.05$); M3b was significantly higher than M4b by 53% ($p < 0.05$); M3 and M4b were significantly higher than M5 and M5b ($p < 0.05$). These results indicate that the use of a backboard significantly enhanced MCC success rates when combined with the indicated mattresses.

3.4 Participant's fatigue (VAS scale)

The median VAS Scale with and without backboard insertion is shown in Table 2 and Fig. 1D. There were no significant differences in any of the median compared to the others.

TABLE 2. Depth of MCC, Recoil of MCC, MCC success rate, participant's fatigue (VAS scale).

	M1	M1b	M2	M2b	M3	M3b	M4	M4b	M5	M5b	F
Depth (mm)											
Mean	46.7	49.8	50.1	51.9	44.9	51.1	45.6	50.8	48.6	51.9	54.5
SD	5.9	5.4	4.6	6.1	3.8	3.7	4.8	2.8	5.1	4.0	3.7
Recoil (mm)											
Mean	41.9	46.1	45.8	47.2	39.2	45.0	41.2	45.6	45.4	47.5	51.1
SD	6.8	6.2	3.9	7.4	4.4	4.6	4.1	3.7	4.6	3.9	3.9
Success rate (%)											
Mean	53	62	57	82	10	67	15	68	37	71	92
IQR	19	36	46	14	9	20	18	25	48	31	11
VAS (mm)											
Median	70.0	59.0	68.0	49.0	48.0	50.0	48.0	50.0	67.0	63.0	74.0
IQR	26.0	35.0	21.0	10.0	28.0	32.0	22.0	12.0	21.0	12.0	25.0

SD: standard deviation; IQR: interquartile range; VAS: visual analog scale. Each time a compression (MCC) is performed, Depth and recoil are measured separately. The measured values are reset to 0 (zero) mm for each round trip.

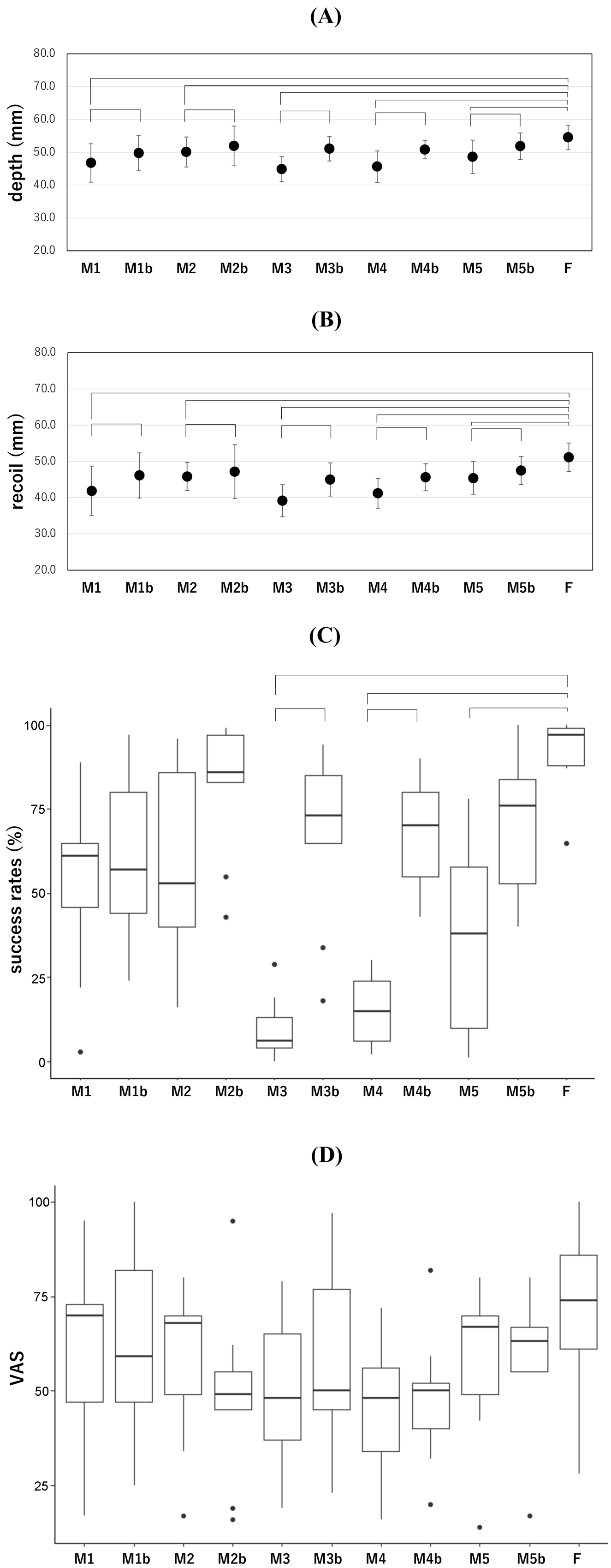

FIGURE 1. Measurement Results. (A) Depth of MCC ($p < 0.01$). (B) Recoil of MCC ($p < 0.01$). (C) MCC success rate (%) ($p < 0.05$). The brackets at the top of the figures for (A), (B) and (C) indicate significant differences at both ends. (D) MCC performing participant's fatigue (VAS Scale). F: when the manikin was placed directly on the floor. VAS: visual analog scale.

4. Discussion

Traditionally, it has been recommended that CPR should be started as soon as possible with the patient lying supine on a stable, hard, flat surface [9, 10]. In addition, the use of backboards has been mentioned in major guidelines for CPR in bed. However, the 2020 guidelines still did not point to the use of backboards in the absence of clear evidence of their usefulness (Table 3). When MCC is needed, time is of the essence, and it is very difficult to get a patient from the bed to the floor, particularly if a patient is receiving dialysis treatment, or is in an intensive care unit where medical equipment and vascular routes are connected. It is therefore necessary to best prepare the patient on the assumption that CPR will be performed in bed. If CPR is to be performed in bed, the question is how to accomplish MCC most effectively. One strategy to increase the effectiveness of MCC in bed is the use of backboards. Recent studies indicate discrepancies in their results. For example, there are reports where MCC was performed using a 10 kg manikin on mattresses or air mattresses showing no significant differences in MCC parameters, with or without backboards for both mattresses and air mattresses. Another study suggested that MCC may not be performed at sufficient depth if the mattress is soft [11, 12]. Notably, it has been reported that backboards had no effect on MCC efficiency when the surface supporting the patient is minimally padded, as in cases when the patient is positioned on a stretcher with a 10 mm mat. Furthermore, there are reports of no significant differences due to the position of the practitioner, the height of the bed, the presence or absence of a backboard, or the posture of the patient [13]. Although some reports have denied the effectiveness of backboards, the usefulness of backboards cannot be determined without clear definition of the actual situation. For example, manikins are made of rigid materials, that are not directly comparable of the condition of a patient's body either in bed or on the floor with respect to the efficiency of MCC results. Thus, it is important to be aware of what would happen to a real human body when evaluating results with manikins which can be a useful surrogate when a study is thoughtfully designed. Importantly, the psychological aspect of the practitioner must also be taken into account as the practitioner's performance is the critical determinant for saving a person's life when CPR is needed. In other words, if the mattress is soft, the practitioner may be inclined to push harder; if it is firm, the practitioner may be inclined to push in the same way as on the floor. In a report on the usefulness of MCCs with backboards inserted, it was the results indicated that the use of backboards deepened the depth of the manikin's MCC by 5 mm [4, 14]. In addition, in terms of backboard width, a narrow backboard (600 mm × 500 mm) deepened the MCC by 1.9 mm, and a wide backboard (890 mm × 500 mm) deepened MCC by 2.6 mm [15]. In addition, this report found that the mattress sink rate was 4.7% less for the narrow backboard and 6.6% less for the wide backboard, compared to the condition without a backboard inserted [15]. Although the backboard used in the current study being presented was narrow (600 mm × 400 mm), the results showed that the depth and recoil of the MCC were significantly better with the backboard. Therefore, it was considered that a wider backboard would be more effective. In a previous validation of two types of backboards, one large and one small, in two directions (vertical and horizontal), it was reported that the larger backboard supported the back of the patient better and increased the efficiency of MCC [16]. In addition, the orientation in which the backboard was placed indicated that it supported the mattress better when it was inserted vertically [17]. Noordergraaf *et al*. [18] also reported that the softer the mattress and the deeper the MCC depth, the greater the effect of the backboard. This suggests that patients placed on softer mattresses could critically benefit from the insertion of a backboard, as the mattress is already sunk to some extent as seen by using heavy manikins in these studies, and that there is less scope for further sinking by the MCC procedure. Prior to the study presented here, the sinking of all mattresses of different thicknesses was measured by placing a 10 kg pillow weight on placed on the mattress (Table 1). Our results showed that the sinkage of the M3 and M5 type mattresses was greater than that of the other mattresses examined. Hypothesizing that MCC can be more effectively performed when using a backboard in cases where the sunken depth is large, the pressure applied during MCC may be reduced when backboards are used in children and light-weight patients, who are considered to have less sunken depth. Regardless of the firmness of each mattress type used in our study, the MCC was more efficient for all mattresses when backboards were used. Based on these results, we consider that the use of backboards has a positive effect. In a mattress-by-mattress comparison, no association was found between hardness, depth and recoil, despite all mattress hardness being different. M3 and M4 were standard thickness (100 mm) and soft. M3 was the softest and had the largest value sunk (−29.5 mm) in Table 1. Prior to the present study, it was assumed that mattress firmness might affect the mean depth of MCC. However, the actual results showed no obvious difference. This could be because the weight of the manikin itself already caused the mattress to sink, which affected the results, or because the manikin is made of a rigid material, which itself produces effective results for MCC on the bed. In addition, as the average depth was around 50 mm, it may be effective to perform MCC with an awareness of a target depth of 5 mm deeper in actual CPR. According to information published by the manufacturer, M1 is the hardest mattress and M3 is the softest. However, the mean values of the actual measured depths were different. This suggested that mattress firmness had little effect, but it cannot be ruled out that the order of mattresses in which MCC was performed and the fatigue level of the person performing the MCC had an effect. Furthermore, the patient's weight on the mattress is an important factor to consider, especially for children and lighter patients, and the pressure applied during MCC should be adjusted accordingly. The mean values were higher when performed with a backboard inserted in case of all tested mattresses. Furthermore, the mean value of recoil was significantly higher when MCC was performed on the floor compared to the other cases. This confirms that the presence or absence of the use of a backboard is associated with recoil. It was inferred that the elasticity was improved by the insertion of the backboard.

The success rate of MCC may be influenced not simply by

TABLE 3. CPR Guideline statements.

	Guidelines 2010	Guidelines 2015	Guidelines 2020
JRC	Consider using a backboard when performing CPR in a hospital bed, but minimize delay in starting chest compressions or interruption of chest compressions due to the use of a backboard.	Evidence is insufficient. Consider using a backboard when performing CPR on a hospital bed, but minimize delay in starting chest compressions or interruption of chest compressions due to the use of a backboard. When CPR is performed on a soft bed, it makes sense to perform CPR with a backboard, which should be large enough to hold the patient from head to pelvic region to increase the depth of chest compressions. If a backboard is used, delays in starting chest compressions and interruptions of chest compressions should be minimized, and care should be taken to avoid dislodging the catheter or tubing when the backboard is placed.	Not stated (Conditions noted). If possible, CPR should be performed on a firm support surface. If CPR is performed on a bed in a hospital, use a CPR mode that allows for a firm mattress, if available.
AHA	Use of a backboard is recommended.	Not stated	Not stated
ERC	No evidence, but if a backboard is used, do not delay the start of CPR, shorten the interruption time and avoid placing tubes and lines under the backboard.	Evidence of dorsal plate use is ambiguous.	Not stated
CoSTR	There is not enough evidence to recommend or oppose backboards.	There is no sufficient evidence to support or oppose the use of a backboard. If a backboard is used, minimize the delay in starting chest compressions and the time between chest compression interruptions, and take care not to remove the catheter or tubing during insertion.	CPR on a solid support surface, *i.e.*, backboard, floor, inflatable or special mattress.

JRC: Japan Resuscitation Council; AHA: American Heart Association; ERC: European Resuscitation Council; CoSTR: Consensus on Science with Treatment Recommendations; CPR: Cardiopulmonary resuscitation.

the firmness of the mattress, but also by the rigidity, back area, and weight of the manikin itself. By mattress type, it is inferred that mattress M1 was the standard 100 mm thick and the stiffest mattress, so no significant difference was found between the mattresses with or without a backboard; mattress M2 was slightly softer than M1, but 20 mm thinner, so no significant difference was found between the mattresses with and without a backboard; M3 and M4 are the same type of mattress, but with a standard thickness of 100 mm, and are even softer than M2, so we infer that there was a significant difference because the success rate would be lower if a backboard was not inserted. Regarding this finding, the backboard used in this study was 600 mm × 400 mm × 15 mm, so it cannot be ruled out that the effect may have been somewhat less than about the size of the upper body due to the backboard not being large enough, as reported by Cloete *et al.* [19]. Furthermore, M5 was the first mattress on which MCC was performed in the present study, and it is inferred that the difference between in MCC depth with and without backboard was not significant because the mattress tended to be pushed deeper without the backboard inserted. Fatigue experienced by the MCC practitioner was higher in the floor than when MCC was applied on the bed. This was thought to be because MCC on the bed was performed using the practitioner's whole body, whereas MCC on the floor was performed mainly with the upper body on the knees. In this study, there were no significant differences in the participants' fatigue levels "VAS" were found depending on the type of mattress or whether a backboard was inserted or not (Table 2). This suggests that posture and other factors influence fatigue of the person applying the MCC procedure. However, when MCC is performed on patients, the less manpower required for example to lift the patient out of bed or repositioning the patient and the sooner and the longer the MCC procedure can be applied, the better the outcome for the patient. Therefore, further detailed studies on factors that influence the fatigue experienced by the MCC performing practitioner are also needed in the future. Further studies to verify the effects of the mattress type, mattress firmness, and bed type as well as the size of the backboard with respect to a patient's weight and size will help to optimize the outcome for patients requiring MCC. There is also concern that the human body is softer than a manikin, which would further reduce the efficiency of the MCC. Practitioners performed the MCC with at least 60 minutes of rest in between until the next trial, and the VAS was measured each time. Therefore, it is possible that fatigue increased during the sessions in this study, which may have affected the VAS. With the advancement and increase in medical equipment, the effectiveness of CPR varies between past and new products. However, the immediate application of CPR and the efficiency of MCC given to a patient in need, is still one of the most critical first responses to save a patient's life. Thus, this research should continue with perseverance. The results from our study indicate that it is still too early and likely not warranted to conclude that backboards are unnecessary.

5. Conclusions

The results of this study indicate and therefore confirm that MCC can be performed more reliably with the insertion of a backboard, regardless of the firmness of a hospital bed mattress. Whenever possible, MCC should be performed with a backboard inserted if MCC is given to a patient in bed. In addition, when training MCC on the bed, consideration should be given to the firmness of the mattress and the weight of the manikin used.

ABBREVIATIONS

AHA, American Heart Association; CPR, Cardiopulmonary resuscitation; CoSTR, Consensus on Science with Treatment Recommendations; ERC, European Resuscitation Council; MCC, Manual chest compression; JRC, Japan Resuscitation Council; VAS, visual analog scale.

AVAILABILITY OF DATA AND MATERIALS

The data presented in this study are available on reasonable request from the corresponding author.

AUTHOR CONTRIBUTIONS

AO, YK, TH and TY—designed the research study. AO, YK, MT, MK, KH and TS—performed the research. AO, YK, TT and TH—analyzed the data. AO and TH—wrote the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The Institutional Review Board at Jikei University of Health Care Sciences, Tokushima Bunri University and Kyushu university confirmed that no ethical approvals were required. Consent to participate in the study and written signatures were received.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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