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THE EFFICACY OF CHEST COMPRESSIONS USING A MANIKIN ACCORDING TO DIFFERING SUPPORT SURFACES

Tai-Hwan Uhm[1], Sang-Kyu Park[2] and Jee Hee Kim[3*]
[1]Professor, Department of Paramedicine, College of Health Sciences, Eulji University, Seongnam, Republic of Korea
[2]Professor, Department of Paramedicine, College of Health Sciences, Gachon University, Incheon, Republic of Korea
[3]Professor, Department of Paramedicine, College of Health Sciences, Kangwon National University, Samcheok, Republic of Korea
[1]emtec@eulji.ac.kr, [2]psk9322@gachon.ac.kr and [3]kjh1962@hanmail.net

Corresponding Author: Jee Hee Kim
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ABSTRACT
It was intended to present a training method so that high-quality cardiopulmonary resuscitation (CPR) can be performed by analyzing chest compression according to differing support surfaces. 33 participants did 150 chest compressions based on the adult CPR in the conditions of hard floor, bed, bed with backboard, ambulance stretcher, and ambulance stretcher with backboard by using manikin. 165 manikin assessed scores were collected and compression depth, compression rate, incorrect pressure point, incomplete recoil, and chest compression correctness were analyzed by using one-way ANOVA. The compression depth in all participants was a statistically significant difference (p<.001), and the difference between the hard floor and the other surfaces was confirmed. The compression rate in all participants was a statistically significant difference (p<.001), and the difference between the hard floor and the bed & bed with backboard was confirmed. The compression correctness in all participants was a statistically significant difference (p<.001), and there was the hard floor (93.2%), bed (67.8%), bed with backboard (66.8%), ambulance stretcher (9.0%), and ambulance stretcher with backboard (7.8%). To perform correct depth, correct pressure point, and complete recoil accordance with the American Heart Association (AHA) guidelines, chest compression on the floor must be performed.

Keywords: High-Quality, Cardiopulmonary Resuscitation (CPR), Hard Floor, Bed, Ambulance Stretcher

1. INTRODUCTION

Basic cardiopulmonary resuscitation (CPR) is a technique that lay rescuers as well as health care providers (HCPs) should be trained, and a treatment provided to cardiac arrest patient. Since high- quality CPR can improve the survival among cardiac arrest patient, the American Heart Association (AHA) has proposed adult cardiopulmonary resuscitation guidelines to minimize compression interruption and to maintain chest compression depth and rate (Panchal et al., 2020). The Resuscitation Education Guidelines also emphasizes that effective education contributes to improving cardiac arrest survival outcomes and can improve training performance by presenting realistic situations (Cheng et al., 2020).

As mentioned above, there were studies that analyzed height and hardness of support surfaces (Uhm et al., 2010), or studies that analyzed body weight and height of providers, however there were no studies that analyzed support surfaces and providers together. In this study, the efficiency of chest compression using a manikin according to differing support surfaces and providers was analyzed to propose a chest compression training method so that high-quality CPR can be conducted in the field and clinical.

1. LITERATURE REVIEW

Since standard CPR training is generally applied to manikin placed on a hard floor, it may not be familiar to provide CPR to cardiac arrest patient lying on a bed or ambulation stretcher (Perkins et al., 2006; Cheng et al., 2018; Ho et al., 2021). It is not easy to achieve an optimal compression depth in case of the higher compression point and the softer mattress (Chi et al., 2008; Boe & Babb, 1999; Tweed et al., 2001; Perkins et al., 2003). Cardiac arrest is occurring more frequently in places such as home and residential area as well as hospital, so providers should be trained to provide high-quality CPR at any condition (Kim & Uhm, 2014).

2. RESEARCH METHODOLOGY

The participants of this study were paramedic students in the 3rd and 4th grades of 00 University who participated in prerequisite training for clinical internship on June 23, 2022. The researchers obtained consent from the students for this study and examined personal data. Thirty-five students were able to withdraw their consent at any time during and after the training, and there was no disadvantage. Excluding two who withdrew their consent among the students, 33 participants practiced HCP adult CPR for 20 minutes using Resusci Anne Skill Reporter (Laerdal Medical, Stavanger, Norway) on a hard floor based on the 2020 AHA Guidelines: Adult Cardiovascular Life Support (Panchal et al., 2020).

2.1. Data Collection

This research was conducted with randomized controlled cross-over manikin study. Just after training, the participants did standard, bedside, and ambulance stretcher-side chest compression in the conditions of hard floor, bed (61cm-high, Sungsim, Seoul, Korea), bed with backboard (Laerdal Medical, Stavanger, Norway), ambulance stretcher (105cm-high, Stryker Cot EZ-Pro R3, Michigan, USA), and ambulance stretcher with backboard by using Resusci Anne manikin. This skill assessment of 150 chest compressions in five surface conditions was carried out randomly to remove bias due to order effects, and 165 manikin assessed scores were collected from the participants.

2.2. Data Analysis

The collected data was analyzed by using SPSS 22.0 for Windows (IBM Inc, New York, USA) at the α=.05 (two-tailed) level. To compare hard floor and the other conditions at compression depth, compression rate, incorrect pressure point, incomplete recoil, and chest

compression correctness (correct depth + correct pressure point + complete recoil) number/compression number) was analyzed by using one-way ANOVA. Also, hard floor and the other conditions by the providers' body weight, height, and sex was analyzed by using one-way ANOVA. The body weight and height were divided into two groups based on the medians respectively.

3. RESULT AND DISCUSSION

The average age of 33 participants was 21.6 years, with 25 female students and 28 third graders. The average body weight was 60.1kg, and the lighter body weight was 51.7kg, and the heavier body weight was 69.0kg based on the median 58.0kg. The average height was 164.8cm, and the shorter height was 159.2cm, and the taller height was 170.8cm based on the median 163.0cm. The detail of 33 participants is summarized in Table 1.

Table 1: Participants' characteristics

Participants	**M(SD)**
Age(year)	21.6(1.5)
Body weight(kg)	60.1(10.1)
Median	58.0
Lighter	51.7(3.3)
Heavier	69.0(6.1)
Height(cm)	164.8(7.6)
Median	163.0
Shorter	159.2(2.4)
Taller	170.8(6.5)
Gender	
female	25
male	8
Grade	
3rd	28
4th	5

M: mean, SD: standard deviation

The compression depth in all participants was a statistically significant difference (p<.001), and the difference between the hard floor and the other surfaces was confirmed. The compression depth at the hard floor (57.9 mm), bed (53.5 mm), and bed with backboard (52.4 mm) was comply with the guidelines. The compression rate in all participants was a statistically significant difference (p<.001), and the difference between the hard floor and the bed & bed with backboard was confirmed. The compression rate at the bed (117.8/min), bed with backboard (118.0/min), and ambulance stretcher (119.5/min) was complied with the guidelines. The compression correctness in all participants was a statistically significant difference (p<.001), and the difference between the hard floor and the other surfaces was confirmed. The compression correctness was the hard floor (93.2%), bed (67.8%), bed with backboard (66.8%), ambulance stretcher (9.0%), and ambulance stretcher with backboard (7.8%). The manikin-assessed scores between differing surfaces are summarized in Table 2.

Table 2: Comparison of manikin assessed skills between differing surfaces

Manikin assessed skills	**ⓐHard floor**	**ⓑBed**	**ⓒBed+ backboard**	**ⓓAmbulance stretcher**	**ⓔAmbulance stretcher+ backboard**	***p***
Compression depth (50-60mm)	57.9(1.7)	53.5(5.3)	52.4(6.1)	25.2(12.0)	25.1(11.4)	<.001*
	ⓑⓒⓓⓔ**	ⓐⓓⓔ**	ⓐⓓⓔ**	ⓐⓑⓒ**	ⓐⓑⓒ**	
Compression rate (100-120/min)	123.3(4.5)	117.8(6.5)	118.0(5.7)	119.5(8.9)	122.1(8.8)	<.001*
	ⓑⓒ**	ⓐ**	ⓐ**	-	-	
Incorrect pressure point (#)	6.5(17.3)	11.0(20.9)	7.8(29.2)	8.7(21.7)	11.2(24.3)	.901
Incomplete recoil (#)	0.1(0.4)	7.2(19.7)	0.5(1.4)	0.2(1.1)	1.4(7.5)	.161*
Compression correctness(%)	93.2	67.8	66.8	9.0	7.8	<.001*
	ⓑⓒⓓⓔ**	ⓐⓓⓔ**	ⓐⓓⓔ**	ⓐⓑⓒ**	ⓐⓑⓒ**	

Data are presented as mean (standard deviation).

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The compression depth in lighter body weight was a statistically significant difference (p<.001), and the difference between the hard floor and the other surfaces was confirmed. The compression depth at the hard floor (57.2mm) and bed (52.7mm) was comply with the guidelines. The compression depth in heavier body weight was a statistically significant difference (p<.001), and the difference between the hard floor and bed & ambulance stretcher & ambulance stretcher with backboard was confirmed. The compression depth at the hard floor (58.8mm), bed (54.3mm), and bed with backboard (56.4mm) was comply with the guidelines, and the compression depth was deeper than lighter body weight group. The compression rate in lighter body weight was a statistically significant difference (p=.002), and the difference between the hard floor and bed & bed with backboard was confirmed. The compression rate at the bed (117.4/min), bed with backboard (117.9/min) was comply with the guidelines. The compression correctness in lighter body weight was a statistically significant difference (p<.001), and the difference between the hard floor and the other surfaces was confirmed. The compression correctness was the hard floor (98.2%), bed (66.1%), bed with backboard (55.8%), ambulance stretcher (5.3%), and ambulance stretcher with backboard (1.2%). The compression correctness in heavier body weight was a statistically significant difference (p<.001), and the difference between the hard floor and the ambulance stretcher & ambulance stretcher with backboard was confirmed. The compression correctness was the hard floor (87.9%), bed with backboard (78.5%), bed (69.6%), ambulance stretcher with backboard (14.8%), and ambulance stretcher (12.9%). The manikin-assessed scores between differing surfaces by body weight are summarized in Table 3.

Table 3: Comparison of manikin assessed skills between differing surfaces by body weight

Manikin assessed skills	Body weight	ⓐHard floor	ⓑBed	ⓒBed+ backboard	ⓓAmbulance stretcher	ⓔAmbulance stretcher+ backboard	*p*
Compression depth(50-60mm)	Lighter	57.2(1.9)	52.7(5.3)	48.5(3.6)	18.8(9.6)	18.7(3.2)	<.001*
		ⓑⓒⓓⓔ**	ⓐⓓⓔ**	ⓐⓓⓔ**	ⓐⓑⓒ**	ⓐⓑⓒ**	
	Heavier	58.8(0.8)	54.3(5.4)	56.4(5.6)	31.9(10.7)	31.9(12.9)	<.001*
		ⓑⓓⓔ**	ⓐⓓⓔ**	ⓓⓔ**	ⓐⓑⓒ**	ⓐⓑⓒ**	
Compression rate(100-120/min)	Lighter	124.6(4.3)	117.4(7.2)	117.9(5.7)	118.5(11.3)	122.4(9.3)	.002*
		ⓑⓒ**	ⓐ**	ⓐ**	-	-	
	Heavier	122.0(4.4)	118.3(5.8)	118.1(6.0)	120.1(5.3)	121.8(8.6)	.217
Incorrect pressure point (#)	Lighter	0.2(0.8)	9.2(20.2)	0.3(1.2)	1.7(4.4)	6.4(14.0)	.120*
	Heavier	13.1(23.4)	12.9(22.2)	15.7(41.1)	16.2(29.5)	16.4(31.5)	.995
Incomplete recoil (#)	Lighter	0.0(0.0)	7.5(21.3)	0.2(0.8)	0.0(0.0)	0.0(0.0)	-
	Heavier	0.3(0.6)	6.8(18.5)	0.7(1.9)	0.5(1.5)	2.8(10.7)	.468*
Compression correctness (%)	Lighter	98.2	66.1	55.8	5.3	1.2	<.001*
		ⓑⓒⓓⓔ**	ⓐⓓⓔ**	ⓐⓓⓔ**	ⓐⓑⓒ**	ⓐⓑⓒ**	
	Heavier	87.9	69.6	78.5	12.9	14.8	<.001
		ⓓⓔ***	ⓓⓔ***	ⓓⓔ***	ⓐⓑⓒ***	ⓐⓑⓒ***	

Data are presented as mean (standard deviation)

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The compression depth in shorter height was a statistically significant difference (p<.001), and the difference between the hard floor and the other surfaces was confirmed. The compression depth at the hard floor (57.7mm) and bed (53.2mm) was comply with the guidelines. The compression depth in taller height was a statistically significant difference (p<.001), and the difference between the hard floor and bed & ambulance stretcher & ambulance stretcher with backboard was confirmed. The compression depth at the hard floor (58.3mm), bed (53.7mm), and bed with backboard (55.8mm) was comply with the guidelines. The compression rate in shorter height was a statistically significant difference (p<.010), and the difference between the hard floor and bed with backboard was confirmed. The compression rate at the bed (117.8/min), bed with backboard (117.3/min), and ambulance stretcher (119.4/min) was complied with the guidelines. The compression correctness in taller height was a statistically significant difference (p<.001), and the difference between the hard floor and ambulance stretcher & ambulance stretcher with backboard was confirmed. The compression correctness was the hard floor (90.6%), bed with backboard (89.6%), bed (66.8%), ambulance stretcher (18.5%), and ambulance stretcher with backboard (12.6%). The manikin-assessed scores between differing surfaces by height are summarized in Table 4.

Table 4: Comparison of manikin assessed skills between differing surfaces by height

Manikin assessed skills	Height	ⓐHard floor	ⓑBed	ⓒBed+ backboard	ⓓAmbulance stretcher	ⓔAmbulance stretcher+ backboard	*p*
Compression depth(50-60mm)	Shorter	57.7(1.8)	53.2(5.2)	49.1(6.1)	18.9(5.4)	20.2(4.3)	<.001*
		ⓑⓒⓓⓔ**	ⓐⓓⓔ**	ⓐⓓⓔ**	ⓐⓑⓒ**	ⓐⓑⓒ**	
	Taller	58.3(1.5)	53.7(5.6)	55.8(3.9)	31.8(13.5)	30.3(14.1)	<.001*
		ⓑⓓⓔ**	ⓐⓓⓔ**	ⓓⓔ**	ⓐⓑⓒ**	ⓐⓑⓒ**	
Compression rate(100-120/min)	Shorter	123.8(4.8)	117.8(7.2)	117.3(5.7)	119.4(11.5)	122.2(9.9)	.010*
		ⓒ**	-	ⓐ**	-	-	
	Taller	122.9(4.2)	117.8(5.9)	118.8(5.9)	119.6(5.1)	121.9(7.9)	.086
Incorrect pressure point (#)	Shorter	4.1(14.5)	10.7(22.0)	14.4(40.1)	10.4(27.7)	2.5(7.4)	.414
	Taller	9.1(20.0)	11.4(20.5)	0.7(2.8)	7.0(13.4)	20.5(31.9)	.014*
Incomplete recoil (#)	Shorter	0.06(0.2).	7.7(21.2)	0.2(0.8)	0.0(0.0)	0.0(0.0)	-
	Taller	0.2(0.5)	6.6(18.5)	0.7(1.9)	0.5(1.5)	2.8(10.7)	.414*
Compression correctness (%)	Shorter	95.7	68.8	45.4	0.0	3.2	-
	Taller	90.6	66.8	89.6	18.5	12.6	<.001*
		ⓓⓔ**	ⓓⓔ**	ⓓⓔ**	ⓐⓑⓒ**	ⓐⓑⓒ**	

Data are presented as mean (standard deviation).

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The compression depth in the female was a statistically significant difference (p<.001), and the difference between the hard floor and the other surfaces was turned out. The compression depth at the hard floor (57.6mm), bed (53.8mm), and bed with backboard (50.5mm) was comply with the guidelines. The compression depth in the male was a statistically significant difference (p<.001), and the difference between the hard floor and ambulance stretcher & ambulance stretcher with backboard was turned out. The compression depth at the hard floor (59.0mm), bed (52.4mm), and bed with backboard (58.1mm) was comply with the guidelines. The compression rate in the female was a statistically significant difference (p<.001), and the difference between the hard floor and bed & bed with backboard was turned out. The compression rate at the bed (117.3/min), bed with backboard (117.1/min), ambulance stretcher (119.4/min) was complied with the guidelines. The compression correctness in the female was a statistically significant difference (p<.001), and the difference between the hard floor and the other surfaces was turned out. The compression correctness was the hard floor (96.9%), bed (71.4%), bed with backboard (59.4%), ambulance stretcher (18.0%), ambulance stretcher with backboard (2.2%). The compression correctness in the male was a statistically significant difference(p<.001), and the difference between the hard floor and ambulance stretcher & ambulance stretcher with backboard was confirmed. The compression correctness was the

bed with backboard (89.9%), hard floor (81.8%), bed (56.5%), ambulance stretcher (25.8%), ambulance stretcher with backboard (25.3%). The manikin-assessed scores between differing surfaces by sex are summarized in Table 5.

Table 5: Comparison of manikin assessed skills between differing surfaces by gender

Manikin assessed skills	Gender	ⓐHard floor	ⓑBed	ⓒBed+ backboard	ⓓAmbulance stretcher	ⓔAmbulance stretcher+ backboard	*p*
Compression depth(50-60mm)	Female	57.6(1.8)	53.8(5.0)	50.5(5.9)	20.4(8.4)	19.5(3.8)	<.001*
		ⓑⓒⓓⓔ**	ⓐⓓⓔ**	ⓐⓓⓔ**	ⓐⓑⓒ**	ⓐⓑⓒ**	
	Male	59.0(0.8)	52.4(6.4)	58.1(1.1)	40.0(9.0)	42.5(9.1)	<.001*
		ⓓⓔ**	ⓓ**	ⓓⓔ**	ⓐⓑⓒ**	ⓐⓒ**	
Compression rate (100-120/min)	Female	123.2(4.7)	117.3(7.0)	117.1(6.1)	119.4(9.7)	120.6(9.1)	.001*
		ⓑⓒ**	ⓐ**	ⓐ**	-	-	
	Male	123.8(3.7)	119.4(4.8)	120.8(3.6)	119.6(6.2)	126.6(6.3)	.029
		-	ⓔ***	-	-	ⓑ***	
Incorrect pressure point (#)	Female	2.8(12.0)	8.2(18.5)	9.8(33.4)	7.7(23.2)	7.0(16.9)	.192
	Male	18.1(25.9)	19.9(26.7)	1.4(3.9)	12.0(17.2)	24.6(38.1)	.411
Incomplete recoil (#)	Female	0.04(0.2)	7.8(21.2)	0.2(0.6)	0.2(1.2)	0.0(0.0)	-
	Male	0.4(0.7)	5.3(14.8)	1.3(2.6)	0.3(0.7)	5.6(15.1)	.622*
Compression correctness (%)	Female	96.9	71.4	59.4	3.6	2.2	<.001*
		ⓑⓒⓓⓔ**	ⓐⓓⓔ**	ⓐⓓⓔ**	ⓐⓑⓒ**	ⓐⓑⓒ**	
	Male	81.8	56.5	89.9	25.8	25.3	<.001
		ⓓⓔ***	-	ⓓⓔ***	ⓐⓒ***	ⓐⓒ***	

Data are presented as mean (standard deviation)

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There was a difference between the hard floor and the other surfaces in the compression depth in all participants, and much lower than the guidelines in the ambulance stretcher & ambulance stretcher with backboard. This result is consistent with the height impact in the studies designed with 78cm-high(2-min compression) and 63.5cm-high (5-cycle CPR) (Lee et al., 2012; Edelson et al., 2012), the compression depth result within the guideline range at 61cm-high bed (150 compressions) of this study suggests that compression within the guideline range is possible for a while under the bed condition. The compression rate in all participants show the results within or above the guideline range, which shows that it is more difficult to comply with compression depth than compression rate under the conditions of higher compression point. The need for a backboard is a controversy among researchers (Perkins et al., 2006; Andersen et al., 2007; Nishisaki et al., 2012; Cuvelier et al., 2022), however it is inferred that a backboard was unnecessary due to harder mattress

in this study. In other words, it is necessary to determine whether to apply a backboard according to the softness of mattress, so it is necessary to further check the correlation between the softness of mattress and compression depth. There was a difference between the hard floor and the other surfaces in the compression correctness in all participants, and it showed superior performance in the hard floor. This means that chest compression should be performed on a hard floor for correct depth, correct pressure point, and complete recoil, and that standing, kneeling, and footstool CPR should be trained to facilitate chest compression on a bed and ambulance stretcher (Hong et al., 2014).

There was a difference between the hard floor and the other surfaces in the compression depth by body weight, and much lower than the guidelines in the ambulance stretcher & ambulation stretcher with backboard. The fact that the results were like compression depth in all participants means that there was no effect due to the relative weight difference of the participants in this study. In this experimental condition, 51.7kg of the lighter body weight group did not affect the compression depth, so it is inferred that it will affect negatively below this (Uhm et al., 2010), the need for training focusing on compression depth by body weight is raised. There was a difference between the hard floor and the other surfaces in the compression correctness by body weight, and the performance was superior in the hard floor. This means that chest compression should be applied on a hard floor for correct depth, correct pressure point, and complete recoil, and that chest compression should be trained to perform perfectly on a bed and ambulation stretcher.

There was a difference between the hard floor and the other surfaces in compression depth by height, and much lower than the guidelines in the ambulance stretcher & ambulation stretcher with backboard. The fact that the results were like the compression depth in all participants means that there was no effect due to the relative height difference of the participants in this study. 159.2cm of the shorter height group did not affect the compression depth, so it is inferred that it will affect negatively below this (Uhm et al., 2010), the need for training focusing on compression depth by height is raised. There was a difference between the hard floor & bed & bed with backboard and the other surfaces in the compression correctness in taller height, and the performance was superior in the hard floor & bed with backboard. This means that chest compression should be applied on a hard floor & bed for correct depth, correct pressure point, and complete recoil, also means that for shorter height CPR training should be conducted on an ambulance stretcher & ambulation stretcher with backboard.

There was a difference between the hard floor and the other surfaces in the compression depth in the female, and much lower than the guidelines in the ambulance stretcher & ambulance stretcher with backboard. There was a difference between the hard floor and ambulance stretcher & ambulance stretcher with backboard in the compression depth in the male. The compression depth in the female & male complies with the guidelines in the hard floor, bed, and bed with backboard. It was extremely low in the ambulance stretch & ambulance stretcher with backboard in the compression correctness in the female, especially meaning that female should be skilled to facilitate chest compression on the ambulance stretcher & ambulance stretcher with backboard.

4. CONCLUSION

For correct depth, correct pressure point, and complete recoil, chest compression should be performed on a hard floor, and standing, knelling, and footstool CPR training should be carried out to correctly perform chest compression on a bed and ambulation stretcher.

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