The Effect of Trunk Muscle Exercise on Cardiopulmonary Resuscitation

hyunmo yang

Korea National University of Transportation <https://orcid.org/0000-0002-4663-9075>

Gyoungyong Kim (✉ sikpan26@naver.com)

Korea National University of Transportation

Jinwoo Kim

Daejeon Health Institute of technology

Yongseok Kim

Myongji Hospital

Research article

Keywords: cardiopulmonary resuscitation, plank exercise, muscle activity

Posted Date: October 6th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-78854/v1>

License: This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Abstract

Background: The purpose of this study is to find how trunk muscles mainly used in cardio-pulmonary resuscitation, including pectoralis major, rectus abdominis, and erector spinae, influence the result of 8-minute when the muscles have six-weeks plank exercise, and to analyze the duration time of exercise effect.

Methods: Study subjects were 30 participants taking a relevant course for 24 months. After they had plank exercise for six weeks, they didn't have any exercises including plank exercise for six weeks. As such, the students participated in the 12-weeks program. For chest compression simulation, a practical mannequin was used. Without any respiration, a single rescuer continued to perform only chest compression for 8 minutes.

Results: Regarding their change in a muscle mass by plank exercise, there was a statistically significant difference in the change from 4th to 8th week after the program ($p < .01$). The muscle activity change had a statistically significant difference from 3rd to 10th week ($p < .01$). The chest compression depth had a statistically significant difference from 4th to 8th week ($p < .01$). The chest compression rate didn't have a statistically significant difference for 12 weeks. In addition, insufficient chest relaxation height after compression had a statistically significant difference from 4th to 10th week ($p < .01$). The chest compression maintenance time had a statistically significant difference from 2nd to 12th week ($p < .01$).

Conclusion: If the study subjects have three sets of plank exercise program for five weeks, which consisted of one set of 10 times of 30-second motion and 20-second rest and does not have up to two weeks of detraining, the plank exercise is considered to be helpful for them in out of hospital cardiac arrest at the time when there is no use of mechanical chest compression device.

Trial registration: The study was registered on 12/15/2015 in the Chungnam National University Hospital with number 2015-10-035-005.

1. Background

Currently in Korea, two paramedics are in charge of assessment, first aid and transportation of patients from the field to the hospital [1]. Except for one ambulance driver, the number of first aid personnel can be regarded as one paramedic. Therefore, in case of cardiac arrest, one paramedic should perform CPR and all necessary first aid for an average time of 8 minutes [1]. However, in previous studies, the accuracy of chest compression decreased with increasing chest compression time [2], and it was appropriate to alternate the performers of chest compression two minutes after the onset of chest compression [3]. However, the current situation of the paramedics cannot apply these suggestions in practice. In general, chest compressions by only hands are reported to not provide enough blood flow as a life sustaining organ [4–5]. So an automated mechanical chest compression device is recommended [6–8], but it is not owned by 95% of 1,294 ambulances deployed in Korea [1]. In addition, due to personnel problems for the smooth use of mechanical chest compression devices, it is difficult to use in the field. Therefore, current cardiopulmonary resuscitation for cardiac arrest patients occurring out-of-hospital is forced to use chest compressions by only hands without the help of mechanical compression. Based on the research that mainly uses erector spinae, pectoralis major, rectus abdominis during chest compressions [9], the researcher conducted a plank exercise to train trunk muscles anywhere, without any equipment. The purpose of this study is to investigate the training method and duration of training for more effective chest compression in out-of-hospital cardiac arrest without mechanical chest compression device.

2. Methods

2.1. Participants in the Research

The participants of this study were paramedic students who have been in the same curriculum for 24 months. Based on the research by previous [10], G * power 3.0 was used to calculate the effect size 0.5, significance level $\alpha = .05$, and the power 80%. So, 30 people were recruited. The selection criteria were selected as students who do not exercise regularly and who can continue to participate in the program. After receiving the approval of the research committee of Chungnam National University Hospital (No.2015-10-035-005), the subjects were recruited by announcing the explanation of the exercise program. The participants were excluded from the study if they could not perform chest compression due to health reasons or if they did not agree to participate in the experiment. The duration of this study was a schedule of applying a six-week programmed plank exercise based on previous studies [11]. After six weeks of plank exercise, a total of twelve weeks were conducted on a schedule of no exercise, including plank exercise. In order to prevent the

participants from feeling uncomfortable, the indoor environment of the test and test sites was maintained at the comfort index to make the surrounding environment comfortable by setting the room temperature to 26 degrees and the humidity to 40% [12].

2.2. Research tools and methods

The muscle mass of the study participants was measured using Avis 333® (Jawon medical, Korea), a body composition measurement tool. A total of 13th measurements were recorded. Noraxon Clinical DTS 546® (Noraxon Inc., ARIZONA, USA) was used to determine the muscle activity of the erector spinae, pectoralis major, rectus abdominis and measured using four radiochannel surface electromyograms. The collected EMG digital signal was filtered and other signal processing on the computer using MR-XP Master program (Noraxon Inc., Arizona, USA). The electrode attachment point is Erector Spinae is 6 cm later from L1 spinous process, Pectoralis Major is (sternal portion) horizontally on the chest-wall over the muscle mass that arises (approximately 2 cm out from the axillary fold), Rectus Abdominis is 3 cm later from the umbilicus. Plank exercise was performed in a single posture, maintaining the shoulder angle at 90 degrees based on previous study and no other postural changes were performed. The abdominal drawing-in maneuver was performed after maintaining the lumbar neutral posture. Three sets of one set at 10 times were performed by 30 seconds of exercise and 20 seconds of rest. Performed rest after each set of exercise to prevent fatigue. Chest compression was determined by a single rescuer performing continuous chest compressions only on a mannequin (Resusci Anne simulator®, Laerdal® PC skill reporting system, Stavanger, Norway) for 8 minutes without artificial respiration. Effective chest compression was defined as the number of chest compressions between 100 ~ 120 times per minute, chest compression depth of at least 50 ~ 60 mm, and chest compression recoil of the chest to 20 mm. During the experiment, no feedback was provided to the participants.

2.3. Statistical analysis

SPSS 21.0 for Windows was used for statistical analysis. The mean and standard deviation was used to analyze confidence in percent error values and bleeding estimation accuracy before and after simulation training. One-way ANOVA was used to analyze subjects' grade differences. If p value is less than 0.05, it is defined as statistically significant.

3. Results

3.1. General Characteristics of Subjects

Thirty participants 16 males(53.33%) and 14 females(46.66%) participated in this study. The average age was 23.33 ± 1.68 years, the average height was 168.00 ± 6.74 cm, and the average weight was 68.53 ± 12.81 kg.

3.2. Analysis of Chest Compression Quality According to Trunk Muscle Training

The results of repeated measures analysis of variance that muscle mass changes were statistically significant ($F(12,348) = 62.212$, $p < .001$). Changes in muscle activity were found in pectoralis major ($F(12,348) = 49.859$, $p < .001$), erector spinae ($F(12,348) = 40.898$, $p < .001$), rectus abdominis ($F(12,348) = 40.134$, $p < .001$). The change in chest compression depth was statistically significant ($F(12,348) = 98.843$, $p < .001$). The change in the chest compressions rate due to flank exercise was not statistically significant for a total of 12 weeks ($F(12,348) = 1.882$, $p = .093$). Insufficient recoil after chest compression was statistically significant ($F(12,348) = 80.592$, $p < .001$). The change in effective chest compression maintenance time was statistically significant ($F(12,348) = 19.017$, $p < .001$) (Table 1–2).

Table 1
Analysis of muscle mass and muscle activation according to plank exercise

		Muscle Mass from			Muscle Activation from Chest Compression								
		Plank Exercise			Pectoralis Major			Erector Spinae			Rectus Abdominis		
		M ± SD	F	p	M ± SD	F	p	M ± SD	F	p	M ± SD	F	p
BL	0	28.66 ± 6.04 ^{abc}	62.212	< .001	41.81 ± 19.28 ^a	49.859	< .001	139.96 ± 64.14 ^a	40.898	< .001	81.94 ± 37.57 ^a	40.134	< .001
PE	1	28.49 ± 6.16 ^{ab}			41.77 ± 19.26 ^a			139.96 ± 64.16 ^a			81.92 ± 37.56 ^a		
	2	28.60 ± 6.09 ^{ab}			41.71 ± 19.20 ^a			140.00 ± 64.19 ^a			81.96 ± 37.54 ^a		
	3	28.52 ± 6.21 ^{ab}			43.03 ± 19.59 ^{bc}			143.45 ± 65.31 ^b			83.91 ± 38.20 ^b		
	4	29.26 ± 6.17 ^d			43.59 ± 19.90 ^{cd}			145.31 ± 66.36 ^{cd}			85.00 ± 38.81 ^{cd}		
	5	29.68 ± 6.17 ^e			44.16 ± 20.10 ^e			147.21 ± 67.03 ^e			86.12 ± 39.21 ^e		
	6	29.96 ± 6.20 ^f			44.66 ± 20.13 ^f			148.90 ± 67.13 ^f			87.10 ± 39.27 ^f		
NE	1	29.68 ± 6.22 ^e			44.22 ± 19.98 ^e			147.42 ± 66.61 ^e			86.24 ± 38.96 ^e		
	2	29.04 ± 6.19 ^{cd}			43.73 ± 19.80 ^d			145.79 ± 66.00 ^d			85.28 ± 38.61 ^d		
	3	28.73 ± 6.19 ^a			43.21 ± 19.60 ^c			144.03 ± 65.34 ^c			84.26 ± 38.22 ^c		
	4	28.52 ± 6.20 ^b			42.81 ± 19.46 ^b			142.71 ± 64.87 ^b			83.48 ± 37.95 ^b		
	5	28.59 ± 6.16 ^{ab}			41.75 ± 19.22 ^a			139.87 ± 64.17 ^a			81.75 ± 37.52 ^a		
	6	28.52 ± 6.15 ^{ab}			41.70 ± 19.23 ^a			139.91 ± 64.18 ^a			81.94 ± 37.53 ^a		
Note. Significant differences between group means are indicated by different letters. Means having the same subscript are not significantly different.													
BL ; Base Line, PE ; Plank Exercise, NE ; Non Exercise, M ± SD ; Mean ± Standard Deviation													
M ± SD ; Mean ± Standard Deviation, a ≤ b ≤ c < d < e < f													

Table 2
Analysis of chest compression quality according to Trunk Muscle Training

		Chest Compression Depth			Chest Compression Rate			Chest Compression Incomplete Recoil			Chest Compression Maintenance Time		
		M ± SD	F	p	M ± SD	F	p	M ± SD	F	p	M ± SD	F	p
BL	0	47.10 ± 3.39 ^a	98.843	<.001	104.30 ± 1.51	1.882	.093	4.66 ± 2.10 ^a	80.592	<.001	417.60 ± 73.03 ^a	19.017	<.001
PE	1	46.90 ± 2.60 ^a			104.56 ± 1.71			4.40 ± 1.84 ^{ab}			417.06 ± 72.86 ^a		
	2	47.16 ± 2.37 ^a			104.13 ± 1.61			4.53 ± 1.99 ^a			425.43 ± 63.78 ^b		
	3	47.36 ± 2.51 ^a			104.26 ± 1.63			4.40 ± 1.92 ^{ab}			444.33 ± 45.37 ^c		
	4	49.36 ± 2.89 ^b			104.26 ± 1.63			3.53 ± 1.90 ^c			473.86 ± 15.48 ^{de}		
	5	50.53 ± 2.77 ^c			103.96 ± 1.62			1.40 ± 1.49 ^e			474.56 ± 14.91 ^{de}		
	6	51.43 ± 2.07 ^d			104.16 ± 1.53			0.43 ± 0.77 ^f			479.00 ± 5.47 ^e		
NE	1	50.46 ± 2.27 ^c			104.23 ± 1.27			0.86 ± 0.77 ^e			479.53 ± 2.55 ^e		
	2	50.06 ± 2.25 ^{bc}			104.23 ± 1.75			2.23 ± 0.97 ^d			475.26 ± 11.02 ^{cde}		
	3	47.00 ± 2.28 ^a			104.40 ± 1.61			2.90 ± 1.06 ^c			467.13 ± 22.36 ^{cde}		
	4	46.70 ± 2.50 ^a			104.46 ± 1.16			3.80 ± 1.86 ^{bc}			458.96 ± 28.82 ^{bcd}		
	5	47.03 ± 2.68 ^a			104.70 ± 1.76			4.33 ± 1.64 ^a			441.93 ± 42.80 ^{bc}		
	6	46.76 ± 2.89 ^a			104.43 ± 1.63			4.23 ± 1.92 ^{ab}			447.36 ± 38.47 ^{bc}		
<i>Note.</i> Significant differences between group means are indicated by different letters. Means having the same subscript are not significantly different.													
BL ; Base Line, PE ; Plank Exercise, NE ; Non Exercise, M ± SD ; Mean ± Standard Deviation ; M ± SD ; Mean ± Standard Deviation, a ≤ b ≤ c < d < e < f													

3.3. Relation between Muscle Mass, High Quality Depth, Compression Maintenance Time

The correlation coefficient between muscle mass and effective compression depth was .79, which was very high. In other words, the greater the muscle mass, the deeper the depth of effective compression. The correlation coefficient between muscle mass and effective chest compression time was .61. In other words, the more muscle mass, the longer the effective chest compression time (Table 3).

Table 3
Relation between Muscle Mass, High Quality Depth, Compression Maintenance Time

	HQD	CMT
MM	.79	.61
MM = Muscle Mass ; HQD = High Quality Depth ; CMT = Compression Maintenance Time		

3.4. Relation between High Quality Depth, Compression Maintenance Time

The correlation coefficient between effective chest compression depth and effective chest compression maintenance time was .58, which was high. In other words, the maintenance time to compression the chest to the effective depth is increased (Table 4).

Table 4
Relation between High Quality Depth, Compression Maintenance Time

	CMT
HQD	.58
HQD = High Quality Depth ; CMT = Compression Maintenance Time	

4. Discussion

Six weeks of plank exercise had an effect on muscle mass and muscle activity. In particular, 4 weeks after the start of the plank exercise showed a significant effect, and even after stopping the plank exercise showed a significant result until 2 weeks. In addition, the pectoralis major, erector spinae and rectus abdominis which are mainly used for chest compressions, had a significant effect from 3 weeks after the start of the plank exercise and even after stopping the plank exercise showed a significant result until 4 weeks. These results showed the same results as the present study showing the increase in muscle activity in the major muscles including the abdominal muscle in a previously published study of muscle activity during plank exercise [13].

Analyzing the depth of chest compressions of the study participants, it showed a significant increase after 5 weeks of starting the plank exercise, and after 3 weeks of stopping the plank exercise, it did not become effective chest compression and continued to decrease afterwards. Although chest compression proficiency increases with increasing rate of chest compressions, the decrease in chest compression depth after stopping plank exercise is considered to be due to the change of muscle mass following plank exercise. As the activity of trunk muscles, which is mainly used for chest compression, increases the chest compression depth, which is a high level of force, through the plank exercise. In addition, the previous study showed a rapid increase rate from 4 weeks to 6 weeks after the start of exercise. Since then, there is no significant change in the increase rate. According to these results, in order to achieve effective chest compression depth through plank exercise, plank exercise should be continued for at least 5 weeks, and should not have a break period of at least 2 weeks. As a result of analyzing the change in the rate of chest compressions, there was no significant result about the number of chest compressions by the plank exercise. This is because the depth of chest compression decreases significantly over time in several published studies, but the number of chest compressions is relatively free from problems such as physical consumption compared to chest compression. Incomplete chest compression recoil showed the highest duration of exercise in the effect of chest compression through plank exercise. However, 5 weeks after stopping the plank exercise, the incomplete recoil of chest compressions increases again, and it is thought that the plan should be continued for at least 4 weeks for effective chest compressions and there should be no break of at least 4 weeks. As a result of analyzing the chest compression maintenance time, as shown in the result of analyzing the incomplete chest compression rate, the plank exercise seems to be a result of the significant improvement of muscle endurance. In addition, the effective chest compression success rate increased significantly after 5 weeks of starting exercise, and significantly increased after until 2 weeks of stopping exercise. This means that the maintenance time to chest compression has been increased to the chest compression depth recommended by the 2015 AHA Guidelines. The plank exercise not only increased the maintenance time for chest compression, but also increased the maintenance time for effective chest compressions, which is practically helpful for cardiac arrest patients.

The results of this study showed that for effective chest compressions, plank exercise was effective in increasing proper chest compression depth and muscle endurance for chest compressions. Through this, plank exercise is expected to be effective for long-term chest compression, and furthermore, it can reduce muscle fatigue by centering the trunk muscle.

The limitations of this study are first, the number of study participants is difficult to generalize to 30, and secondly, the use of educational mannequins, it did not accurately reflect the anatomy of the chest. Third, it was that the laboratory was familiar to the participants, not the actual emergency. Fourth, the condition regarding diet that could affect muscles was not considered. Fifth, there is a possibility that psychological factors that subjects can speculate and control the results of research due to continuous experiments. Sixth, the study participants were composed of college students in their twenties and did not reflect the change according to age.

In conclusion, it was found that there was a positive effect on effective chest compressions when the chest compression was performed after training trunk muscles using plank exercise. It is recommended to perform 3 sets of one set (every 10 times for 30 seconds exercise and 20 seconds rest) for 5 weeks as a plank exercise. Unless you have a period of up to two weeks of inactivity, it may be helpful in out-of-hospital cardiac arrest situations where mechanical chest compressions are not available.

Abbreviations

CPR: Cardio-Pulmonary Resuscitation; BL: Base Line; PE: Plank Exercise; NE: Non Exercise; M±SD: Mean±Standard Deviation; MM: Muscle Mass; HQD: High Quality Depth; CMT: Compression Maintenance Time

Declarations

Ethics approval and consent to participate

The study was approved by the ethical committee of Chungnam National University Hospital with ethical code number 2015-10-035-005. The written informed consent was obtained from all participants. In the form, the participants had given their consent for publishing the study data. They were informed that their names and characteristics will not be published.

Consent for publication

Not applicable.

Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This research received no external funding.

Authors' contributions

YHM participated in the design of the study, acquisition and analysis of the data and writing of the manuscript. KGY contributed in writing the manuscript. KJW and KYS verified the analytical methods and contributed to the interpretation of the results. All authors read and approved the final version of the submitted manuscript.

Acknowledgements

The authors are grateful to all participants who took part in the cooperation and time for this study.

References

1. National Emergency Management Agency. Fire administration data and statistics. 2015.
2. Kim YB, Choi SM, Kim YM, et al. Effect of single-rescuer fatigue on the quality of cardiopulmonary resuscitation with 30:2 and 15:2 compression to ventilation ratios. *J Kor Soc Emerg Med.* 2006;7(6):519–27.
3. Na JH, Park SO, Baek KJ, et al. Analysis of the time-dependent changes of chest compression quality and related rescuer factors in cardio-pulmonary resuscitation by lay-persons. *J Kor Soc Emerg Med.* 2010;22(5):431–7.

4. Wik L, Kramer-Johansen J, Myklebust H, et al. Quality of cardiopulmonary resuscitation during out-of-hospital cardiac arrest. *JAMA*. 2005;293(3):299–304.
5. Chandra N, Rudikoff M, Weisfeldt ML. Simultaneous chest compression and ventilation at high airway pressure during cardiopulmonary resuscitation. *Lancet*. 1980;315(8161):175–8.
6. Halperin HR, Guerci AD, Chandra N, et al. Vest inflation without simultaneous ventilation during cardiac arrest in dogs: improved survival from prolonged cardiopulmonary resuscitation. *Circulation*. 1986;74(6):1407–15.
7. Halperin HR, Tsitlik JE, Gelfand M, et al. A preliminary study of cardiopulmonary resuscitation by circumferential compression of the chest with use of a pneumatic vest. *N Engl J Med*. 1993;329(11):762–8.
8. Timmerman S, Cardoso LF, Ramires JA, et al. Improved hemodynamic performance with a novel chest compression device during treatment of in-hospital cardiac arrest. *Resuscitation*. 2004;61(3):273–80.
9. Tsou JY, Su FC, Tsao PC, et al. Electromyography activity of selected trunk muscles during cardiopulmonary resuscitation. *Am J Emerg Med*. 2014;32(3):216–20.
10. Baek HJ, Lee SJ, Shin KS, et al. Effect of Resistance Band Exercise on Body Composition, Physical Fitness and Health Promoting Behavior in Nursing Students. *Journal of Korean Public Health Nursing*. 2014;28(2):310–9.
11. Park JS, Cha JH, Shin SY. The Effect of the Exercise Remedy on the Increase of Muscular Strength in the Low Back Pain Patients. *The Journal of Korea Safety Management Science*. 2010;12(1):49–54.
12. Sung SP, Sim MS, Ko BS, et al. Experimental studies on thermal comfort requirements of college - age subjects under the summer condition in Korea (Part Ⅱ : Effects of temperature and humidity on thermal comfort). *The Journal of the Society of Air-conditioning Refrigerating Engineers*. 1992;21(5):102–6.
13. Byrne JM, Bishop NS, Caines AM, et al. Effect of using a suspension training system on muscle activation during the performance of a front plank exercise. *J Strength Cond Res*. 2014;28(11):3049–55.