Original Article

The relationship between upper extremity functional performance and anthropometric features and the quality criteria of cardiopulmonary resuscitation

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ABSTRACT

Objectives: This study aims to examine the effect of upper extremity performance using the Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) on cardiopulmonary resuscitation (CPR) quality criteria according to the European Resuscitation Council (ERC) Guidelines for Resuscitation 2015, including chest compression rate, depth, and recoil.

Patients and methods: This simulation-based study included 105 paramedic students (43 males, 62 females; median age: 19 years; range, 18 to 20 years) attending a two-year paramedic program between February 2018 and April 2018. The CKCUEST was used to determine upper extremity performance scores, including the touch number, normalized, and power score of the paramedic students. A TrueCPR® feedback device was used to measure CPR quality criteria throughout the study. The characteristics of the providers, such as height, weight, body mass index (BMI), and fat-free mass were also analyzed.

Results: Adequate compression depth had a positive correlation with body fat-free mass (r=0.397, p<0.001), power score (r=0.326, p=0.001), height (r=0.326, p=0.001), weight (r=0.314, p=0.001), and BMI (r=0.204, p=0.037). Full chest recoil had a negative correlation with the power score (r=-0.249, p=0.010) and height (r=-0.219, p=0.025). None of the variables were significantly different between the groups with and without the correct compression rate. In the receiver operating characteristic curve analysis for power score and correct compression depth as 100%, the area under the curve was 0.845 (p<0.001).

Conclusion: The power score combination of upper extremity functionality and the rescuer's weight is the main factor affecting chest compression depth. However, this score is negatively correlated with full chest recoil.

Keywords: Functional test, high quality cardiopulmonary resuscitation, upper extremity.

The cardiopulmonary resuscitation (CPR) guidelines highlight the importance of early and high-quality CPR applications for patient survival and good neurological results. For high-quality CPR, it is of utmost importance to attain a sufficient number and depth of chest compressions, allow the chest to fully recover after each compression, make a minimum interruption or uninterrupted compression, and ensure adequate ventilation.[1] Many studies have shown that a provider's physical features, such as sex, height, weight, and muscle strength, can affect the CPR quality.[2-4] However,

no clear factor determining CPR quality has been identified, yet.

Rescuer position, shoulder muscle strength, shoulder motion, and shoulder arm position are interrelated factors that affect the CPR kinematics and quality.[5-7] The Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST) is an upper limb functional performance test designed to evaluate the function of elbow, shoulder, and shoulder girdle musculature.[8] It determines shoulder muscle strength objectively and accurately, and also evaluates proprioception and motor control. This test is easy to perform, cost-effective, easily understandable and its validity and reliability are high.[9] It is mostly used to prepare rehabilitation protocols by measuring the performance and ability of patients or athletes.[9-11] The effects of shoulder performance on CPR can be assessed using this test, as shoulder muscles and movements also contribute to the strength applied during chest compression and recoil. To the best of our knowledge, there is no study regarding the evaluation of the CKCUEST among CPR providers in the literature.

In the present study, we aimed to examine the effect of upper extremity performance using the CKCUEST on CPR quality criteria according to the European Resuscitation Council (ERC) Guidelines for Resuscitation 2015, including chest compression rate, depth, and recoil. In this study, we also aimed to investigate the characteristics of the providers, such as height, weight, body mass index (BMI), and fat-free mass.

PATIENTS AND METHODS

This cross-sectional, simulation-based study was conducted at Gazi University Faculty of Medicine, Department of Emergency Service between February 1st, 2018 and April 30th, 2018. The participants consisted of 105 paramedic students (43 males, 62 females; median age: 19 years; range, 18 to 20 years) attending a two-year paramedic program of Gazi University Health Services Vocational School. Those with any musculoskeletal injuries or pain, orthopedic disability, or any disease that may affect the quality of CPR at the time of the study were excluded. The study was conducted on a voluntary basis.

Equipment and procedure

The Prestan® Professional Adult CPR Training Manikin (Prestan Products, OH, USA) was used and placed on an AneticAid QA3® wheeled bed (AneticAid

Ltd., West Yorkshire, UK) in the study. The use of a step booster to achieve the appropriate position was left to the participants' discretion. To standardize chest compressions to 2 min without interruptions, a digital stopwatch was used in the study. Weight, BMI, and body analysis measurements (body fat ratio, body fat mass, and body fat-free mass) were analyzed with the TANITA BC-418 MA device (Tanita Corp., Tokyo, Japan), and the participants' height was measured.

A TrueCPR™ (Physio-Control Corp., WA, USA) feedback device was used to measure CPR quality criteria throughout the study. This device consists of two different parts connected via a cable. One part is placed on the back of the patient's shoulder and the other on the sternum, and the device is designed for chest compression on this latter part. The device uses three-dimensional magnetic fields to measure the distance between two objects (the chest pad and the back pad) and, thus, accurately computes chest compression depth, rate, and full chest recoil.[12]

According to the 2015 ERC CPR guidelines, CPR providers should ensure chest compressions of adequate depth (at least 5 cm but no more than 6 cm) with a rate of 100 to 120 compressions per min. After each compression, providers should allow the chest to recoil completely and should minimize interruptions in compressions.[1] Therefore, the optimal chest compression depth for the device is 5 to 6 cm, and the appropriate compression depth applied during the procedure was given as a percentage. Similarly, full chest recoil is considered optimal, and it gives a percentage of recoil quality during CPR. In addition, the device gives an average compression rate per min. A rate of 100 to 120 chest compressions per min was considered optimal and this parameter was analyzed between two groups as correct (100 to 120/min) and incorrect (<100, >120/min) compression rate. During the CPR application, the screen of the device and voice features were completely closed, and any feedback for participants was blocked at any time.

The CKCUEST was first demonstrated by an experienced physical medicine and rehabilitation physician and then applied to all study participants. This test was performed in the push-up position for male participants and the crawling position for female participants, with the hands approximately 91.5 cm apart. Per procedure, one hand reached across the body, touched the other hand, and returned to the starting position; the same movement was, then, performed by the other hand. The participant was instructed to perform as many touches as possible

in 15 sec while maintaining the correct position. Meanwhile, the physician checked the accuracy of the position, while the second researcher determined the time and noted the number of touches in the study. Those who performed the test incorrectly were required to repeat it. After a successful test, the touch number score, normalized score, and power score were obtained for each participant.[10] The normalized score was obtained by dividing the number of touches by subject height. The power score was obtained by multiplying the average number of touches by 68% of subject's body weight (kg) divided by 15.[13]

In the study of Tucci et al.,[10] the reference values were stated for the touch number score, power score, and normalized score of CKCUEST as 18.5, 150, and 0.26 for males, and 20.5, 135, and 0.31 for females, respectively. However, these results varied among different studies and populations.[11,13] Therefore, there are no accepted standard scores in the literature.

The participants were also asked whether they received basic life support training and had regular weekly exercise hours.

Statistical analysis

Statistical analysis was performed using the SPSS for Windows version 16.0 (SPSS Inc., Chicago, IL, USA). The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to determine whether the continuous variables fit the normal distribution. Continuous variables were expressed in median (IQR), while categorical variables were expressed in number and frequency. The differences between the two groups, according to continuous variables, were determined by the Mann-Whitney U or Student t-test. The Spearman correlation analysis was used to analyze the relationship between the CPR quality criteria and the CKCUEST scores and participants' continuous variables. The area under the receiver operating characteristic (ROC) curve (AUC) was calculated to determine the relationship between the power score and anthropometrics and the correct compression depth as 100%. A *p* value of <0.05 was considered statistically significant.

RESULTS

The median touch number score was 16 (range, 14 to 17), median normalized score was 0.09 (range, 0.08 to 0.10), and median power score was 42.8 (range, 37.6 to 51.7). The median rate of correct compression depth applied during the CPR was 50% (range, 5 to 98%), median rate of full chest recoil was 36% (range, 7 to 77%), and median rate of compression was 120% (range, 104 to 134%).

TABLE 1 Demographic and baseline characteristics of the participants according to sex												
	Female (n=62)				Male (n=43)				Total (n=105)			
Characteristics	n	%	Median	IQR	n	%	Median	IQR	n	%	Median	IQR
Age (year)			19	18-19			19	18-20			19	18-20
CPR training in the past year	52	83.9			29	67.4			81	77.1		
Regular weekly exercise time (h)			1	0-2			2	0-6			1	0-3
Height (cm)			165	161-168			178	174-181			168	163-177
Weight (kg)			55.7	51-63			71.1	63-80			61.8	54-70
Body mass index (kg/m²)			20.6	19-23			22.4	20-25			21	19-24
Body fat ratio (%)			25	19-28			13.9	11.5-16			18	14-25
Body fat mass (%)			14	9.5-18			10.3	7-12			11	9-15
Body fat-free mass (%)			43.8	40-45			62.5	56-67			46	42-61
Touch number score			15	14-17			16	15-18			16	14-17
Normalized score			0.09	0.08-0.10			0.09	0.08-0.10			0.09	0.08-0.10
Power score			39.6	33.4-44.4			52	44.6-61.6			42.8	37.5-51.7
Correct compression depth (%)			19.5	0.7-80.2			90	35-99			50	5-98
Full chest recoil (%)			50	15-78			29	1-74			36	7-77
The rate of compression (/min)			120	104-131			119	100-141			120	104-134
IQR: Interquartile range; CPR: Cardiopulmonary resuscitation.												

| TABLE 2 Correlation analysis results				
	Correct compression depth (%)		Full chest recoil (%)	
	r	p	r	p
Regular weekly exercise time (h)	0.124	0.206	-0.198	0.043
Height (cm)	0.326	0.001	-0.219	0.025
Weight (kg)	0.314	0.001	-0.185	0.058
Body mass index (kg/m²)	0.204	0.037	-0.104	0.290
Body fat ratio (%)	-0.247	0.011	0.066	0.505
Body fat mass (%)	-0.135	0.170	-0.048	0.626
Body fat-free mass (%)	0.397	<0.001	-0.182	0.063
Touch number score	0.180	0.066	-0.190	0.052
Normalized score	0.088	0.370	-0.117	0.236
Power score	0.326	0.001	-0.249	0.010

Demographic and baseline characteristics of the participants are presented in Table 1.

Adequate compression depth had a positive correlation with body fat-free mass (r=0.397, p<0.001), power score (r=0.326, p=0.001), height (r=0.326, p=0.001), weight (r=0.314, p=0.001), and BMI (r=0.204, p=0.037), and a negative correlation with the body fat ratio (r=-0.247, p=0.011). Full chest recoil had a negative correlation with the power score (r=-0.249, p=0.010), and height (r=-0.219, p=0.025) (Table 2). None of the variables were significantly different between the groups with and without the correct compression rate (Table 3).

Eight participants performed correct compression depth as 100%. In the ROC curve analysis for power score and correct compression depth using 100% cut-off value, the AUC was 0.845 (p<0.001) (Figure 1). For a power score of 50.7, the sensitivity was 87.50% (95% confidence interval [CI]: 47.3-99.7) and the specificity was 77.32% (95% CI: 67.7-85.2). AUC was 0.669 for height, 0.655 for body fat-free mass, 0.652 for weight, 0.609 for body fat ratio, and 0.580 for BMI (p<0.05). The ROC analysis could not be done for full chest recoil, as only two participants performed it as 100%.

TABLE 3 Comparison between groups with and without the correct compression rate					
	Correct compression rate (100-120/min) (n=35)		Incorrect compression rate (<100, >120/min) (n=70)		
	Median	IQR	Median	IQR	
Regular weekly exercise time (h)	2	0-3	1	0-3	0.646
Height (cm)	168	163-178	168	163-177	0.698
Weight (kg)	62	53-67.6	61.7	55-73	0.467
Body mass index (kg/m²)	20.3	19.1-23.1	21.7	19.6-24.4	0.166
Body fat ratio (%)	19.2	13-27.8	18.1	14-25	0.605
Body fat mass (%)	11.1	8.6-16.8	11.2	43.4-62.6	0.892
Body fat-free mass (%)	45	40.6-53.5	47.4	43.4-62.6	0.105
Touch number score	15	14-17	16	14-18	0.468
Normalized score	0.091	0.084-0.098	0.096	0.083-0.104	0.405
Power score	41.4	35.7-51.2	43.5	38-53.6	0.436
IQR: Interquartile range; The Mann-Whitney U or Student-T tests were used.					
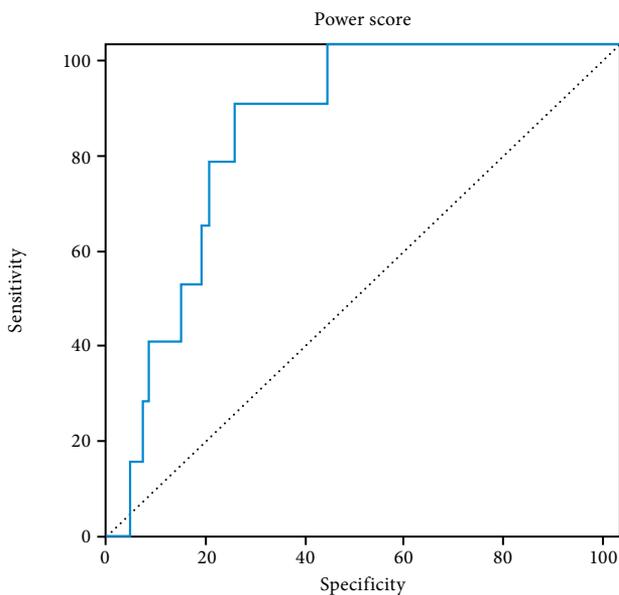
Figure 1. Receiver operating characteristic curve for the correct depth of chest compression and power score.

DISCUSSION

In the present study, the power score as a measurement of upper extremity functional performance was found to be related to the correct depth of compression. This relationship was more decisive than anthropometric measurements alone, such as height, body fat-free mass, weight, body fat ratio, and BMI according to the ROC analysis. In addition, the power score was negatively correlated with full chest recoil. No factors were found to be related to the correct chest compression rate.

In a manikin study on medical students, the main determinant of chest compression depth for novice rescuers was found to be the body weight.[3] The authors reported that rescuers weighing more than 70.5 kg could reach a depth of 5 cm for chest compressions. A similar study found that lighter rescuers had difficulty in achieving the correct compression depth.[14] It has been previously shown that low rescuer weight causes a decrease in chest compression depth due to increased fatigue over time.[15] A study related to the impact of physical fitness reported that rescuers with a higher BMI and better physical fitness performed better external chest compression.[16] These results were also present in the entire cohort and sex-based subgroups. In a study of muscular fitness involving college students, the ability to provide adequate external chest compression was influenced by the rescuer's muscle strength.[17]

Similarly, good correlations were observed between the numbers of correct compressions and muscle strength during CPR in a manikin study.[18] The multiple regression analyses further revealed that only muscle strength affected the quality of correct chest compression. Fat-free mass, trunk muscle mass, and left and right arm muscle mass were positively correlated with chest compression depth in another study.[4]

Healthcare professionals can apply CPR in the kneeling position when the patient is on the floor, or in the standing position when the patient is on a stretcher, depending on the clinical setting. In one study, chest compressions were mainly done by flexion and extension of the hip joint while kneeling on the ground and by the elbow and shoulder joints while in the standing position.[6] In this study using integrated electromyography during CPR, the strength values of the deltoid, pectoralis major, triceps brachii, vastus lateralis, and gastrocnemius muscles were found to be significantly higher in CPR performed in the standing position compared to the kneeling position. In emergency departments and the remaining units of the hospital, CPR is performed on a suitable stretcher. Therefore, shoulder strength and upper extremity closed kinetic chain performance are more important during CPR in a standing position.

Among the CKCUEST scores, the power score includes both the physical performance and the weight of the providers. In our study, factors affecting the correct chest compression depth were more valuable, when physical performance was evaluated with weight rather than alone or vice versa. Therefore, it can be considered that both weight and upper extremity performance are sufficient for compression depth.

The chest release is also as important as the depth of chest compressions. As it affects venous return positively, full chest recoil increases the effectiveness of CPR.[19] Leaning on the chest, which is frequently encountered during CPR, affects the full recovery of the chest.[20] Contri et al.[21] showed that providers who were taller, heavier, and had a greater BMI were less likely to achieve a correct chest recoil. In the study of Oh,[22] in contrast to these findings, it was argued that full chest recoil needed greater muscle activity, as rescuers had to lift their body mass against gravity during decompression. Therefore, the normal weight or overweight status of rescuers could be disadvantageous to the chest wall recoil. In our study,

the effect of weight alone was not determined, whereas physical performance and weight were found to be negatively correlated.

Many studies have shown that regular exercise is important in increasing CPR quality.[17,23] In our study, no significant relationship was found between chest compression depth and weekly exercise hours. The most important reason for this is possibly the low average weekly exercise hours. Insufficient regular exercise also caused low CKCUEST scores. Therefore, evaluating the shoulder performance (upper extremity closed kinetic chain performance) of professional CPR providers using CKCUEST and arranging appropriate exercise programs may have a positive effect on the quality of CPR.

Although the CKCUEST has become more common in both clinical and research settings, normative values have not been established in many areas. Normative values are essential for CKCUEST, since it is a bilateral test, limb symmetry cannot be calculated, and the raw scores are difficult to interpret in terms of test success. As a limitation, this study was done on a manikin and in a calm environment. Therefore, it does not include the conditions that occur during CPR applied to a real patient. Also, since CPR is performed in a standing position, it is not known exactly what the results would be when it is performed on the floor in the kneeling position. In addition, the rescuer's standing position was not corrected during CPR; however, the position such as excessive leaning may also affect the CPR quality. Furthermore, only healthy paramedic students were included in the study. Therefore, the physical characteristics of the participants, whose age group is very young, do not cover the entire adult age group. The number of samples size required for the study was not calculated, as all paramedic students in the relevant institute who gave consent for participation were included in the study, which may have affected the power of the study.

In conclusion, the main factor affecting chest compression depth among the parameters considered in this study was the power score combination of upper extremity functionality and the rescuer's weight. In contrast, the power score was negatively correlated with full chest recoil. Finally, no factors were found to be related to the correct chest compression rate. Based on these findings, we concluded that CKCUES test or anthropometric features are not relevant in determining high-quality CPR.

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