Maan Jamjoom et al. Saudi J Er Med. 2023;4(2):105-111
https://doi.org/10.24911/SJEMed/72-1674858076

ORIGINAL ARTICLE

The association of chest compressor's physical activity level with the quality of continuous chest compressions during a stimulated cardiac arrest in an education center

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ABSTRACT

Background: Cardiopulmonary resuscitation (CPR) is a lifesaving procedure performed by qualified rescuers. The quality of CPR depends on effective chest compression (CC) characteristics: rate, depth, hand position, and chest recoil. Besides CC, previous research has proven that physical activity level (PAL) varies among rescuers and affects CPR quality. This study aims to assess the association between PAL and the quality of continuous chest compressions-cardiopulmonary resuscitation (CCC-CPR) for 5 minutes by qualified rescuers at the National Guard Hospital in Jeddah (NGHA-J).

Methods: This is a cross-sectional study. The global physical activity questionnaire was used to measure the participants' PALs, and the SimMan 3G mannequin was used to measure the four CC characteristics. The recommended sample size is 45 of the rescuers at NGHA-J.

Results: A total of 45 members were involved in the study, and most participants were 27 (60%) males. Most participants are classified as having high PAL 21(46.67%). The study indicates that there is no significant effect among the PALs and the CCC-CPR effectiveness according to (p 0.65) which is determined by the non-parametric Kruskal Wallis test. The optimal effective CCs between the three groups of PALs were achieved by the moderate PAL participants with a median of 47.5 (IQR 35).

Conclusion: The study findings deny any relationship between the quality of the CCC-CPR and the PAL of the rescuers.

Keywords: CPR, physical activity level, continuous chest compressions, CCC-CPR, qualified rescuers.

BACKGROUND

Cardiopulmonary resuscitation (CPR) is a lifesaving procedure performed when a person shows no signs of life during a cardiac arrest that is usually responded to by cardiac arrest rescuers in the hospital [1]. In only a few minutes, cardiac failure reduces the flow of oxygenated blood to vital organs, which can cause brain damage, and possible death in 8-10 minutes if CPR is not applied effectively [2]. According to a study conducted at the King Abdulaziz University Hospital, 7.76 out of 1,000 adult hospital admissions were sudden cardiac arrests [3].

Although cardiac arrest increases the chance of mortality and morbidity, high-quality CPR increases the chance of survival [4-6].

The quality of CPR is determined by effective chest compressions (CCs) that depend on four characteristics: rate, depth, hand position, and chest recoil [7]. Furthermore, if high-quality CPR and minimal interruptions are

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Received: 27 January 2023 | **Accepted**: 12 May 2023

maintained, the chances of spontaneous circulation returning are enhanced [7]. The criteria for achieving high-quality CCs, according to the American Heart Association (AHA), was defined as a rate of 100-120 compressions per minute, depth of 5 cm (2 inches) at least but not more than 6 cm, hand's heel above each other while interlocking the fingers in the lower half of the sternum in the middle of the victim's chest, and full chest recoil without losing contact between hands and sternum with minimum interruption [7-9]. The perfect continuous chest compressions in CPR (CCC-CPR) effectiveness during the 5 minutes requires achieving the AHA criteria for each of the four factors [7]. The European Resuscitation Council recommended CCC-CPR in out-of-hospital setting cardiac arrest cases for the public, where usually the breathing equipment is nonfunctioning or inaccessible, if suspects of infected patients such as COVID-19 patients, otherwise, healthcare professionals are well trained to perform conventional CPR (30 CCs: 2 breaths) [8,10,11]. Compared with traditional CPR, CCC-CPR minimizes interruptions in compressions, increases spontaneous circulation, and maintains cerebral and coronary perfusion more effectively in the first few minutes of a cardiac arrest [12,13].

Ineffective CCs will not provide the required blood flow through the body during CPR [14]. The quality of CCs is affected by other factors, such as physical activity level (PAL), body mass index (BMI), age, and gender [15,16]. Furthermore, research has demonstrated that fatigue is a critical factor that decreases the quality of CCs after 60-90 seconds of CCC-CPR [7]. Moreover, other studies have shown that physical fatigue develops within minutes of starting CPR, and the quality of the first CC produced by a rescuer was much higher than the earlier one [7,15]. In addition, a study found that the decay speed is faster in CCC-CPR than that in conventional CPR [17]. However, previous research has proven that PAL varies among rescuers and affects the CPR quality, duration, and fatigue level [17]. Consequently, the rescuer's PAL appears crucial [17]. This may include any daily activity at work, house, or in leisure time [18]. However, a recent study suggested that a lay rescuer could only perform good-quality CPR with a high PAL [19].

On the other hand, a previous study determined that first responders' exercise habits and BMI influence CPR quality [20]. Despite that, there needed to be more data on the relationship between PAL and the quality of CPR. This study aimed to assess the association between the PAL of participants and the quality of CCC-CPR for 5 minutes among qualified rescuers at the National Guard Hospital in Jeddah (NGHA-J).

Methods

Study design

This is a cross-sectional study that assesses PAL's relationship with high-quality CCC-CPR using the global physical activity questionnaire (GPAQ) and the SimMan 3G mannequin (Laerdal, Stavanger, Norway) (Model 212-01033). The study was conducted in the laboratories of the Clinical Stimulation Center in King Abdulaziz Medical City after being approved by the local research ethics committee and obtaining the Institutional Review Board's approval from the King Abdullah International Research Center. The Clinical Stimulation Center is following the King Saud bin Abdulaziz University for Health and Science College of Medicine, which is fully accredited for the Bachelor of Medicine and Surgery Program from the Education and Training Evaluation Commission 2021-2028.

Subject and Material

The study involved cardiac arrest responders who were advanced cardiovascular life support certified, including critical-care emergency physicians and nurses for in-hospital responses, in addition to paramedics for outpatient clinics and pre-hospital responses, at the NGHA-J during the study's timeframe (September 1 to December 13, 2021), and those aged more than 21 and less than 60 years. Pregnant women, people with disabilities or special needs, asthmatic people with chronic respiratory disease or cardiac pathologies, and those with recent surgery or fractures and joint pain were excluded from the study.

GPAQ, which is the updated version of the international physical activity questionnaire developed by the World Health Organization to measure the PAL in the population, was used to determine the PAL of the participants [17]. The GPAQ contains 16 questions to evaluate the PAL in three domains: occupational, transport from and to places, and leisure time. PAL was classified into three primary levels: high, moderate, and low [21]. To ensure the reliability and validity of the questionnaire, there is a pre-set list for each domain of the PAL [21]. Moreover, factors that could affect the validity and reliability of GPAQ typically are gender and education degree [17]. The measurements of GPAQ state that the questionnaire is valid in measuring moderate to vigorous PAL; meanwhile, in sedentary behavior, the GPAQ is not or is less valid [22].

For analyzing the data obtained from the GPAQ, the analysis file that comes along with the questionnaire has to be used. As mentioned in the analysis file, metabolic equivalents (METs) are a unit of measurement used to indicate the intensity of PAL. One MET is the energy cost of sitting quietly, equivalent to 1 kcal/kg/hour of caloric consumption. To calculate a person's overall energy expenditure according to GPAQ data, the time spent in moderate activities is assigned to 4 METs. In comparison, the time spent on vigorous activities is posted at 8 METs, as described in (Table 1) [22,23].

Table 1. *The criteria for classifying PAL [22].*

High	≥3 days of vigorous-intensity activity with a minimum of 1,500 MET minutes per week Or Seven days of moderate or vigorous-intensity activity with a minimum of 3,000 MET-minute per week.
Moderate	≥3 days of vigorous-intensity activity of ≥20 minutes per day Or ≥5 days of moderate-intensity activity of ≥30 minutes per day Or ≥5 days of moderate or vigorous-intensity activity with a minimum of 600 MET-minutes per week.
Low	Any person who does not meet any of the above criteria.

SimMan 3G (Laerdal, Stavanger, Norway) is one of the advanced high-quality Laerdal mannequins used for simulation training. It monitors many skills, including CPR skills, that feature detection of depth, recoil, and CC rate of CCs [24]. Besides, immediate feedback on the quality of CPR based on 2020 guidelines makes it ideal for this research [24].

Study protocol

Participants give their consent and fill out the online GPAQ on an iPad provided by the team members, which is conducted in a room containing a maximum of three participants in front of team members. In addition, most of the participants had inquiries regarding the survey questions, which they got answered before attending the stimulated trial. Participants were informed to perform CCC-CPR for 5 minutes with an interruption of less than 10 seconds, advised to adjust the bed's height as preferred, and advised to use the footstool. However, participants were advised to stop if they reached extreme fatigue.

Afterward, participants performed CCC-CPR for 5 minutes on the SimMan 3G mannequin above the bed in a prone position in the setting of a cardiac arrest state and without a backboard underneath. The Laerdal Debrief Viewer Software records the rate of compression, depth of sternum depression, hand positioning, and the chest recoil automatically every 10 seconds during the 5 minutes of CCC-CPR [24].

The data collection sheet contains the participant's ID, age, weight and height, BMI category, PAL according to the analyzed GPAQ, the average depth, rate, hand positioning, and chest recoil for 1 and 5 minutes for each factor. The measurements of CC characteristics are depth in millimeters, chest recoil in percentage, and hand position in percentage. The effective frequency of the CCC-CPR among the PAL during the 5 minutes was calculated by dividing the 100% among the four factors. The effectiveness of each factor depends on achieving the required AHA criteria, which indicates a rate of 100-120 compressions per minute, sternum depth of 5 cm (50 mm), hand positioning, and chest recoil of 100%.

Statistical methods

Based on Raosoft, an online sample size calculator, from a population of 50 qualified rescuers with critical care knowledge, the recommended sample size is 45 participants. The calculation is based on a confidence level of 95% and a 5% margin of error. Data were analyzed using John's Macintosh Project. Normally distributed data are presented as mean ± SD. Otherwise, they are presented as a median and interquartile range (IQR). Categorical variables are presented as frequencies and percentages and analyzed by chi-square analysis. Continuous variables were analyzed by correlation. The analysis of variance non-parametric Kruskal Wallis test was used to assess the effect of PAL with CCC-CPR effectiveness and CCC-CPR effectiveness with BMI. The p-value < 0.05 was considered statistically significant.

Results

Demographic variables of the participants

A total of 45 members from qualified rescuers at NGHA-J filled the GPAQ and performed CCC-CPR on the SimMan 3G mannequin. Most of the participants were males, 27 (60%). Most of the participants were classified as having a high PAL, 21 (46.67%), and 15 (33.33%) of the participants were classified as having a low PAL (Table 2). The overall median of CCC-CPR effectiveness among participants is 45 (IQR 30).

The relationship between PAL and the effectiveness of CCC-CPR

The study indicates no statistically significant association between PAL and the effectiveness of CCC-CPR (p = 0.65), according to the non-parametric Kruskal Wallis test. The median CCC-CPR effectiveness frequency among participants with high PAL is 42.5 (IQR 26.25) (Table 3). None of the three groups of the PAL among the code blue team achieved a high quality of CCC-CPR criteria according to the AHA criteria. However, moderate PAL participants achieved optimal CCs among the three groups with a median of 47.5 (IQR 35).

The CC's parameters average during the first 2 minutes and the second last 2 minutes among PALs

CC rate was above normal among all PALs during the first 2 minutes and the last 2 minutes on average. However, the moderate PAL maintained the same rate in both durations, while the high PAL compressions rate increased by 1.9\minute in the last 2 minutes, also the low PAL compression rate increased by 0.6\minute (Figure 1).

Chest depth was less than the required value among all PALs during the first 2 minutes and the last 2 minutes on average. Although there was a deterioration of all groups during the second last 2 minutes, the low PAL has a minimal decrease of chest depth in the last 2 minutes by 2.9 mm (Figure 2).

Hand positioning was maintained perfectly in high and moderate PALs, while the low PAL hand positioning

Table 2. *Demographic variables of participants (n = 45).*

Demographics variables		Count	%
Age	Median, IQR	23 (4.5)	-
Gender	Female	18	40
	Male	27	60
BMI	Underweight	1	2.22
	Normal	26	57.78
	Overweight	14	31.11
	Obese	4	8.89
Type of physical activity	High	21	46.67
	Moderate	9	20
	Low	15	33.33

Table 3. *Participants' characteristics and parameters of CCC-CPR factors and effectiveness (n = 45).*

Demographics variables	Age			Average of Rate per 5 minutes			Average of Depth per 5 minutes			Average of Chest recoil per 5 minutes			Average of Hand position per 5 minutes	CCC-CPR Effectiveness Frequency		
	Median	IQR	*p* value	Mean	SD	*p* value	Mean	SD	*p* value	Media n	IQR	*p* value	*p* value	Median	IQR	*p* value
Gender																
Female	23	4	0.7	114.14	21.84	0.0135	29.74	6.78	0.003	100	0.5	0.0094	1	45	22.5	0.56
Male	22	6		132.07	16.22		36.95	6.27		96.95	17.47			45	27.5	
BMI																
Underweight	21	0	0.0296	123.3		0.75	17		0.006	100	0	0.33	1	30	0	0.38
Normal	22	3		125.47	23.55		32.78	6.24		99.9	4.58			45	30	
Overweight	25.5	8.25		123.57	14.18		37.81	6.83		99.35	7.28			50	15	
Obese	21	1.5		138.07	10.36		39.83	4.97		93.5	28.4			35	15	
Type of physical activity																
High	24	5.5	0.29	131.64	19.31	0.21	33.98	6.65	0.81	99.2	13.92	0.14	1	42.5	26.25	0.65
Moderate	22	3.5		121.73	23.31		35.94	6.82		97.3	8.03			47.5	35	
Low	22	5		119.74	18.09		34.15	8.69		100	1.75			50	32.5	

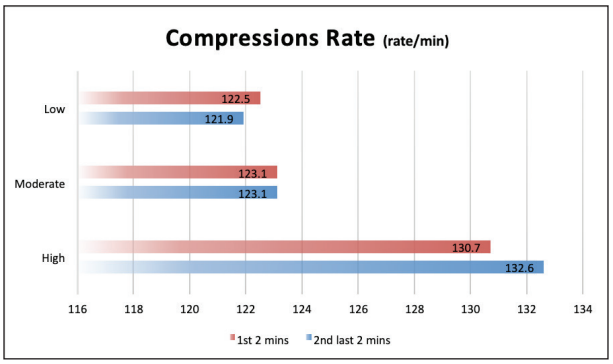

Figure 1. *Comparison of compressions rate among PALs in the first 2 minutes and the second last 2 minutes.*

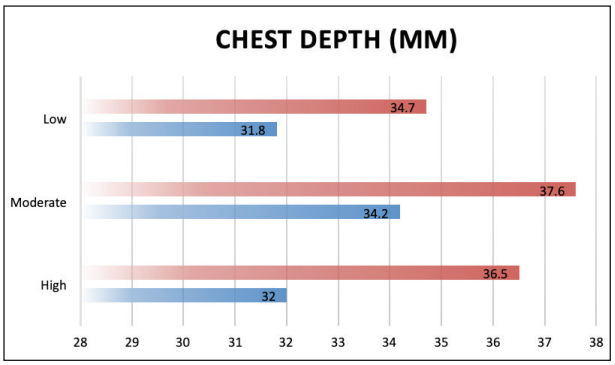

Figure 2. *Comparison of chest depth among PALs in the first 2 minutes and the second last 2 minutes.*

accuracy decreased in the last 2 minutes by 0.1% (Figure 3).

Chest recoil was less than the required value among all PALs. Nevertheless, the high and moderate PALs got better in the last 2 minutes than in the first 2 minutes.

The nearest group to the required recoil percentage was performed by the low PAL in the first 2 minutes (Figure 4).

The effect of the CC's characteristics on the effectiveness of CCC-CPR

The elements of CC that affect the quality of CCC-CPR are rate, depth, hand position, and chest recoil. The study found an association between the measurements of CC characteristics and the effectiveness of CCC-CPR. There is a significant relationship negatively with the rate (p 0.0001) and positively with chest recoil (p 0.0216) along with the effectiveness of CCC-CPR using correlation. On the other hand, there was no correlation between the effectiveness of CCC-CPR and both depth (p 0.87) and hand position (p 1).

The difference between the PAL of the two genders

Twenty-one participants (46%) had high PAL; out of them, 15 (71.43%) were males. Moreover, nine participants (20%) had moderate PAL; out of them, six (66.67%) were *males*. Meanwhile, 15 participants (33.33%) showed low PAL, including 9 (60%) females. Using the chi-square

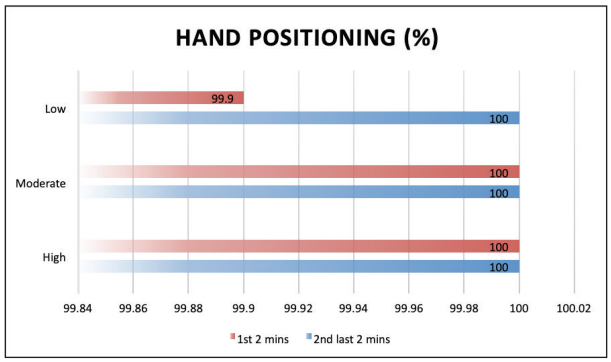

Figure 3. *Comparison of hand positioning among PALs in the first 2 minutes and the second last 2 minutes.*

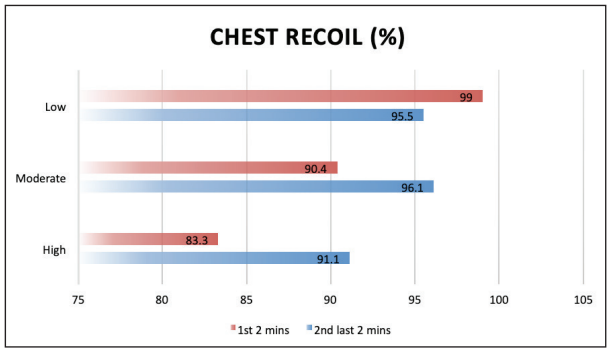

Figure 4. *Comparison of chest recoil among PALs in the first 2 minutes and the second last 2 minutes.*

test with $p = 0.15$ indicates that there is no difference between the PAL of the two genders.

The relationship between the CCC-CPR and the BMI

The median of the CCC-CPR effectiveness frequency among normal BMI is 45 (IQR 30), while the CCC-CPR effectiveness frequency among overweight BMI is 50 (IQR 15) (Table 3). The *p*-value of 0.38 indicates no relationship between BMI and the effectiveness of CCC-CPR, which is determined by the non-parametric Kruskal Wallis test.

IQR: Interquartile range, SD: Standard deviation, CCC-CPR: Continuous chest compression-cardiopulmonary resuscitation, p-value < 0.05 was considered significant.

Discussion

This cross-sectional study aimed to discover the association of PAL with the CCC-CPR effectiveness among the cardiac arrest responders at NGHA-J. The study showed no significant difference between the PAL and the quality of the CCC-CPR for 5 minutes and the factors of effective CCC-CPR. However, participants with moderate PAL achieved the optimal CCC-CPR effectiveness, and most were males. Our findings are consistent with a study performed on trained lay rescuers. The study mentioned that PAL had no relationship with the quality of CPR or CCs during 1- and 2 minutes of CPR [8]. On the contrary, another study that included trained water lifeguards mentioned that high fitness is related to high-quality CPR [25]. The study accounted 311 for these results by; water lifeguards who usually need to 312 make an extra effort in swimming to rescue victims 313 before performing CPR [25]. One more study stated that a strength training program positively impacted the performance of high-quality CC [26].

Our study found that the BMI among participants does not significantly affect performing a high-quality CCC-CPR. Furthermore, there was a significant relationship between CPR performers' BMI and sternum depth. As seen, adequate depth was achieved by the participants with high BMI. According to a study performed in Spain, the weight of the rescuers did not significantly impact the quality or correctness of CCs [27]. Another study in Poland on medical students revealed that CCs are affected by fat-free mass, basal metabolic rate, trunk, and left and right arm muscle mass. Moreover, they mentioned that a rise in arm muscle mass caused a rise in compression depth [28]. Furthermore, our study revealed that gender does not significantly impact performing a high-quality CCC-CPR. In concordance, the study performed in Spain mentioned that the quality and correctness of CCs were significantly unaffected by rescuers' gender [27]. Conversely, researchers in a Korean study reported that correct compressions were significantly higher among the male gender than in the female gender [14].

In the present study, CC rate and chest recoil affected CCC-CPR effectiveness significantly. Also, gender was correlated to CC characteristics, males performed more effective sternum depth, and females had more effective CC chest recoil. Meanwhile, rate and hand position showed no significant difference between genders. Our findings regarding sternum depth can be supported by the study performed in Poland, where the female gender was associated with decreased compression depth [28]. Moreover, compression rates in their study were not affected by gender [28].

The strengths of this present study are that, to our knowledge, it is the first study conducted to determine the relationship between PAL and CCC-CPR through the code-blue team. The study used electronic software records to gather data to minimize errors. On the other hand, the limitation of this study is the inability to generalize the research results since it was conducted in one hospital, in addition to five participants who did a CCC-CPR for 2 minutes before they got fatigued. Moreover, the SimMan 3G mannequin is slightly rigid compared to actual patients due to the manufacturing aspects, which made the CCC-CPR effectiveness more challenging than doing it in a real patient chest.

Conclusion

To conclude, there was no significant association between PAL and the quality of CCC-CPR during the 5 minutes provided by qualified rescuers at NGHA-J. Therefore, the study indicates that adhering to CCC-CPR performance standards based on AHA criteria is the determining factor of high-quality CPR regardless of the PAL of the rescuer. The researchers recommended applying the study to a more inclusive population and using a mannequin more

like the actual patient's chest. In addition, to conduct further studies that use different methods to evaluate the PAL among participants.

Acknowledgment

Special Thanks to the Clinical Simulation Center at King Abdulaziz City for their collaboration to conduct the research in their laboratories.

List of Abbreviations

AHA	American Heart Association
BMI	Body mass index
CCC-CPR	Continuous chest compressions - cardiopulmonary resuscitation
CCs	Chest compressions
CPR	Cardiopulmonary resuscitation
GPAQ	Global physical activity questionnaire
IQR	Interquartile range
MET	Metabolic equivalents
NGHA-J	National Guard Hospital in Jeddah
PAL	Physical activity level

Conflict of interests

The authors declare that there is no conflict of interest regarding the publication of this article.

Funding

None.

Consent to participate

Written informed consent was obtained from all participants.

Ethical approval

Ethical approval was granted by the Institutional Review Board, KAIMRC, via reference letter number: IRBC/1396/21. Study No.: SP21J/089/03, dated: 21/July/2021.

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