ORIGINAL ARTICLE

Influence of Physical Activity of the Rescuer on Chest Compression Duration and its Effects on Hemodynamics and Fatigue Levels of the Rescuer: A Simulation-based Study

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Abstract

Background: Cardiopulmonary resuscitation (CPR) is a lifesaving skill performed during the cardiac arrest. Various factors of rescuer affect CPR quality, and rescuers physical fitness is one among the important factors needs to be explored for improved CPR quality. This study aimed to assess the physical activity (PA) levels of the health care providers (HCPs) who were trained in basic life support (BLS) and its relationship on chest compression duration, hemodynamic parameters, and fatigue levels of the rescuers.

Materials and methods: A single-center, cross-sectional study was conducted on 48 HCPs who were trained in BLS within one year. Eligible participants were contacted by email, and the responders' level of PA was determined using the global physical activity questionnaire (GPAQ). The participants were recruited for chest compression-only cardiac arrest scenarios. Each subject performed continuous chest compression on the manikin until they perceived maximum fatigue. Heart rate (HR), blood pressure (BP), oxygen saturation (SpO_2), and fatigue level were assessed at baseline, immediately after and following two minutes of cessation of chest compressions. The total duration of chest compression was also documented.

Results: Most participants (24, 50%) reported high levels of PA while 22 (45.83%) and 2 (4.17%) reported moderate and low intensity of PA, respectively. The mean age of the 35 participants was 26.08 ± 4.60 years. The mean duration of chest compressions was 193.25 seconds with higher times reported for those with high PA when compared to those with moderate PA ($p = 0.017$). Similar findings were also observed for fatigue.

Conclusion: Rescuers who reported high PA had lower levels of fatigue and could perform longer duration of chest compressions.

Keywords: Cardiopulmonary resuscitation, Chest compression, Fatigue, Hemodynamic, Physical activity.

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Introduction

Cardiopulmonary resuscitation (CPR) is a lifesaving skill performed during the cardiac arrest. It combines the use of chest compressions and ventilation to maintain circulatory blood flow and oxygenation to vital organs.[1] Following cardiac arrest, early initiation of CPR improves the chances of survival and reduces neurological manifestations.[2] Cardiopulmonary resuscitation guidelines by the American Heart Association (AHA) recommends 5 cycles of CPR in 2-minute intervals with each cycle consisting of 30 effective chest compressions, up to a depth of at least 5 cm and providing two rescue breaths.[3] In the presence of an advanced airway or airway adjuncts, continuous chest compression at a rate of 100–120 compressions per minute is recommended along with 10 breaths/minute.[3] Irrespective of the situation and duration, the emphasis is on a high-quality CPR.[4,5]

Factors such as knowledge of the rescuer, body weight, body position, age, underlying problems, physical fitness, and hemodynamic changes play a vital role in the quality of chest compressions.[6–9] Manikin studies have demonstrated that physical fatigue occurs within a minute of initiating CPR which reduces effective chest compressions which is completely oblivious to the rescuer, while further altering hemodynamics of the rescuer after 5 or 10 cycles of CPR.[8–11] Along with hemodynamic status, levels of physical activity (PA) have been found to vary across rescuers.[12] Nevertheless, there is a paucity of data on the impact of PA levels of the rescuer on the duration of CPR, quality of chest compression, and hemodynamic alterations. Thus, we aimed to study the PA levels of the CPR-trained healthcare professional (HCP) and its effect on chest compression duration, hemodynamic parameters of the rescuers, and their fatigue level during the simulated chest compression-only CPR.

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Materials and Methods

The study was carried out on the participants aged between 18 years and 50 years after obtaining institutional ethical approval

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(IEC 307/2017) from April 2017 to March 2018. The study was registered in the Clinical Trial Registry of India (CTRI/2017/12/010752) before the enrollment of the first participant. The participants were HCPs trained in BLS by an AHA-approved international training center affiliated to our University during the period of May 2016 to April 2017. The participants were excluded if they had a history of recent surgery, joint pain, fractures, and underlying cardiac pathology. Written informed consent was obtained from all the participants before enrollment.

Physical activity levels were assessed using the global physical activity questionnaire (GPAQ version 2), which is a valid and reliable tool for assessment of PA.[13] In brief, GPAQ analyzes the PA mainly by three domains, i.e., activity at work (vigorous activity 8MET. minute/week, moderate activity 4MET. minute/week), traveling to and from places (moderate 4MET.minute/week), and recreational activities (vigorous activity 8MET.minute/week, moderate activity 4MET.minute/week). Baseline hemodynamic parameters, i.e., heart rate (HR), oxygen saturation (SpO_2) and blood pressure (BP), were assessed using the pulse oximeter (Dr Trust™, NY, USA) and sphygmomanometer. After the baseline evaluation of hemodynamic parameters, participants took part in a simulated chest compression scenario in the respiratory therapy laboratory. All participants performed continuous chest compressions on a CPR manikin (Little Anne CPR manikin ©2001–2018 Laerdal medical) until they perceived fatigue, which was assessed using the Modified Borg's rating of perceived exertion (RPE). To ensure the specific rate (100 compressions/minute) and depth of chest compressions (5 cm), feedback through a metronome (TempoPerfect Metronome software ©NCH software) and audible clicks were provided. The number of audible clicks was recorded and reflected as effective compression depth and rate. The duration of chest compressions (in seconds) was timed using a stopwatch. Immediately at the end of the compressions and after two minutes, hemodynamic parameters were reassessed. Additionally, hand pain during the chest compressions was assessed using the visual analog scale (VAS).

The analysis was carried out using SPSS v 20, Bengaluru, India, South Asia. Descriptive statistics were used for representing the demographic details. The normality of the continuous variables was assessed using the Shapiro–Wilk test. Hemodynamic parameters were analyzed using the repeated-measures ANOVA, and comparison of chest compression duration between the PA groups was analyzed by an independent *t*-test. *Post hoc* analysis was performed using Bonferroni correction. The level of significance was set at $p < 0.05$.

Results

The distribution of participants in the study is illustrated in Flowchart 1. Of the 35 participants, 11 (31.43%) were males and 24 (68.57%) were females with an average age of 26 ± 4 years. The demographics, PA characteristics, and chest compression characteristics are summarized in the Table 1. A statistically significant difference was observed for chest compression duration provided by those with high PA than moderate PA levels ($p = 0.017$). Furthermore, males provided a significantly longer duration of chest compression than females ($p < 0.001$), irrespective of the PA levels (Table 1). No statistically significant difference was observed for chest compression duration provided by females (189.37 ± 60.73 seconds) and males (239.5 ± 74.36 seconds) among those with high PA levels ($p = 0.144$). Also, in moderate PA group, the chest compression duration provided by male participant was 220 seconds and females was 162.12 ± 32.94 seconds.

The overall hemodynamic changes during the study are represented in Table 2. Further analysis between moderate and high PA levels for the difference in HR, SBP, DBP, and SpO_2 showed a statistically significant difference ($p < 0.001$) within the group. However, no differences were observed between these groups ($p > 0.05$) (Table 2). The difference between males and females in HR, SBP, DBP, and SpO_2 within the group was significant at $p < 0.001$ (Table 2). Furthermore, a significant difference was found in SBP and DBP between males and females ($p < 0.05$). Interestingly, the median RPE after chest compression was higher in moderate PA group when compared to the high PA group, 3 (2,3) vs 2 (2,3). The median hand pain score was 3 (3,5) across the participants.

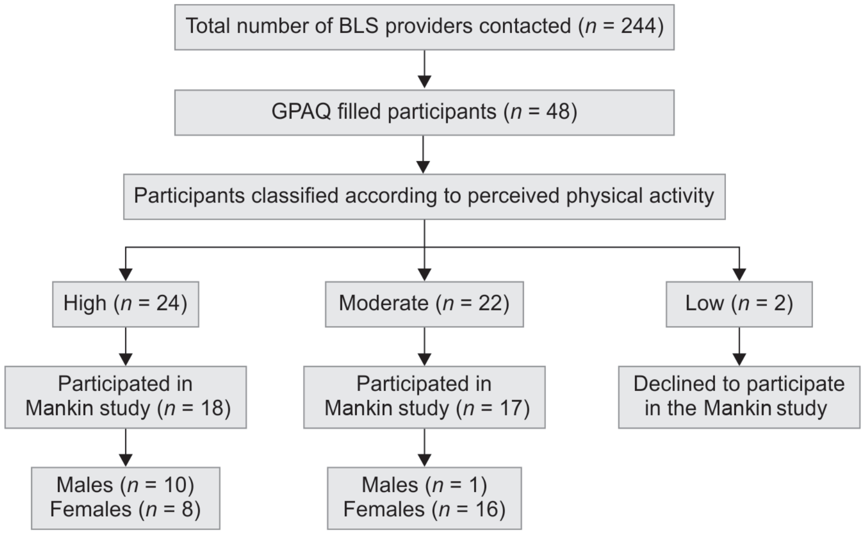
Discussion

Knowledge of the PA levels among HCPs is very important to predict their capacity to provide high-quality CPR during the resuscitation. In our study, we found that the majority of BLS-trained HCPs were physically active with most having a moderate to high level of the PA. Majority of the male rescuers in the high PA group show that they are more conditioned for high PA with more muscle mass and upper extremity strength. The hemodynamic parameters were increased significantly from baseline to post-chest compression irrespective of the PA level. Interestingly, rest for two minutes of post-chest compression effectively reduced the hemodynamic parameters to baseline, so the emphasis on two-minute rest and rotation during the chest compression helps to normalize the hemodynamics of rescuer. The present study did not show a statistically significant difference in hemodynamic changes between high and moderate PA levels among HCPs, whereas Lucía et al. found a significant increase in heart rate in sedentary participants than in physically active participants.[14] However, the absence of low PA participants in our study limited this differentiation of hemodynamic changes at rest and during the chest compression scenario. The mean age-predicted heart rate post-chest compression reached 50.7%, which shows participants could provide a longer duration of chest compression to reach their maximum exercise limit. Slightly higher mean maximum heart rate (61%) was found by Riera et al.[15] The other interesting finding of this study is the gender difference in BP. The change in BP was significant ($p < 0.05$) between males and females during the study. Females had significantly lower baseline BP than males. Previous studies on the gender differences in BP have shown these results.[16,17]

Chest compression duration is another important factor to be considered. Termination and decreased quality of chest compression are indicative of fatigue,[8,9,11] so obtaining an optimum duration of chest compression and the influence of PA on it helps to optimize the chest compression quality with less fatigue. The chest compression duration provided by high PA participants in our study was significantly higher than the moderate PA group, and similar results were found by Lucía et al.[14]

The high-quality chest compression is achieved by ensuring adequate depth and rate to better the chances of survival and early return of spontaneous circulation.[5,18] Several studies have shown that compression depth decreases significantly after a minute of initiation of chest compression.[2,10,11] We found a stable chest compression depth and rate during the study. The feedback for

Flowchart 1: Flow of participants into the study



compression rate by metronome and compression depth by audible clicks may have helped the participants in providing good-quality chest compression during the study. Tanaka et al. observed similar findings that the visual and audible feedback improves the quality of CPR.[19] In the real-world situations, the use of feedback devices like a metronome for rate and CPR meter for depth would be helpful to ensure high-quality CPR.

The overall chest compression duration provided by all the participants in our study was 193.25 ± 62.62 seconds. McDonald et al.[20] and Ochoa et al.[6] showed similar results. McDonald et al.[20] observed maximum fatigue and reduced quality of CPR in rescuers at an average of 167 seconds of CPR, whereas Ochoa et al.[6] observed at an average of 180 ± 84.1 seconds. The differences in the duration of chest compression were observed between men and women and between the levels of PA. Reasons for women achieving lower chest compression durations could be attributed to build muscle mass and cardiorespiratory fitness. These were, however, not assessed in this study, and therefore, no definite relation can be established. Nevertheless, the data suggest that in a simulated environment, continuous chest compression can be provided by all HCPs with moderate to high levels of PA.

The median RPE reported by moderately active participants was higher than that of the high PA group. Participants stopped chest compression after the maximum fatigue which is seen by the shorter duration of chest compression (167.88 ± 39.76 seconds vs 217.22 ± 71.43 seconds) and higher RPE score in moderate PA participants. This may be due to early-onset fatigue during the chest compression. Lopez–Gonzalez et al. observed rescuers' muscle strength and arm strength exercises improve the quality of CPR.[21] So screening HCPs for PA levels and advising routine exercises may help to overcome the fatigue in moderately low PA group HCPs during the CPR.[7,14]

Limitations of the Study

This was a time-bound study, and we faced the loss of participants after BLS certification. The PA levels were measured by GPAQ rather than by objective exercise testing. It is important in a study like ours to separate out strength vs endurance of the individuals performing CPR. The strength would be important for depth of

Table 1: Demographics, PA, and chest compression characteristics of the participants

Demographic variables of the participants (n = 35)		*Values*	
Age (years) mean ± SD		26.08 ± 4.60	
BMI (kg/m²)		22.3 ± 3.15	
Gender, *n* (%)	Male	11 (31.43)	
	Female	24 (68.57)	
PA characteristics (*n* = 35)			
Overall MET.minute/week median (IQR)		4,020 (1,830, 8,250)	
MET.minute/week for different PA levels	Moderate median (IQR)	1,920 (1,200, 2,400)	
	High median (IQR)	8,280 (6,040, 10,760)	
Physical activity level after GPAQ analysis	Moderate, *n* (%)	17 (48.57)	
	High, *n* (%)	18 (51.43)	
Chest compression characteristics (*n* = 35)			
Overall duration of chest compression (second), mean ± SD		193.25 ± 62.62	
Categories		Duration (second)	*p* value
Chest compression duration between PA levels (second), mean ± SD	High PA, (*n* = 18)	217.22 ± 71.43	$p = 0.017$
	Moderate PA (*n* = 17)	167.88 ± 39.76	
Chest compression duration between gender (second), mean ± SD	Males (*n* = 11)	241.3 ± 70.82	$p < 0.001$
	Females (*n* = 24)	171 ± 44.75	
Chest compression rate (range) (rate/minute)			(95–106)

Table 2: Overall hemodynamic changes and comparison between gender and PA measured at baseline, post-chest compression, and two minutes of cessation of chest compression

		Hemodynamic changes			
Parameters	*Stratification*	*Baseline mean ± SD*	*After chest compressions (mean ± SD)*	*Two minutes after cessation of chest compression (mean ± SD)*	*p value*
HR (beats/minute)	Overall	72.65 ± 5.93	99.05 ± 10.80	74.54 ± 5.54	
	Female (*n* = 24)	73.37 ± 6.81	100.58 ± 10.65	75.45 ± 5.89	0.12
	Male (*n* = 11)	71.09 ± 3.01	95.72 ± 10.86	72.54 ± 4.25	
	Moderate PA (*n* = 17)	73.35 ± 7.07	98.47 ± 6.82	75.35 ± 5.53	0.77
	High PA (*n* = 18)	72.00 ± 4.74	99.61 ± 13.74	73.77 ± 5.59	
SBP (mm Hg)	Overall	111.8 ± 9.87	126.4 ± 9.20	113.42 ± 8.72	
	Female (*n* = 24)	107.20 ± 8.18	123.54 ± 9.38	109.58 ± 7.50	<0.001[a,b]
	Male (*n* = 11)	121.81 ± 4.04	132.72 ± 4.67	121.81 ± 4.04	
	Moderate PA (*n* = 17)	108.52 ± 8.97	124.70 ± 9.43	111.17 ± 7.81	0.12
	High PA (*n* = 18)	114.88 ± 9.92	128.05 ± 8.93	115.55 ± 9.21	
DBP (mm Hg)	Overall	78.57 ± 11.41	84.8 ± 11.72	84.85 ± 11.72	0.002[a]
	Female (*n* = 24)	74.58 ± 11.41	81.25 ± 12.26	77.08 ± 9.99	<0.001[b]
	Male (*n* = 11)	87.27 ± 4.67	92.72 ± 4.67	86.36 ± 5.04	
	Moderate PA (*n* = 17)	75.88 ± 11.21	84.11 ± 12.27	78.82 ± 9.92	0.40
	High PA (*n* = 18)	81.11 ± 11.31	85.55 ± 11.49	81.11 ± 9.63	
SpO_2 (%)	Overall	98.8 ± 0.63	98.74 ± 0.50	98.88 ± 0.53	
	Female (*n* = 24)	98.95 ± 0.35	98.83 ± 0.38	98.91 ± 0.28	0.27
	Male (*n* = 11)	98.72 ± 1.00	98.54 ± 0.68	98.81 ± 0.87	
	Moderate PA (*n* = 17)	99.00 ± 0.35	98.76 ± 0.43	98.83 ± 0.70	0.47
	High PA (*n* = 18)	98.77 ± 0.80	98.72 ± 0.57	98.94 ± 0.24	

HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure

*None of them reported with low PA level

[a]$p < 0.05$ between males and females measured pre-chest compression, post-chest compression, and two-minute post-cessation of chest compression

[b]$p < 0.001$ *post hoc* analysis was significant for the same from baseline to post-chest compression and post-chest compression to two minutes after cessation of chest compressions

the CPR while the endurance will decide how long the CPR can be given by the performer, but in the current study, we do not have this information. Also based on the current data, we cannot comment on the influence of the gender on the duration of CPR. Irrespective of the gender, the duration of chest compression was longer in high PA than in moderate PA. The absence of participants in the low PA group was an important limitation. The quality of chest compression was constant with metronome and depth monitored using click sounds, and the unclicked compressions were missed because of difficulty in the follow-up.

Conclusion and Future Directives

Fitness level of the HCP is an important factor to determine chest compression duration. Higher the PA, lower the fatigue level and longer duration of chest compression.

Further studies can consider changes in hemodynamics across different age groups, oxygen consumption levels, and exercises to promote overall physical fitness to improve the CPR.

Disclosure Statement

This study was presented as a scientific poster in CRITICARE 2018, 24th Annual Conference of Indian Society of Critical Care Medicine held in Varanasi, Uttar Pradesh, India

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References

1. Okonta K, Okoh BN. Theoretical knowledge of cardiopulmonary resuscitation among clinical medical students in the university of Port Harcourt, Nigeria. African J Med Heal Sci 2015;14(1):42. DOI: 10.4103/2384-5589.153391.
2. Hightower D, Thomas SH, Stone CK, Dunn K, March JA. Decay in quality of closed-chest compressions over time. Ann Emerg Med 1995;26(3):300–303. DOI: 10.1016/s0196-0644(95)70076-5.
3. Monica EK, Erin EB, Zachary DG, Robert AS. AHA guidelines update for CPR and ECC. Circ. Ahajournals 2015. 1–14.
4. Edelson DP, Abella BS, Kramer-Johansen J, Wik L, Myklebust H, Barry AM, et al. Effects of compression depth and pre-shock pauses predict defibrillation failure during cardiac arrest. Resuscitation 2006;71(2):137–145. DOI: 10.1016/j.resuscitation.2006.04.008.
5. Kramer-Johansen J, Myklebust H, Wik L, Fellows B, Svensson L, Sørebø H, et al. Quality of out-of-hospital cardiopulmonary resuscitation with real time automated feedback: a prospective interventional study. Resuscitation 2006;71(3):283–292. DOI: 10.1016/j.resuscitation.2006.05.011.
6. Ochoa FJ, Ramalle-Gómara E, Lisa V, Saralegui I. The effect of rescuer fatigue on the quality of chest compressions. Resuscitation 1998;37(3):149–152. DOI: 10.1016/s0300-9572(98)00057-4.

7. Ock SM, Kim YM, Chung JH, Kim SH. Influence of physical fitness on the performance of 5-minute continuous chest compression. Eur J Emerg Med 2011;18(5):251–256. DOI: 10.1097/MEJ.0b013e328345340f.
8. Choi H, Lee HJ, Jeong E, Lee CC, Kim HJ, Singer AJ. iMedPub journals an observational study on importance of CPR provider medical safety: hemodynamic changes and fatigue in young healthy adults after multiple cycles of CPR abstract. 2016. 4–8.
9. Abelairas-Gómez C, Barcala-Furelos R, Szarpak Ł, García-García Ó, Paz-Domínguez Á, López-García S, et al. The effect of strength training on quality of prolonged basic cardiopulmonary resuscitation. Kardiol Pol 2017;75(1):21–27. DOI: 10.5603/KP.a2016.0165.
10. Charles P, Adam A, Stephen P, De'ann M, David B. Abstract P168: early markers of rescuer's fatigue. Circulation [Internet] 2009;120(suppl_18):S1478–S1478.
11. Ashton A, McCluskey A, Gwinnutt CL, Keenan AM. Effect of rescuer fatigue on performance of continuous external chest compressions over 3 min. Resuscitation 2002;55(2):151–155. DOI: 10.1016/s0300-9572(02)00168-5.
12. Colbert LH, Matthews CE, Schoeller DA, Havighurst TC, Kim K. Intensity of physical activity in the energy expenditure of older adults. J Aging Phys Act 2014;22(4):571–577. DOI: 10.1123/japa.2012-0257.
13. http://www.who.int/chp/steps/GPAQ/en/index.html.
14. Lucía A, de las Heras JF, Pérez M, Elvira JC, Carvajal A, Álvarez AJ, et al. The importance of physical fitness in the performance of adequate cardiopulmonary resuscitation. Chest 1999;115(1):158–164. DOI: 10.1378/chest.115.1.158.
15. Riera SQ, González BS, Álvarez JT, Fernández M, del MF, Saura JM. The physiological effect on rescuers of doing 2 min of uninterrupted chest compressions. Resuscitation 2007;74(1):108–112. DOI: 10.1016/j.resuscitation.2006.10.031.
16. Wiinberg N, Høegholm A, Christensen HR, Bang LE, Mikkelsen KL, Nielsen PE, et al. 24-h ambulatory blood pressure in 352 normal danish subjects, related to age and gender. Am J Hypertens 1995;8(10 Pt 1):978–986. DOI: 10.1016/0895-7061(95)00216-2.
17. Reckelhoff JF. Gender differences in the regulation of blood pressure. J Am Heart Assoc 2001;37(5):1199–1208. DOI: 10.1161/01.hyp.37.5.1199.
18. Aufderheide TP, Pirrallo RG, Yannopoulos D, Klein JP, von Briesen C, Sparks CW, et al. Incomplete chest wall decompression: a clinical evaluation of CPR performance by trained laypersons and an assessment of alternative manual chest compression-decompression techniques. Resuscitation 2006;71(3):341–351. DOI: 10.1016/j.resuscitation.2006.03.021.
19. Tanaka S, Tsukigase K, Hara T, Sagisaka R, Myklebust H, Birkenes TS, et al. Effect of real-time visual feedback device "quality cardiopulmonary resuscitation (QCPR) classroom" with a metronome sound on layperson CPR training in Japan: a cluster randomized control trial. BMJ Open 2019;9(6). DOI: 10.1136/bmjopen-2018-026140.
20. McDonald CH, Heggie J, Jones CM, Thorne CJ, Hulme J. Rescuer fatigue under the 2010 ERC guidelines, and its effect on cardiopulmonary resuscitation (CPR) performance. Emerg Med J 2013;30(8):623–627. DOI: 10.1136/emermed-2012-201610.
21. Lopez-Gonzalez A, Sanchez-Lopez M, Garcia-Hermoso A, Lopez-Tendero J, Rabanales-Sotos J, Martinez-Vizcaino V. Muscular fitness as a mediator of quality cardiopulmonary resuscitation. Am J Emerg Med 2016;34(9):1845–1849. DOI: 10.1016/j.ajem.2016.06.058.