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The Relationship Between Physical Activity and the Quality of Chest Compressions During Cardiopulmonary Resuscitation

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Abstract

Introduction. Cardiopulmonary resuscitation is a critical intervention in cardiac arrest, and the quality of chest compressions may be related to the physical fitness of the person performing them.

Aim. This study aimed to examine the relationship between physical activity level and the quality of chest compressions during simulated cardiopulmonary resuscitation, while also considering potential gender differences.

Methods. The study included 34 out-of-hospital emergency medical service employees who completed a socio-demographic questionnaire and the International Physical Activity Questionnaire to determine their physical activity level. Participants performed chest compressions on a simulated manikin for eight minutes, with parameters measured every two minutes. Parameters analyzed included compression depth, chest recoil, frequency of compression and overall quality of chest compressions.

Results. A statistically significant positive correlation was found between physical activity level and the quality of chest compressions ($p<0.001$). Participants with higher physical activity levels achieved better results in overall compression quality ($p=0.001$), compression depth ($p=0.009$), and frequency ($p=0.003$). No statistically significant differences were found for chest recoil ($p=0.470$). Gender had no significant effect on overall compression quality, depth, or frequency; however, female participants achieved significantly better results in chest recoil (*p*=0.034).

Conclusion. Physical activity level was significantly associated with the quality of chest compressions, while the effect of gender was limited to specific parameters such as chest recoil. These findings underscore the relevance of physical fitness among emergency medical service personnel in improving CPR performance.

Introduction

Cardiopulmonary resuscitation (CPR) is a vital procedure for survival in individuals experiencing cardiac arrest. According to the Resuscitation Council UK, the annual incidence of out-of-hospital cardiac arrest (OHCA) is approximately 55 cases per 100,000 population, with a survival rate to hospital discharge of around 9% (1). Globally, the average incidence of OHCA in adults is similar, yet the overall survival rate remains low, with an average of just 7% (2). In such critical situations, timely and high-quality CPR is essential to maintain blood flow and oxygen supply to vital organs until emergency medical services arrive or more advanced interventions can be applied.

The basic components of CPR include chest compressions and artificial respiration. The quality of these measures is closely associated with resuscitation outcomes. The European Resuscitation Council guidelines recommend a compression rate of 100–120 compressions per minute and a depth of 5-6 cm, with full chest recoil between compressions (3). Performing CPR in accordance with these guidelines requires not only proper technique but also considerable physical strength and endurance—particularly during prolonged efforts.

Previous studies have suggested that the physical fitness of emergency medical service (EMS) personnel may be associated with their ability to maintain high-quality chest compressions over time. Nayak et al. (2020) observed that individuals with higher levels of physical activity maintained compression quality more consistently, while less active individuals showed signs of fatigue earlier (4). Similarly, Ock et al. (2011) reported a significant decline in compression quality after just a few minutes of CPR, with effectiveness decreasing to only 28% after five minutes (5). These findings highlight the relevance of physical preparedness in sustaining CPR performance.

While some authors have explored gender-related differences in CPR performance, results remain inconclusive. For example, Ochoa et al. (1998) found no significant differences between male and female participants in overall CPR quality, suggesting that gender alone may not be a decisive factor (6).

Although the relationship between physical activity and CPR performance has been increasingly addressed in international research, no such studies have, to our knowledge, been conducted in the Republic of Croatia. This highlights the need for locally relevant data on this topic.

Aim

The aim of this study was to examine the relationship between the level of physical activity and the quality of chest compressions during cardiopulmonary resuscitation among emergency medical service personnel, while also considering potential gender differences.

Methods

The study was designed as a cross-sectional study. A total of 34 employees from the out-of-hospital emergency medical service participated in the research. Inclusion criteria allowed for participants aged between 18 and 65 years; however, the final sample included individuals aged between 20 and 62 years. The average age of participants was 38.4 years (SD=11.6), and the average length of work experience in emergency medical services was 11.2 years (SD=7.9). The sample included professionals from various occupational backgrounds, including nurses (n=18), drivers (n=10), and physicians (n=6).

Participation was voluntary, and informed consent was obtained from all participants prior to inclusion. The study was conducted between June 1 and July 18, 2024. The researcher was present during individual data collection to provide standardized instructions and technical support. While the researcher had access to participants' performance during testing, no documents or records linking individual identities to performance data were retained. The final dataset contained only anonymized identification codes ("Participant N"), ensuring confidentiality.

All participants had completed formal cardiopulmonary resuscitation training in accordance with national regulations (Official Gazette No. 12/2025), which is a mandatory requirement for working in the emergency medical service. Given their professional roles and years of experience, all participants had previously encountered CPR situations in real-life emergency settings.

Data were collected in two phases. In the first phase, participants completed a structured socio-demographic questionnaire developed for the study, which included questions on age, gender, height, weight, occupation, and years of work experience. They also completed the International Physical Activity Questionnaire (IPAQ – long version, 2006), validated in Croatian by Pedišić et al. (2011) (7). This instrument categorized participants into low, moderate, or high physical activity levels; however, for the purposes of statistical analysis, raw IPAQ scores (MET-minutes/week) were used to preserve accuracy.

In the second phase, participants performed an eight-minute CPR session on a simulation manikin (Resusci Anne QCPR, Laerdal Medical, Stavanger, Norway) connected to the Laerdal QCPR application (version 6.2.10). This system enabled automated measurement of chest compression parameters, including depth (in millimeters), rate (compressions per minute), proper chest recoil (percentage), and overall CPR performance (percentage). Participants could stop the simulation at any point if they experienced fatigue or were unable to continue. Prior to testing, all participants received standardized instructions based on the European Resuscitation Council guidelines.

Descriptive statistics included a categorization of CPR performance into three levels—Basic ability (0–49%), Intermediate ability (50–74%), and Advanced ability (75-100%). However, all inferential statistical analyses were conducted using continuous (raw) performance scores to maintain measurement precision and sensitivity.

Ethics

Approval for the study was obtained from the Ethics Committee of the Teaching Institute of Emergency Medicine of Istria County (Ref. No.: 2163-5-1-336/24). The study was conducted according to ethical principles while maintaining the anonymity of the participants. All participants provided a written consent for the use of the data collected via questionnaires exclusively for the purposes of this research.

Statistics

The collected data was analyzed using IBM SPSS Statistics software, version 22. The normality of the distribution of the continuous variables was tested using the Kolmogorov-Smirnov test and the Shapiro-Wilk test, both of which showed significant deviations from a normal distribution. The data were then analyzed using descriptive statistics, the Kruskal-Wallis test and the chi-square test (χ^2). A linear mixed model (LMM) was used to assess the impact of physical activity level on the quality of chest compressions across the measurement intervals. The results were interpreted using F-values and p-values, with the significance level set at $p<0.05$.

Results

A total of 34 emergency medical service personnel participated in the study. Of these, 19 were male (55.9%) and 15 female (44.1%). Participants were categorized into three levels of physical activity based on IPAQ: low (n=10; 29.4%), moderate (n=12; 35.3%), and high (n=12; 35.3%) (Table 1).

Table 1. **Distribution of participants by gender and physical activity level**

Gender	Low activity	Moderate activity	High activity	Total
Male	6	6	7	19
Female	4	6	5	15
Total	10	12	12	34

Note: There is no statistically significant difference in gender distribution across physical activity levels (χ^2=0.476, p=0.788).

Relationship between physical activity and chest compression quality

The Linear Mixed Model (LMM) analysis showed a statistically significant positive relationship between physical activity level (measured continuously using total MET-minutes/week) and chest compression quality over time (F=1272.954; p<0.001). Estimates indicated that compression quality improved steadily across the four 2-minute intervals, with the increase plateauing slightly between the third and fourth interval (Table 2).

Table 2. **Estimates from the Linear Mixed Model (LMM) for chest compression quality**

Time Interval	Estimate	Standard Error	t-value	*p-value*
1st	0.507	0.124	4.09	<*0.001*
2nd	0.606	0.147	4.12	<*0.001*
3rd	0.687	0.168	4.09	<*0.001*
4th	0.693	0.169	4.10	<*0.001*

Note: Estimates reflect progressive improvement in compression quality across time intervals. The trend stabilizes from the third interval onward.

Estimated marginal means by activity group

To improve interpretability, estimated marginal means (EMMs) were calculated for each activity level at each time point (Table 2a). These values show how performance varied across groups.

Table 2a. **Estimated marginal means for compression quality by activity level**

Time Interval	Low Activity	Moderate Activity	High Activity
1st	45.7	62.1	78.4
2nd	47.3	64.9	82.0
3rd	49.2	66.8	84.2
4th	49.0	67.1	84.5

Note: High activity participants maintained consistently higher predicted CPR quality across all time points.

Post-hoc comparisons of compression quality by physical activity level

The Kruskal-Wallis test indicated significant differences in chest compression quality between physical activity groups at all time intervals. Mann-Whitney post-hoc tests identified pairwise differences, especially between low and high activity participants, and to a lesser extent between moderate and high groups (Table 3).

Overall compression quality and specific parameters

Overall CPR quality was calculated as the arithmetic mean across all four time intervals. Kruskal-Wallis and Mann-Whitney tests showed significant differences between groups in quality, depth, and frequency, but not in chest recoil (Table 4).

Correlation between physical activity and chest compression quality

Spearman's correlation analysis confirmed a strong and statistically significant positive relationship between overall physical activity level, measured in MET-minutes per week, and average chest compression quality (ρ=0.79, p<0.001). This result suggests that individuals with higher levels of physical activity tend to perform higher-quality chest compressions during CPR.

Gender differences on chest compression quality

While gender did not significantly affect overall CPR quality, depth, or frequency, a statistically significant difference was found for chest recoil, where female participants performed better (Table 5).

Discussion

The results of this study indicate a statistically significant positive association between physical activity level and the quality of chest compressions during cardiopulmonary resuscitation (p<0.001). Participants with higher activity levels generally maintained better compression quality throughout the eight-minute simulation, while those with lower activity levels showed a more noticeable decline in performance after the first minute. This pattern is reflected in the estimated marginal means (EMMs), which increased steadily until the third interval and

Table 3. **Kruskal-Wallis and Mann-Whitney post-hoc tests for time intervals**

Time	Group Comparison	Median (Low-Mod-High)	Mean Rank	χ^2 (KW)	*p* (KW)	U (MW)	*p* (MW)
1st	Low – Moderate	46.0 – 66.5 – 81.0	9.70–18.00–23.50	14.71	<0.001	24.5	0.007
	Moderate – High					37.0	0.036
2nd	Low – Moderate	43.0 – 68.0 – 83.0	9.55–17.63–24.00	15.30	<0.001	23.0	0.005
	Moderate – High					36.5	0.030
3rd	Low – Moderate	48.0 – 70.5 – 85.0	11.35–16.29–23.83	10.48	0.005	36.5	0.046
	Moderate – High					30.0	0.021
4th	Low – Moderate	50.0 – 71.0 – 84.0	12.40–15.92–23.33	8.53	0.014	42.0	0.068
	Moderate – High					28.0	0.018

Note: Significant differences were observed between most group pairs. Differences between low and moderate in the fourth interval approached significance (*p*=0.068).

Table 4. **Group comparison of performance parameters (with medians and post-hoc tests)**

Parameter	Median (L-M-H)	Mean Rank (L-M-H)	χ^2	*p* (KW)	Significant Comparisons (MW)
Chest compression quality	44.5 – 62.0 – 82.0	10.2 – 16.58 – 24.50	14.63	<0.001	Low–Mod (p=0.011), Mod–High (p=0.041)
Compression depth	51.0 – 64.0 – 73.5	12.3 – 16.83 – 22.50	9.31	0.009	Low–High (p=0.014)
Compression frequency	42.5 – 67.0 – 74.0	10.4 – 18.33 – 22.58	11.70	0.003	Low–Mod (p=0.019), Mod–High (p=0.047)
Chest recoil	66.5 – 65.0 – 68.0	17.0 – 15.58 – 19.83	1.51	0.470	None

Note: The high physical activity group outperformed others in all parameters except chest recoil, which did not significantly differ between groups.

Table 5. **Chest compression performance by gender**

Parameters	Gender	Below Average (%)	Above Average (%)	Chi-square test (χ^2)	*p*
Compression depth	Female	40.0	60.0	1.449	*0.229*
	Male	21.05	78.95		
Compression frequency	Female	40.0	60.0	0.035	*0.851*
	Male	36.84	63.16		
Chest recoil	Female	26.67	73.33	4.480	*0.034*
	Male	63.16	36.84		

Note: Above/below average classification based on median split. Only chest recoil showed a statistically significant gender difference in favor of female participants.

then plateaued, with the highest predicted values consistently observed in the high activity group across all time points. In contrast, the low activity group consistently displayed lower mean ranks and median values across all intervals.

Post-hoc comparisons further revealed that differences in compression quality were statistically significant between physical activity groups at nearly all intervals. The strongest differences were observed between the low and high activity groups, with some significant differences also found between moderate and high activity participants. These results support the idea that higher physical activity levels are associated with the ability to maintain higher compression quality over time.

These findings are in line with current recommendations suggesting frequent rotation of team members performing compressions to minimize fatigue and help maintain CPR quality (8). Similar observations were reported by Nayak et al. (4), while Ippolito et al. (9) did not find significant differences in overall CPR quality by activity level but did observe variation in compression depth. This suggests that certain CPR components may be more closely related to physical fitness than others.

Our findings also correspond with the results of Oermann et al. (10), who reported that nursing students with higher physical activity levels achieved better compression rate and depth during simulations. Likewise, Krarup et al. (11) found that professional EMS teams involved in regular physical conditioning performed CPR at higher quality levels than volunteers without such training. These results indicate that physical activity may be associated with improved CPR performance, even in non-professional settings.

Additional insights come from McDonald et al. (12), who showed that individuals with greater muscle mass and higher BMI were more likely to achieve adequate compression depth, regardless of gender. In our study, gender did not have a statistically significant effect on compression depth or frequency. Interestingly, female participants performed significantly better in chest recoil (p=0.034). This finding was consistent across intervals and was statistically significant when data were aggregated. This may reflect greater precision or control among female participants, as proper chest recoil requires full release of pressure between compressions—an action that is likely more dependent on technique than physical strength.

These findings are consistent with previous research by Ochoa et al. and Jaafar et al. (6,13), which suggests that women may demonstrate greater accuracy in certain CPR components. When controlling for variables such as BMI and physical fitness, gender alone does not appear to be a major factor influencing overall CPR quality (14,15).

Vaillancourt and Stiell (16) similarly highlighted the relevance of physical preparedness, noting that lay responders with lower fitness levels experienced a noticeable decline in CPR performance within the first few minutes. Ahn et al. (17) emphasized the importance of team coordination and structured task rotation, showing that planned switching of roles can help maintain compression quality—even among physically fit responders.

The practical implications of these findings point to the potential benefits of training programs that include physical conditioning components, particularly those targeting endurance and upper body control. Structured rotation protocols—particularly during prolonged resuscitation—may help compensate for fatigue-related declines in performance, especially among less physically active responders. While the design of this study does not allow for conclusions about causality, the observed associations support the relevance of physical fitness in CPR-related performance.

Despite the significance of the findings, several limitations must be acknowledged. The sample size was relatively small (N=34), which may limit the generalizability of results. Physical activity levels were assessed via the self-reported IPAQ questionnaire, which may introduce response bias. Additionally, other potentially important variables—such as age, BMI, and prior CPR experience—were not included in the analysis. Finally, while manikin-based simulations offer controlled environments for measuring CPR quality, they do not fully replicate the stress and variability of real-life cardiac arrest situations.

Future studies should involve larger, more diverse samples and incorporate objective fitness metrics. Research should also examine the role of age and body composition, as well as the combined effects of fatigue, stress, and environmental conditions on CPR performance. Longitudinal designs could provide insight into the long-term impact of physical training on resuscitation outcomes.

Overall, these results align with a growing body of evidence associating physical activity with CPR quality. They highlight the importance of physical preparedness among EMS personnel and suggest that combining physical and technical training components may help improve the quality of resuscitation efforts in both professional and lay responder settings.

Conclusion

The results of this study show that a high level of physical activity significantly improves the quality of chest compressions during cardiopulmonary resuscitation. Participants with a high level of physical activity were able to maintain the quality of compressions over a longer period, while participants with a lower level of activity experienced a more rapid decline in performance. These results underline the importance of the physical fitness among emergency medical service personnel in ensuring the effectiveness of CPR, especially during prolonged resuscitation efforts.

Although gender was not a determining factor in the overall quality of chest compressions, differences were observed in certain parameters such as chest recoil, where women performed better.

Author contributions

Conceptualization and methodology (DT, BO, KI); Data curation and formal analysis (DT, KI); Investigation and project administration (DT); and Writing – original draft and review & editing (DT, BO, KI). All authors have approved the final manuscript.

Conflict of interest

The authors declare no conflicts of interest.

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