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ARTYKUŁ ORYGINALNY / *ORIGINAL ARTICLE*

The effect of strength training on quality of prolonged basic cardiopulmonary resuscitation

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Abstract

Background: Providing high-quality chest compressions and rescue breaths are key elements in the effectiveness of cardiopulmonary resuscitation.

Aim: To investigate the effects of a strength training programme on the quality of prolonged basic cardiopulmonary resuscitation on a manikin.

Methods: This was a quasi-experimental trial. Thirty-nine participants with prior basic life support knowledge were randomised to an experimental or control group. They then performed a test of 10 min of chest compressions and mouth-to-mouth ventilation on manikins equipped with a skill reporter tool (baseline or test 1). The experimental group participated in a four-week strength training programme focused on the muscles involved in chest compressions. Both groups were subsequently tested again (test 2).

Results: After training, the experimental group significantly increased the mean depth of compression (53.7 ± 2.3 mm vs. 49.9 ± 5.9 mm; p = 0.003) and the correct compression fraction (68.2 ± 21.0% vs. 46.4 ± 29.1%; p = 0.004). Trained subjects maintained chest compression quality over time better than the control group. The mean tidal volume delivered was higher in the experimental than in the control group (701.5 ± 187.0 mL vs. 584.8 ± 113.6 mL; p = 0.040) and above the current resuscitation guidelines. In test 2, the percentage of rescue breaths with excessive volume was higher in the experimental group than in the controls (31.5 ± 19.6% vs. 15.6 ± 13.0%; p = 0.007).

Conclusions: A simple strength training programme has a significant impact on the quality of chest compressions and its maintenance over time. Additional training is needed to avoid over-ventilation of potential patients.

Key words: cardiopulmonary resuscitation, quality, physical fitness, strength training

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INTRODUCTION

Sudden cardiac arrest (SCA) is a leading cause of death in Europe, with an overall resuscitation success rate less than 10% despite widespread training in cardiopulmonary resuscitation (CPR) and defibrillation [1, 2]. The quality of chest compressions (CC) performed by laypersons and staff with duty to assist is a decisive factor in the success of CPR [3]. However, some studies demonstrate that the quality of CPR performance during SCA is poor, even when CPR is conducted by medical staff [4–7]. Due to the fact that CC must be performed as continuously as possible and maintained over time, fatigue may be also a critical quality factor in CC [8–10]. European Resuscitation Council (ERC) guidelines have acknowledged this evidence and recommend a switch of rescuers every

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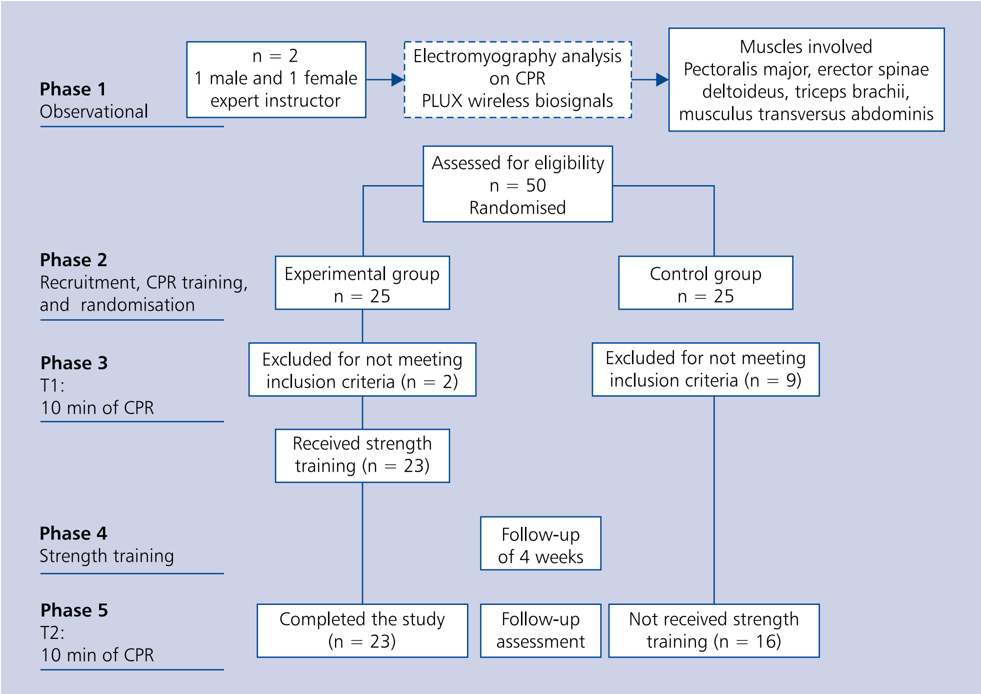

Figure 1. Study design flowchart; CPR — cardiopulmonary resuscitation

2 min [1]. CC quality has been related to the upper extremity and trunk strength [11–13], but no studies have been done to ascertain the effect of power training specifically designed to increase the strength of the muscles used in CPR.

In the case of out-of-hospital cardiac arrest, bystanders may need to maintain CPR efforts for a relatively prolonged period of time (estimated around 10 min, even in best conditions) until the arrival of Emergency Medical Services (EMS).

We hypothesised that a simple physical training programme would improve basic CPR performance and endurance by young citizens.

METHODS

The study project was approved by the Ethics Committee of the School University of Education and Sport Sciences at the University of Vigo, Spain and followed the ethical guidelines outlined in the Declaration of Helsinki (as revised in Brazil 2013). After receiving detailed information about the study's objectives and methods, all participants provided voluntary written informed consent.

As a starting point, we tried to identify the muscles used when applying CC. Two people outside the sample (male and female) who were proficient in basic life support (BLS) — following the international 2010 guidelines for resuscitation [1] — participated in a 10-min pilot test at the same location and with the same material as the other participants. Surface electromyography was used for identifying them and was performed with the PLUX wireless biosignals (PLUX wireless biosignals S.A., Portugal) device with the electrodes located according to the procedures done by Perotto and Delagi [14].

Fifty active and first-year university students who were free of physical handicaps were invited to the study. Their anthropometric data including height, weight, body mass index, fat factor (in %), total lean mass, right and left upper limb muscle mass, and trunk muscle mass were measured. Body composition was estimated by means of a Tanita BC-418MA bioelectrical impedance analyser (Tokyo, Japan). Participants completed the International Physical Activity Questionnaire (IPAQ) [15]; a reliable and valid [16] seven-item retrospective and self-report survey to quantify physical activity in the last week.

Subjects participated in a 1-h basic CPR training session by a certified instructor and were randomly allocated into two groups of 25 (experimental [EG] and control [CG]; Fig. 1). Just after the training, the participants were tested on a manikin with a skill reporter. Only people who obtained at least 70% CC quality were considered for participation in the next phase. Of them, 23 (14 male and 9 female) were from the EG and 16 (9 male and 7 female) were from the CG group (Fig. 1).

The experimental group subjects followed a supervised, individualised training programme that included a maximum isometric strength test and four-week training period of three sessions per week (total of 12 sessions). The purpose of the maximum isometric strength test was to individualise the training programme of each participant. The test included triceps pushdown (150° elbow flexion) and upright barbell row in low pulley (180° shoulder abduction), and was performed in a Multi Jungle CMJ-6000 (Hoist® fitness system, California, USA). Romanian deadlift (60° trunk flexion) and standing barbell bench press (150° elbow flexion) was performed in a Smith HF-4985 Half-Cage (Hoist® fitness system, California, USA). After the assessment and according to the physical fitness of each participant, the four-week training period was programmed; three sessions per week (total of 12 sessions). In order to achieve an acute effect on maximum isometric power in the selected muscular groups, the minimum time between sessions was 48 h. For the first two weeks, each workout session included three series of 30 s of isometric contraction at an intensity of 40% of maximum isometric power, with a 30-s rest between each series. In the other two weeks, the volume was increased in each workout session to four series of 30 s, maintaining the intensity at 40% with a 30-s rest between series. In addition, the training programme included an abdominal hollowing exercise on all-fours to activate the musculus transversus abdominis, due to its essential role in postural trunk stability. When the training programme was completed, all participants repeated the CPR quality test (T2) with the same conditions as the baseline test (T1).

A Laerdal Resusci Anne manikin with a Laerdal Wireless SkillReporter® system, software version 2.0 (Laerdal Medical, Stavanger, Norway) was used for registering CPR variables. Variables related to CC and rescue breaths (RB) were recorded. In order to analyse CC, we registered CC depth (in mm), CC rate (in CC per minute), percentage of correct CC, and different types of errors (insufficient and excessive depth, insufficient chest recoil, and hand position). In order to assess RB quality, the number and percentage of correct RB and RB with excessive and insufficient volume were recorded. CC and RB were considered correct when no error was detected. The manikin was programmed according to the quality goals recommended by the ERC [1]: 50–60 mm for CC depth, 100–120 CC/min and 500–600 mL of volume for RB.

Statistical analysis

Continuous variables were described by mean and standard deviation after testing for normality using the Shapiro-Wilk test. The analysis was performed with two intragroup factors: minute (1–10 min), and test (T1 vs. T2) and with one intergroup factor: group (EG vs. CG). In order to analyse the effect of each factor and the interaction between factors, a repeated measures ANOVA with Bonferroni test was performed. A significance level of $p < 0.05$ was considered statistically significant. Statistical calculations were made with SPSS for Windows, version 20 (SPSS Inc., IBM, USA).

RESULTS

Participants were 22.5 ± 5.3 years old; 16 (41%) were female. According to the IPAQ, participants had weekly physical activity of 3523.7 METS. No differences were found between EG and CG ($p = 0.619$). At baseline anthropometry, no differences were observed between groups for any of the analysed variables; however, after training the mean body fat percentage decreased from 18.4 to 16.4 in the EG ($p = 0.004$). In addition, total lean mass ($p = 0.002$) and upper limb muscle mass right ($p = 0.005$) and left ($p = 0.011$) increased during the training programme.

Regarding CPR, no differences were observed for any of the analysed variables when EG and CG were compared at T1 (Table 1). However, after training, EG participants obtained significantly better results than controls in variables related to CC. In T2, mean depth and number and percentage of correct CC were higher in EG (53.7 mm and 68.2%) than in CG (47.6 mm and 40.4%; $p < 0.05$ in both). Also, the EG delivered less shallow CC than CG (106.9 vs. 429.1; $p < 0.05$).

On the other hand, when ventilation results were analysed, the individuals of the EG had significantly over-performed compared to CG (701.5 ± 187.0 mL vs. 584.8 ± 113.6 mL; $p = 0.040$; Table 1).

In the intragroup assessment, trained participants improved their CC quality results from baseline to after training test, but their ventilation quality decreased (Table 1).

When the first to tenth minute CC quality trend was analysed, it was observed that the performance of the CG decreased significantly with time in both tests (Fig. 2). The same occurred with EG before the training programme. However, trained participants were able to maintain the quality around the arbitrary goal of 70% throughout the 10-min test time, with a minimally decreasing trend (Figs. 2, 3).

DISCUSSION

Both skills and strength are needed to achieve high-quality CPR, especially when resuscitation efforts have to be maintained over time, as happens in the case of lone rescuers. Experimental and clinical data indicate that, even in best conditions, CC quality decreases after 2 min [1]. How good a quality of CC can be achieved and maintained over time? Perhaps physical training is one option. If confirmed, this aspect should be considered in life support programmes [17–19].

We observed that in controlled conditions and with manikins, relatively simple muscular workouts improve the ability of potential rescuers to perform good quality CPR, both in the first minutes and throughout a 10-min period of BLS. High-quality CPR is not an easy task, even for healthcare personnel, or those with duty to assist [5]. Several studies have reported that individuals with different backgrounds have difficulties achieving the arbitrary minimum level of 70% of full quality (CC and ventilations) according to guidelines [20–22]. Similar results have been obtained at baseline in our sample of university students.

During BLS in out-of-hospital settings, CPR efforts must be immediately started by bystanders and maintained until the arrival of EMS, which means around 10 min in optimal conditions [1, 23]. Therefore, not only the initial (first 2 min) quality of CC matters. We have observed that — in agreement with prior studies — in the baseline test, CPR quality

Table 1. Analysis for the cardiopulmonary resuscitation variables by group (control [CG] vs. experimental [EG] group). Contrast test with repeated measures ANOVA

		CG	EG	ANOVA	
				CG vs. CE	EG in T1 vs. EG in T2
Compressions					
Depth	T1	47.8 ± 4.6	49.9 ± 5.9	0.243	0.003
	T2	47.6 ± 5.4	53.7 ± 2.3	< 0.001	
Correct CC	T1	301.4 ± 172.4	357.7 ± 223.8	0.403	0.004
	T2	331.7 ± 265.9	538.0 ± 168.4	0.005	
Percentage correct CC	T1	40.5 ± 24.2	46.4 ± 29.1	0.514	0.004
	T2	40.4 ± 31.6	68.2 ± 21.0	0.002	
Insufficient depth	T1	408.7 ± 216.1	297.4 ± 272.0	0.081	0.002
	T2	429.1 ± 263.7	106.9 ± 123.6	< 0.001	
Excessive depth	T1	3.2 ± 4.8	23.3 ± 38.3	0.045	0.120
	T2	9.2 ± 18.7	43.4 ± 60.0	0.034	
Incomplete chest recoil	T1	134.4 ± 162.0	140.0 ± 149.3	0.912	0.605
	T2	84.9 ± 129.6	118.5 ± 161.1	0.493	
Rescue breaths					
Correct RB	T1	15.9 ± 11.0	14.8 ± 8.8	0.733	0.003
	T2	17.6 ± 11.7	6.5 ± 8.3	0.001	
Percentage correct RB	T1	32.5 ± 22.9	32.3 ± 16.7	0.974	< 0.001
	T2	32.7 ± 21.7	12.8 ± 15.4	0.002	
Low volume	T1	15.2 ± 12.9	11.8 ± 11.6	0.394	0.591
	T2	14.0 ± 12.9	10.0 ± 17.3	0.438	
Excessive volume	T1	17.5 ± 16.6	19.5 ± 14.8	0.707	0.013
	T2	15.6 ± 13.0	31.5 ± 19.6	0.007	

Data are presented as mean ± standard deviation; CC — chest compression; RB — rescue breaths; T1 — test 1; T2 — test 2

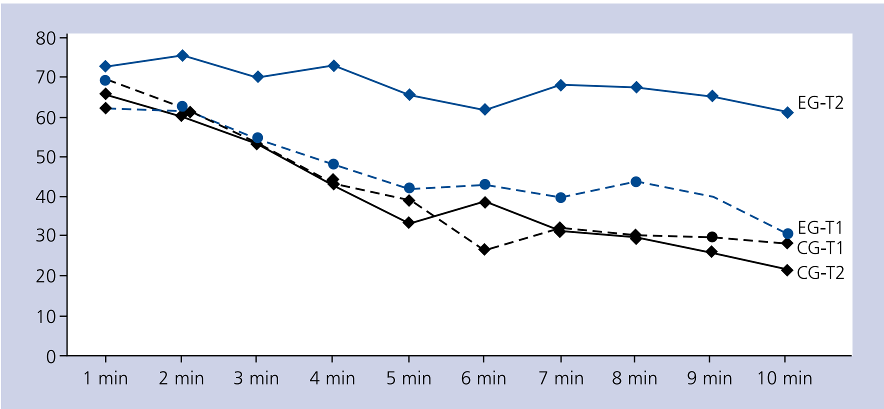

Figure 2. Chest compressions fraction in ten minutes

decreases as the minutes elapse, both in control and trained participants [18, 19].

What can we do to improve CPR quality by laypersons or professionals? From several possible options, we propose that a specific physical training programme would have a significant impact in terms of CC, ventilations, and maintenance of performance throughout the intervention. Our results seem to partially confirm this hypothesis about the CC component. After training, university students significantly improved their performance: mean CC depth increased from 49.9 mm

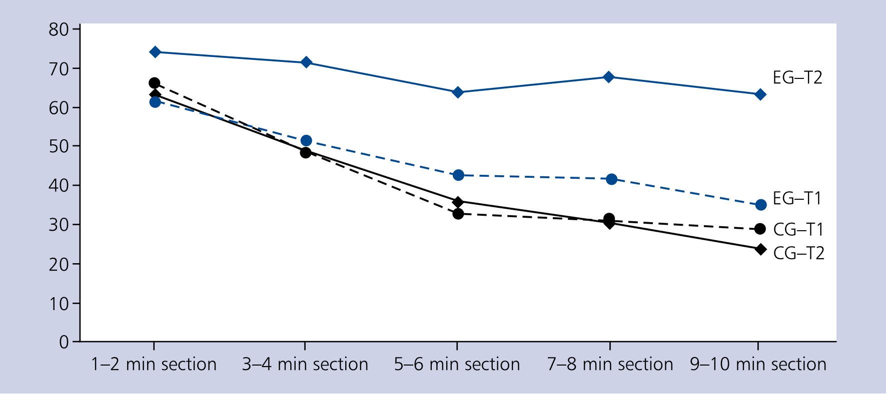

Figure 3. Chest compressions fraction in sections of two minutes

(just at the lower limit of recommended depth) to 53.7 mm (clearly inside in the recommended range of 50–60 mm) [1]. Similarly, the percentage of correct CC increased from 46% to 68%, a fact that suggests a qualitative improvement due to physical fitness.

On the other hand, we observed that physical training resulted in over ventilation of the manikin. This relative paradox has been also observed in studies conducted on professional lifeguards who delivered mean tidal volumes higher than 1000 mL in similar manikins [8, 24], which is clearly above the current recommendations of 500–600 mL [1]. In consequence, we consider that physical training alone is not enough and must be complemented by skill training focused on the monitoring of chest rise during ventilations, in order to ascertain that the lungs are inflated but not overinflated [25].

Limitations of the study

Our study has some limitations. Participants were university students with prior self-reported moderate physical activity, a fact that induces some bias and that should be considered to avoid direct extrapolations to people with other physical activity profiles. As with other studies in controlled conditions and with manikins, the results must be regarded cautiously as real life CPR victims and conditions may present additional difficulties to obtain good quality CC.

CONCLUSIONS

A relatively simple physical power-training programme has a significant impact on immediate (first 2 min) and continuous 10 min of CC. However, physical training might induce over-ventilation of victims, and therefore rescuers must be trained to avoid such an undesirable effect. The potential impact of physical training of rescuers (laypersons and professionals) on victims' outcome and the ideal training and retraining programme remain as knowledge gaps that should be addressed in future studies.

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Conflict of interest: *none declared*

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Wpływ treningu siłowego na jakość przedłużającej się resuscytacji krążeniowo-oddechowej

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Streszczenie

Wstęp: Zapewnienie wysokiej jakości uciskania klatki piersiowej i oddechów ratowniczych stanowią kluczowe elementy wpływające na skuteczność resuscytacji krążeniowo-oddechowej.

Cel: Celem pracy była ocena wpływu treningu siłowego na jakość przedłużającej się resuscytacji krążeniowo-oddechowej.

Metody: Badanie miało charakter quasi-eksperymentu. Trzydzieści dziewięć osób po kursie z zakresu podstawowych zabiegów resuscytacyjnych przydzielono w sposób losowy do dwóch grup: kontrolnej i eksperymentalnej. Następnie uczestnicy, korzystając z manekina szkoleniowego, przeprowadzali 10-minutowy scenariusz resuscytacji krążeniowo-oddechowej, wykonując uciskania klatki piersiowej naprzemiennie z oddechami ratowniczymi metodą usta–usta (test 1). Grupa eksperymentalna uczestniczyła w 4-tygodniowym treningu siłowym, który był nastawiony na ćwiczenie mięśni zaangażowanych podczas uciskania klatki piersiowej. Następnie ponownie obie grupy wykonywały 10-minutowy scenariusz resuscytacji krążeniowo-oddechowej (test 2).

Wyniki: Po treningu siłowym w grupie eksperymentalnej zaobserwowano znaczne zwiększenie głębokości ucisku (53,7 ± 2,3 mm *vs*. 49,9 ± 5,9 mm; p = 0,003) oraz prawidłowej kompresji (68,2 ± 21,0% *vs*. 46,4 ± 29,1%; p = 0,004). Osoby z grupy eksperymentalnej wykazywały utrzymanie jakości uciśnięć klatki piersiowej w czasie lepiej niż osoby z grupy kontrolnej. Osoby z grupy eksperymentalnej w porównywaniu z grupą kontrolną wykonywały wentylację pacjenta wyższymi objętościami (701,5 ± 187,0 ml vs. 584,8 ± 113,6 ml; p = 0,040).

Wnioski: Zastosowanie prostego treningu siłowego znacząco wpływa na jakość uciśnięć klatki piersiowej i utrzymanie tej jakości podczas przedłużającej się resuscytacji. Konieczne są dodatkowe szkolenia w celu uniknięcia wentylacji pacjenta zbyt dużymi objętościami.

Słowa kluczowe: resuscytacja krążeniowo-oddechowa, jakość, sprawność fizyczna, trening siłowy

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