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Original Contribution

Muscular fitness as a mediator of quality cardiopulmonary resuscitation☆

Angel López-González, PhD [a,*], Mairena Sánchez-López, PhD [b], Antonio Garcia-Hermoso, PhD [c], Jaime López-Tendero, MSci [b], Joseba Rabanales-Sotos, PhD [b], Vicente Martínez-Vizcaíno, MD, PhD [b,d]

[a] School of Nursing, University of Castilla-La Mancha, Albacete, Spain
[b] University of Castilla-La Mancha, Health and Social Research Centre, Cuenca, Spain
[c] Laboratorio de Ciencias de la Actividad Física, el Deporte y la Salud, Facultad de Ciencias Médicas, Universidad de Santiago de Chile, USACH, Chile
[d] Universidad Autónoma de Chile, Facultad de Ciencias de la Salud, Talca, Chile

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ABSTRACT

Background: It has been hypothesized that body mass index (BMI) and muscle strength (MS) of the rescuers are predictors of adequate external chest compressions (ECC). The aims of this study were: (*a*) to analyze, in college students, the relationship between BMI and MS with adequate ECC parameters; and (*b*) to examine whether the association between BMI and adequate ECC parameters is mediated by MS.
Methods: A cross-sectional analysis of the evaluation of a CPR performance test involving students ($n = 63$). We determined BMI and MS. After previous training, participants performed cardiopulmonary resuscitation on a mannequin for 20 minutes. PROCESS macro developed by Preacher and Hayes was used to assess whether the association between BMI and ECC was mediated by MS.
Results: Underweight subjects achieved lower results than those with normal weight and overweight/obese in several dependent variables including: correct compression depth ($P < .001$) and adequate ECC ($P < .001$). This differences remained after adjusting for muscle strength except for the compression rate ($P = .053$). Moreover, participants in the low MS quartile were lower in both correct compression depth ($P = .001$) and adequate ECC ($P < .001$) than participants in the medium/high quartile after adjusting for confounding variables. The effect of BMI on adequate ECC was partially mediated by MS. Similar results were obtained in the analysis of the mediator role of MS in the relationship between BMI and correct compression depth.
Conclusions: The ability to provide adequate ECC is influenced by the rescuer's MS. Rescuers should be advised to exercise arm strength to improve the quality of CPR.

1. Introduction

The out-of-hospital cardiac arrest poses a challenge to the health system. Survival rates after these events mainly depend only on effective chest compressions, early defibrillation, and advanced life support [1]. There is consensus that high quality cardiopulmonary resuscitation (CPR) is associated with a higher survival rate and remains essential to improving outcomes [2]. The technique for effective external chest compression (ECC) and positive pressure ventilation is periodically reviewed by international organizations [1,2].

Authors indicate that the rescuer's physical fatigue decreases the quality of ECC a few minutes after the start of the CPR [3–8]. Weight status has been also associated with the quality of ECC, such that those who are underweight perform CPR worse than those with normal weight or excess weight [4,5,9,10]. High levels of muscle strength are positively correlated with the number of adequate ECCs performed [5,10,11]. On the other hand, weight status has been related to muscle strength. Increases in body mass index (BMI) are associated with improved performance in physical fitness tests that do not involve lifting the body, such as dynamometry [12–14]. In this way, muscle strength might be a potential mediator or play a confounding role in the analysis of the relationship between weight status and adequate quality of the ECC.

Mediation analyses are the statistical procedures usually employed in order to clarify the relationship between two variables and how this relationship can be modified, mediated or confounded by a third variable. When the third variable (the mediator) carries the influence of a given independent variable on a given dependent variable, the effect of mediation occurs [15].

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* Corresponding author at: School of Nursing, University of Castilla-La Mancha, Edificio Benjamín Palencia, 02071 Albacete, Spain. Tel.: +34 969 599200x2717; fax: +34 967 599267.
E-mail addresses: angel.lopez@uclm.es (A. López-González), mairena.sanchez@uclm.es (M. Sánchez-López), agarciah@uautonoma.cl (A. Garcia-Hermoso), leman_1988@hotmail.com (J. López-Tendero), Joseba.rabanales@uclm.es (J. Rabanales-Sotos), vicente.martinez@uclm.es (V. Martínez-Vizcaíno).

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To our knowledge, no study has examined the mediator role of muscle strength on the relationship between BMI and adequate ECC parameters by mediation analysis. The objectives of this study were 2-fold: (1) to analyze, in college students, the relationship between BMI and muscle strength with adequate ECC parameters; and (2) to examine whether the association between BMI and adequate ECC parameters is mediated by muscle strength.

2. Methods

2.1. Study design and participants

A cross-sectional analysis of the evaluation of a CPR performance test was conducted from September 2011 to April 2012, which included sixty-three university students (19 men, 44 women), aged 19 to 43 years, from the Nursing Faculty of the Albacete Campus in the University of Castilla-La Mancha, Spain (Table 1). All of them had been previously trained in CPR based on European Resuscitation Council Guidelines [16]. All the participants were required to be able to achieve a maximal voluntary cardiopulmonary exercise test.

All the participants were informed in detail about the nature and risks of this study, and were provided with written informed consent. The study protocol was approved according to the Helsinki declaration by the Clinical Research Ethics Committee of the University Hospital from Albacete, Spain. Participants suffering from any cardiovascular and/or orthopedic injury/dysfunction were excluded.

2.2. Training program

The participants (in groups of 15) received, 48 hours before the measurement of the anthropometric variables and physical fitness, a 30´ session of standardized training in basic CPR. This training, supervised by an instructor who followed the CPR Personal Anytime Learning Programs method, allows each student to practice with a mannequin following the instructions of a DVD, and the amendments of the instructor [17].

2.3. Measurements

Sociodemographic variables (age, sex, education and residence) were collected and the following were also measured in all subjects.

2.4. Anthropometry

Weight was measured to the nearest 100 g with a calibrated digital scale (SECA model 861; Vogel & Halke, Hamburg, Germany), with the participant barefoot and in light clothes. Height was measured to the nearest millimeter with a wall-mounted stadiometer (SECA model 220; Vogel & Halke, Hamburg, Germany), with the students standing straight against the wall without shoes to align the spine with the stadiometer. The head was positioned with the chin parallel to the floor. Finally, the mean of the two measurements of weight and height was used to calculate BMI (kg/m^2). BMI was categorized according to the age and gender cut-off points defined by the World Health Organization in underweight (<18.5 kg/m^2), normal weight (18.5–24.9 kg/m^2) and overweight/obesity (≥25 kg/m^2) [18].

Table 1
Demographic, anthropometric and physical fitness variables of study population, by sex

	Total (n = 63)	Men (n = 19)	Women (n = 44)	*P*
Age (y)	22.7 (5.2)	23.3 (5.5)	22.4 (5.0)	.516
Weight (kg)	63.68 (10.32)	73.68 (7.20)	59.36 (8.28)	<.001
Height (m)	1.67 (0.80)	1.74 (0.05)	1.63 (0.06)	<.001
Body mass index (kg/m^2)	19.02 (2.63)	21.11 (2.11)	18.11 (2.31)	<.001
Weight status (%)				
Underweight	43.5	0	62.8	<.001
Normal weight	51.6	89.5	34.9	<.001
Overweight/obesity	4.8	10.5	2.3	<.001
Handgrip/weight$^{0.67}$	1.85 (0.50)	2.41 (0.46)	1.60 (0.28)	<.001
Cardiorespiratory fitness (VO_2max; mL kg^{-1} min^{-1})	40.7 (7.4)	49.1 (6.0)	37.1 (4.3)	<.001

Values are means ± SD except when indicated.

2.5. Physical fitness tests

Muscle strength: the maximum strength of the upper body (capacity to produce the maximum muscular tension with a muscle contraction) was evaluated using digital handgrip dynamometer Takei TKK 5101 (rank, 5 to 100 kg, accuracy, 0.1 kg), which measured the force of maximum grip strength in both hands alternately (with previous grip adjustment of the dynamometer based on the hand size), making 2 attempts with each hand, with the subject standing up and leaving the arms relaxed and parallel to the body [19]. The final score was the mean of the four measures (kg). Various factors may confound strength performance tests. In addition to sex, age, level of physical activity, and skill, body size is a well-recognized factor affecting muscle strength. Thus, to avoid the potential biasing effect of body weight on the estimation of muscular fitness, handgrip was adjusted for body weight (in kg)$^{0.67}$ in line with standard assumptions about morphologic effects as some authors have suggested [20,21].

Cardiorespiratory fitness (CRF) was estimated through peak or maximum oxygen uptake determined by the maximum effort test according to the Bruce ramp protocol on a treadmill ergometer (HP-Cosmos, model Pulsar 3P). The treadmill stress electrocardiogram testing was performed with the electrocardiograph Cardinal Health model Ergoline ER800. Exhaled breath was registered by an effort basal spirometer and an automatic system of analysis of exhaled gas (model Oxycom Alpha; Jaeger). The instruments were calibrated before each session according to protocol and barometric pressure, temperature and humidity corrections. CRF was dichotomized as higher and lower using the Cooper Institute cut-off points for 20- to 30-year-old adults (VO_2max 38 mL kg^{-1} min^{-1} for women and 43 mL kg^{-1} min^{-1} for men).

2.6. Evaluation of participants' cardiopulmonary resuscitation ability

External chest compressions: after the training session, each participant performed CPR on a manikin Laerdal Resusci-Anne-SkillReporter (Medical Laerdal; Stavanger, Norway) without interruption (30:2 compression-ventilation ratio) for 20 minutes or until exhaustion.

Auditory feedback was provided and measured by the internal metronome of the manikin, and visual feedback was shown on a monitor that allowed visualization of the depth of compressions, incomplete release, released pressure, increased duration, faster compression and slower compression.

During the test, ECCs were considered adequate items**,** according to the recommendations of the European Resuscitation Council [16], when the following conditions were achieved: (a) a rate of 100 to 120 min^{-1}; (b) 100% of compressions in the centre of the patient's chest; (c) full chest recoil after each compression 100% of the time; (d) 100% of compressions with a depth ranging between 50 and 60 mm; and (e) taking approximately equal amounts of time for the compression and relaxation phases 100% of the time.

The measurements were obtained minute by minute during the test, which ended once the participants reached the objective (20 minutes of ECC) or could not continue because of physical limitations such as physical exhaustion or pain in their extremities.

All measurements were taken under standard conditions by the same researchers.