Physiological responses in female rescuers during 30 minutes sustained CPR with feedback: a comparison between medicine and physical education students

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Abstract: Objectives: Since fatigue seems related to poorer physical fitness rather than to gender, we analyzed the physiological responses in female medicine and physical education students during a 30 minutes sustained cardiopulmonary resuscitation (CPR) sequence. Methods: Handgrip strength and maximal aerobic power (VO2 max) determined strength and endurance. Twenty-three medicine (M) and 27 physical education (PE) female students performed 30 minutes CPR. Compression quality and ECG were continuously monitored, heart rate and non-invasive blood pressure (NIBP) every 2 minutes. Capillary pH, PCO2, lactate, potassium and sodium bicarbonate were analyzed every 10 minutes. Results: Handgrip strength (PE 37 kg vs. M 35 kg; p<0.05) and VO2 max (PE 50 ml/kg/min vs. M 44 ml/kg/min; p<0.05) revealed a better strength and endurance in PE students. Six medicine and 1 PE student did not complete the entire 30 minutes of CPR. Percentage compressions > 5 cm was comparable in both groups (PE 80%; M 79%; p=0.67). Mean heart rate during CPR was higher in the M group (148 bpm) compared to the PE group (132 bpm; p<0.05). No intergroup differences in NIBP, pH, PCO2, potassium and sodium bicarbonate were observed. Mean lactate during CPR was higher in the M group: 3.5 mmol/l (SD 1.4) compared to the PE group: 2.5 mmol/l (SD 0.7) (p<0.05). Conclusion: A high quality sustained CPR effort was well tolerated by all female rescuers. Poorer physical condition (M group) resulted in more drop out after 10 and 20 minutes and in a higher heart rate and blood lactate over time. Improving physical condition may result in less physiological strain and lower perceived exertion.

Key words: cardiopulmonary resuscitation; fatigue; physical fitness.

Introduction

Following sudden cardiac arrest, the brain can only survive for 3-5 minutes without oxygen. In almost all cases, this is less time than the emergency medical services take to arrive on scene. Immediate initiation of cardiopulmonary resuscitation (CPR) by lay bystanders improves the survival after out-of-hospital cardiac arrest by a factor of 2-4. (1,3) The 2015 European Resuscitation Council (ERC) CPR guidelines recommend a thoracic compression depth of at least 5 cm at a rate of 100-120 per minute. (4) In comparison to the 2005 guidelines, achieving this depth is more intense and requires a certain physical fitness of the rescuer. (5) It might be hypothesized that rescuer physical fatigue might interfere with delivery of adequate chest compression (i.e. rate and depth). (6,9) Significant physical fatigue and shallow compressions are described after already 1 minute, although rescuers may deny that physical fatigue is present within 5 minutes. (5,10) Considering that women generally have lower levels of physical fitness than men (2), it is not surprising that the influence of gender on the quality of chest compressions is also controversial. (6,7,11,12) Since women are as capable as men to achieve a 5 cm compression depth (13,14), several authors agree on the fact that fatigue is not gender dependent as such. (12,14-16) Lopez-Gonzalez and colleagues confirmed the above statement by concluding that exertion during CPR is higher in wom-
en, but fatigue seems to be related to differences in body mass index and physical condition. (16,17)

Since little is known on how a sustained CPR effort affects the physiological parameters of female rescuers, the aim of this prospective study was to describe and compare the physiological responses in female medicine and physical education students during a 30 minutes sustained CPR sequence.

**Material and Methods**

**Data collection**

Fifty female students who completed a CPR course in accordance with the 2010 ERC Guidelines (4) were recruited on a voluntary base at the faculty of Medicine and Health Sciences (Ghent University, Belgium). Given the reports of several authors that the physical characteristics of the rescuers (including gender) had no impact on their CPR performance, we did not use a male control group. (12,18,19) This prospective data collection was carried out at the Laboratory of Exercise Physiology of the Ghent University and approved by the research Ethics Committee of the Ghent University Hospital (B670201112158). Informed consent was obtained from every participant.

**Study protocol**

The participants were divided into two groups according to their expected physical condition: Medicine students (M; n=23) and Physical Education students (PE; n=27). As a consequence of their curriculum physical education students were expected to have a good or at least better physical condition compared to the medical students. The participants’ height (anthropometer GPM, DKSH Switzerland), weight (electronic SECA, 815 Elégantia) and body fat percentage (Harpende Skinfold Calliper, Fysio Supplies) were measured. Body mass index (BMI; kg/m²) was calculated. To assess baseline strength and endurance respectively, we measured hand grip strength (kg) (Hydraulic hand dynamometer, Sachon corporation, Mason) as a determinant of general muscle strength and we estimated maximal oxygen uptake (ml/kg/min) by means of an endurance shuttle run test as a parameter of maximal aerobic power (VO₂ max). (19,20)

In order to detect unknown cardiac abnormalities a 12 lead ECG (Delta 60 plus, Cardioline) was performed in all volunteers before the CPR exercise. All participants were considered as lay rescuers and had received previous CPR training. However, to avoid any pre-testing difference, each group received a CPR instruction booster, using the ERC-accredited 4-stage approach, one week before the study. (4)

After this, the students were asked to perform a 30 minutes sustained CPR sequence (30:2). Regarding the available evidence on the impact of CPR feedback devices on CPR quality, participants were given real-time feedback on hand positioning, compression depth, ventilation volume and a metronome continuously provided a rhythm of 100-120 compressions per minute. (5) CPR quality data were registered using a Laerdal Resusci Anne manikin (Laerdal, Norway) connected to a Laerdal PC Skill reporting software (version 2.4) and simultaneously monitored by an observer.

To define compressions as adequate, they were automatically evaluated for depth (> 5 cm), frequency (100-120/min) and complete release (< 0.5 cm). The ventilations were automatically evaluated for the inflated volume (400-1000 ml). The 30:2 CPR was performed during 30 minutes with a hands-off period every 2 minutes during the analysis of the automatic external defibrillator. This time interval was used to measure and register the volunteer’s heart rate (bpm), non-invasive blood pressure (NIBP) and peripheral oxygen saturation (SpO₂), which were repeated every 2 minutes. All participants were connected to a continuous 5 lead ECG monitor (SC 9000 xl, Siemens). In addition to the non-invasive monitoring, capillary blood samples from the fingertip were taken every 10 minutes to analyze the pH, PcCO₂, lactate, potassium and sodium bicarbonate (Radiometer ABL90 Flex, Denmark). An anaesthesiologist (LH) and exercise physiologist (JGB) evaluated the results of the non-invasive and capillary monitoring throughout the whole exercise. In case of hypertension or arrhythmia, tiredness, feeling unwell or failure to maintain correct compression rhythm or depth the participant was asked to stop the physical effort and the reason was noted. At the end of the 30 minutes the participants were asked to appraise their feeling of exertion on a “Borg rating of perceived exertion scale” ranging from 6 to 20. (22)

**Statistical analysis**

All statistical analysis were performed using SPSS for windows, version 20. The results are reported as means (SD). According to the parameter different tests were applied. For the demograph-
Handgrip strength was 37 kg (SD 6) in the PE group vs. 35 kg (SD 7) in the M group (p<0.05). Estimated VO2 max was 50 ml/kg/min (SD 4) in the PE group vs. 44 ml/kg/min (SD 6) in the M group (p<0.05).

CPR performance

Seven volunteers were not able to complete the 30 minutes sequence (M group: 6/23 and PE group: 1/27; p<0.05). In the M group three students ceased due to fatigue (1 after 10 minutes and 2 after 20 minutes), two students due to arrhythmia (one atrial fibrillation after 10 minutes and one non-sustained ventricular tachycardia after 20 minutes) and one student due to extreme acidosis after 10 minutes. In the PE group one student was unable to sustain adequate compression depth of >5 cm after 18.5 minutes.

The CPR quality of participants able to sustain a 30 minutes sequence (M=17; PE=26) was comparable between both groups and compression depth was similar. In the M group mean compression depth was 54 mm (SD 2) versus 54 mm (SD 4) for the PE group. Overall, the percentage compressions with depth > 5 cm was comparable in both groups (M 79%; PE 80%; p=0.67).

No differences were observed for the total number of compressions: 2116 (SD 636) in the M group vs. 2379 (SD 206) in the PE group (p=0.54); the mean number of adequate compressions (> 5 cm): 1603 (SD 710) in the M group vs. 1899 (SD 481) in the PE group (p=0.15); the mean total number of ventilations: 146 (SD 9) in the M group vs. 142 (SD 12) in the PE group (p=0.77). In the mean number of adequate ventilations, there is a statistical significance (p=0.03): 86 (SD 45) in the M group vs. 106 (SD 30) in the PE group. Figure 2 shows the evolution of the percentage compressions with adequate depth over time between both groups. No significant differences were observed.

Physiological data

At baseline, no significant intergroup differences were observed for any of the physiological parameters.

Heart rate, NIBP and SpO2

Mean heart rate during CPR performance was higher in the M group compared to the PE group (p<0.05) for every measurement. Between 0 and 30
minutes, a significant intra group increase in mean heart rate was noted in both the M group: 96 bpm, SD 19 to 156 bpm, SD 21 (p<0.05) as the PE group: 88 bpm, SD 16 to 139 bpm, SD 18 (p<0.05). The increase in heart rate was most pronounced during the first 10 minutes of CPR.

No statistically significant intergroup differences were observed for mean arterial blood pressure (MAP = 2/3 diastolic blood pressure + 1/3 systolic blood pressure). In the M group, the mean arterial blood pressures range was between 96 mmHg (SD 10) at the start, to a minimum of 93 mmHg (SD 6) at 2 min (p=0.07) and a maximum of 100 mmHg (SD 8) at 10 minutes (p<0.05). In the PE group mean arterial blood pressure starts at 99 mmHg (SD 12), but significantly dropped at minute 14 to 91 mmHg (SD 17) (p<0.05) to reach a mean value of 97 mmHg (SD 14) after 30 minutes. No significant inter- or intra group differences were observed for peripheral saturation.

Capillary blood samples

No intergroup significant differences in pH, potassium, PcCO2 and sodium bicarbonate were observed.

There was no intragroup difference for pH in the PE group with an average pH of 7.42 (SD 0.02) (p=0.2). The pH in the M group between 0 and 10 minutes dropped from 7.41 (SD 0.03) to 7.39 (SD 0.03) (p<0.05) with an average pH in the M group of 7.40 (SD 0.02). A significant intragroup rise in potassium was noted from 0 to 20 minutes: in the M group the mean potassium raised from 4.2 mmol/l (SD 0.5) to 5.2 mmol/l (SD 0.5) (p<0.05) and in the PE group from 4.3 mmol/l (SD 0.2) to 5.4 mmol/l (SD 1) (p<0.05).

A significant intragroup decrease for PcCO2 was observed in both groups: 38.6 mmHg (SD 3.9) to 33.8 mmHg (SD 3.9) in the M group (p<0.05) and 38.0 mmHg (SD 2.9) to 34.5 mmHg (SD 1.7) in the PE group (p<0.05).

Mean lactate during CPR performance was significantly higher in the M group: 3.5mmol/l (SD 1.4) compared to the PE group: 2.5mmol/l (SD 0.7) (p<0.05). Mean lactate values at 10 min (M: 4.3 mmol/l; PE: 2.8 mmol/l; p < 0.05), at 20 min (M: 3.9 mmol/l; PE: 2.3 mmol/l; p < 0.05) and at 30 min (M: 4 mmol/l; PE: 2.3 mmol/l; p < 0.05) were significantly higher in M compared to PE. As shown in Fig. 3a, a significant intra group increase was observed between 0 and 10 minutes: 2.1 mmol/l (SD 1.0) to 4.3 mmol/l (SD 1.9) in the M group (p<0.05) and 1.9 mmol/l (SD 0.7) to 2.8 mmol/l (SD 1.0) in the PE group (p<0.05).

For sodium bicarbonate (Fig. 3b) a significant intra group decrease was observed in both groups: 24.3 meq/l (SD 2.1) to 21.3 meq/l (SD 3.0) in group M (p<0.05) and 23.9 meq/l (SD 1.2) to 22.7 meq/l (SD 13) in group PE (p<0.05) from 0 to 10min, a significant inter group difference was noted at 10 (p<0.05), and 30min (p<0.05). There was no significant difference at 0 (p=0.20) and 20min (p=0.19).

Perceived exertion

The Borg score was significantly higher in the M group with a hard perceived exertion score of 14 (SD 2) compared to the PE group with a light perceived exertion score of 11 (SD 1) (p<0.05).
Physiological responses during sustained CPR

Our results illustrate the ability of female rescuers to sustain a 30 minutes CPR sequence with feedback whilst maintaining adequate CPR quality. However, students with a higher general basic strength and a better aerobic endurance capacity (PE group) showed significantly less dropouts compared to students with average physical fitness (M group). According to Mpotos and Kriksciouaitiene, female rescuers can achieve as high CPR quality as male rescuers if they are appropriately trained. (13,14) This might, however, be more intense and require more physical exertion of the rescuer, which may lead more rapidly to fatigue. (16) Several authors agree on the fact that fatigue is related to physical fitness and affects the quality of a single rescuer CPR performance. (6-9) Most of the time this results in more shallow compressions after already 1 minute. (5,10) The fact that in our trial CPR quality was consistently adequate during the whole 30 minutes exercise might be explained by the use of real-time feedback. This suggests that the use of feedback devices clearly impacts the quality of CPR delivered, even during a sustained CPR sequence. (23,24) And although six students of the M group and 1 student of the PE group dropped out, this occurred firstly at 10 minutes (3 students) and secondly after 18 minutes to 20 minutes (4 students), meaning that all students were able to sustain 10 minutes of CPR without any problems. In case of a single rescuer CPR in the home setting, this would be the average time for the emergency medical technicians or healthcare provider to arrive at the scene and take over. (6)

With regard to the heart rate, our results confirm the findings of Lucia and co-workers, describing that heart rate remained significantly lower in

Fig. 3a — the mean lactate in the M group was significantly higher at 10, 20 and 30 min (p<0.05): 3.5mmol/l (SD 1.4) compared to the PE group: 2.5mmol/l (SD 0.7) (p<0.05). A significant intra group increase was observed between 0 and 10 minutes: 2.1 mmol/l (SD 1.0) to 4.3 mmol/l (SD 1.9) in the M group (p<0.05) and 1.9 mmol/l (SD 0.7) to 2.8 mmol/l (SD 1.0) in the PE group (p<0.05).

Fig. 3b — Sodium bicarbonate: a significant intra group decrease was observed in both groups: 24.3 meq/l (SD 2.1) to 21.3 meq/l (SD 3.0) in group M (p<0.05) and 23.9 meq/l (SD 1.2) to 22.7 meq/l (SD 1.3) in group PE (p<0.05) from 0 to 10min, a significant inter group difference was noted at 10 (p<0.05), and 30min (p<0.05). There was no significant difference at 0 (p=0.20) and 20min (p=0.19).
physically more active subjects during sustained CPR, when compared with sedentary individuals. (7) Our results confirm that a better maximal aerobic power (VO2 max) in combination with a higher general strength lowers the cardiovascular response (HR and NIBP) during a sustained CPR effort. No differences were found for SpO2.

With regard to fatigue, repeated activation of a muscle causes decreased intracellular potassium and increased extracellular potassium due to the efflux of potassium occurring with each action potential and the inability of the Na+/K+ pumps to adequately compensate. It can be suggested that the potassium changes (M group: from 4.2 to 5.2 mmol/l and PE group: from 4.3 to 5.4 mmol/l) during this 30 minutes sustained CPR sequence are leading to inadequate excitation and force reduction, and thus inducing fatigue. (26) Blood lactate concentration measurements during exercise have been used to get more insight into the metabolic demands of different activities. A blood lactate concentration of 4 mmol/l during steady state endurance exercise has been considered as the transition from dominant aerobic metabolism to partially aerobic-anaerobic metabolism, where lactate production and elimination are still in balance (Fig. 3a). (27) A reciprocal decrease in bicarbonate levels was observed together with the rise of lactate levels in the first 10 minutes. This buffer capacity resulted in steady state pH levels for the PE group, although in the M group a significant drop in pH is observed. During a sustained CPR effort blood lactate concentrations and heart rate increased significantly over time, and with comparable magnitude as reported in previous studies. (6,7,28,29) The increase in blood lactate was significantly higher in the M group and above blood lactate concentration of 4 mmol/l, reflecting the fact that a lower maximal aerobic power faster results in a partially anaerobic energy delivery. Blood lactate concentrations, however, were not related to CPR quality. These data are in line with the findings reported by Hansen et al. and suggest that the cardiopulmonary and/or metabolic responses during sustained CPR do not reflect, or indicate, CPR quality as previously described by Lucia and colleagues. (6,7)

The limitations of this study include the fact that it was carried out in laboratory settings and did not replicate all the aspects of a real-life CPR attempt. Also, participants in our study knew beforehand the length of the CPR and this knowledge could have led to better effort and better tolerance. The relative small study sample and young age of the participants may limit the robustness of some of our findings. However, our results and participants’ characteristics are consistent with previous studies in this field. Furthermore, we chose to compare female students with better physical fitness to average physical fitness and did not use a male control group.

**Conclusion**

A sustained CPR effort with feedback was initially well tolerated by female rescuers in both groups without any difference in CPR quality. Poorer physical condition in the M group resulted in more drop out after 10 minutes and was reflected in a significantly higher heart rate and blood lactate over time. Improving physical condition of rescuers may result in less physiological strain and lower perceived exertion.

**References**

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