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# Acute effect of aerobic and resistance exercises on cardiovascular and neuromuscular responses in normotensive

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**ABSTRACT**

**Introduction**: the literature report the effect of different types of exercise (aerobic and resisted) on cardiovascular and neuromuscular behavior after exercise. **Objective**: the objective of this study was to verify the acute effect after a resisted or aerobic exercise session on arterial pressure (BP), heart rate (HR), muscular strength and electromyography (EMG) activity of the rectus femoris (RF), vastus lateralis (VL) and vastus medialis (MV) in normotensive individuals. **Method**: the study included eight men (27.3 ± 3.1 years, 76.4 ± 9.7 kg, 1.80 ± 0.10 m, 24.3 ± 1.6 kg/m$^2$), physically active individuals who randomly performed an aerobic exercise session (treadmill, 30 min, 60-70% of the reserve heart rate), or a resisted exercise session (nine exercises, three sets, 70% 1RM, 8 -12 repetitions). The BP, HR, EMG and muscle strength, were analyzed at rest before exercise and for 60 min after exercise. **Results**: as a result, systolic BP after the exercises (aerobic and resisted) remained lower than the pre-exercise rest values, with 30, 45 and 60 min ($p<0.05$) of recovery. On the other hand, the diastolic BP was lower after resistive exercise in all periods of recovery ($p <0.01$) in relation to pre-exercise. HR values remained elevated after aerobic and resisted exercise, in all recovery periods ($p <0.05$). Muscle strength and electromyography activity did not show significant differences after exercise. **Conclusion**: independently of the exercise type, occurs post-exercise hypotension (PEH), increase the HR during the recovery period and reestablishment of muscle strength and myoelectric activity of muscles compared to pre-exercise.

**Keywords:** Exercise; Blood Pressure; Heart Rate

## INTRODUCTION

Post exercise hypotension (PEH) is defined as the reduction of the blood pressure (BP) promoted by exercise. It is characterized by the decrease of BP below the rest values after a dynamic exercise session, both in normotensive[(1)] and hypertensive[(2)]. To achieve PEH are recommended both aerobic and resisted exercises.

Casonatto and Polito[(3)] in a systematic review, found that after an aerobic exercise session, PEH occurred in studies with intensities of 50 to 80% of heart rate reserve ($HR_{res}$), and varying the duration of the exercise between 15 and 60 minutes. Anunciação and Polito[(4)] and Dutra et al.,[(5)] in their systematic reviews, analyzed the effect of a resisted exercise session on PEH and concluded that the resisted exercise promotes subacute BP reduction in normotensive and hypertensive patients. Anunciação et al.[(6)]; Abrahin et al.[(7)] and Leal et al.[(8)] indicate that BP reduction after a resisted exercise session seems feasible, especially in hypertensive individuals, who are the major beneficiaries of PEH.

Considering that the mechanisms related to PEH may be different between aerobic and resisted activity and that physical exercise for health include both[(9)], it becomes important to know the cardiovascular behavior after such efforts. In addition, further investigations involving resisted exercise under physiological and neuromuscular aspects are still little explored in the literature, since studies of the PEH relationship and neuromuscular adaptations after a resisted exercise session were not found in the researched literature. In view of the above, it is hypothesized that aerobic exercise provides greater magnitude and duration of PEH when compared to resisted exercise, and that resisted exercise promotes greater alteration of musculoskeletal variables, such as a decrease in muscle strength production and electromyographic (EMG) activity.

The objective of the study was to verify the acute effect after a resisted or aerobic exercise session on blood pressure (BP), heart rate (HR), lower limb muscle strength and

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EMG activity of the rectus femoris muscle (RF), vastus lateralis (VL) and vastus medialis (VM) in normotensive individuals.

## MATERIAL AND METHODS

This is a cross-sectional observational study, in which eight normotensive men (Blood Pressure less than 140/90 mmHg) participated, with at least one year of experience in aerobic and resisted training, non-smokers, without diagnosed heart and/or metabolic diseases. The study was approved by the Research Ethics Committee of the institution (62098916.7.0000.5507) and followed the guidelines of Resolution 466/12 of the National Health Council, about research with humans.

Exclusion criteria were the use of chronotropic or inotropic substances and musculoskeletal and/or neuromuscular limitations/dysfunctions that made the exercise impossible.

### Experimental procedure

To select the sample, all subjects answered the physical activity questionnaire (PAR-Q) to detect possible cardiovascular risk factors or contraindications to exercise practice. Being able to participate in the study, they performed anthropometric evaluation of blood pressure (BP) and resting heart rate (HR). The sample was submitted to the continuous and progressive maximal exercise test in the treadmill (Movement, RT 250), following the protocol of Ellestad et al.,[10] to determine the maximum oxygen consumption ($VO_{2peak}$) and the maximum HR ($HR_{Max}$). Before the beginning of the tes, the $HR_{Max}$ was estimated by the equation proposed in the study of Shargal et al.[11]. The test was composed of stages of 3 minutes, being started with speed of 2.7 km/h and inclination of 10%. At each stage, was added 1.3 km/h at the speed and 2% in the inclination, until the exhaustion or appearance of limiting signs and symptoms. The $HR_{Max}$ was consider the higher HR obtain during the test or when reached the estimated HR, being used to calculate the training zone by HR reserve ($HR_{res}$)[12].

To determine the load of the resisted exercise, a maximal repetition test (1MR) was performed for each activity. The initial load was determined subjectively, indicated by the volunteer himself, who made 3 attempts with an interval of 5 min between them[13], in the exercises: bench press, leg curl, rowing machine, horizontal leg press, triceps pulley, extension chair, developing machine, seated calf and biceps machine.

The order of the exercises (aerobic or resisted) was determined by randomization. All volunteers performed the two exercises following the cross-over design, and the exercises were performed on separate days and separated with a minimum interval of 48 hours.

The aerobic exercise session was characterized by 35 min of total duration (3 min of warm-up, 30 min with intensity of 60-70% of heart rate reserve and 2 min of recovery). The resisted exercise session consisted of the following exercises: bench press, leg curl, rowing machine, horizontal leg press, triceps pulley, extension chair, developing machine, seated calf and biceps machine, performed in 3 sets of 8-12 repetitions with intensity of 70% of 1MR and recovery interval between the series of 1 min and 30 seconds, was oriented to subjects not to perform Valsalva maneuver. The choice of volume and intensity of aerobic exercise and resistance exercise to trigger PEH was based on information available in the literature[1,3,14].

The assessment of BP, HR, strength and electromyographic activity was performed before and after each exercise session (aerobic and resistance).

Immediately after the end of the exercise sessions, the participants were taken to the same chair in which the pre-exercise measures were taken and were seated without verbal and/or gestural communication for 60 minutes for the measurement of the cardiovascular and neuromuscular variables post- effort.

### Measurement of blood pressure and heart rate

In order to measure systolic BP (SBP) and diastolic BP (DBP), the automatic device *Omron HEM-7200 (*EUA) was used and the recommendations of the "VII Diretrizes Brasileiras de Hipertensão" was followed [15]. The BP was evaluated before the beginning of the exercises and during the 60 minutes after the end of the exercises (aerobic or resisted). Before the first BP measurement the subjects remained seated for 10 min, and after that time two BP measurements were performed with a 2-min interval, considering as pre-exercise value the mean of both. After aerobic or resisted exercise (post-exercise), the BP was measured over 60 min with intervals of 15 min, making a total of five records: 0 (immediately after exercise), 15, 30, 45 and 60 min.

HR was assessed before and after exercise by an electronic cardiofrequency (Polar, Finland) just before BP measurements. The delta measurement of recovery HR of 60 seconds (FCR 60 s), obtained by the subtraction of HR at the end of the exercise by the one found after 1 minute of recovery, was performed with the subjects seated in a chair after the aerobic session and seated in the machine itself in the resisted exercise session.

Participants were previously advised not to drink caffeine for at least 72 hours before each session, not to perform any type of vigorous physical activity, not to drink alcoholic drinks in the 24 hours prior to the days of collection and to have made a light meal for at least 3 hours before the experiments.

### Analysis of Strength and Electromyography

Muscle strength of the dominant lower limb was assessed by the MM-100 model load cell (Kratos®, São Paulo, SP, Brazil), connected to the "BIO-EMG 1000-Lynx Electronic Technology Ltd" signal acquisition system. The load cell remained parallel to the floor, attached to the wall and fixed to the volunteer's ankle. Muscle strength was collected concomitantly with electromyographic activity. For this collection was used the "BIO-EMG 1000-Lynx Electronic Technology Ltd" with a analog-to-digital converter with 16-bit resolution and 2000 Hz sampling frequency following the recommendations of the *International Society of Electrophysiology and Kinesiology* (ISEK).

For placement of the electrodes was performed tricotomy in the region and cleaning of the skin with alcohol 70%. The electrodes were placed in the muscles: rectus femoris muscle (RF), 50% of the line between the anterior superior iliac spine and the superior border of the patella; vastus lateralis (VL), 2/3 of the line between the iliac spine and the lateral border of the patella, vastus medialis (VM), 80% of the line between the iliac spine and joint space in front of the medial ligament and the reference electrode positioned on the patella, according to the recommendations of the *SENIAM*[16].

In order to collect the electromyographic signal the volunteer remained seated in a chair without resting his feet on the floor. The electromyographic signal and strength were collected three times during the maximal isometric voluntary contraction (MIVC) of knee extension for 5 seconds, with an interval of 3 minutes between them. The collections were performed pre-exercise and late post-exercise (60 min after exercise).

### Electromyographic Signal Processing

The signals were analyzed offline by the *Matlab®* 8.3 *software* (The MathWorks Inc., Natick, Massachusetts, USA), in which a 4th order Butterworth type digital filter with zero phase delay, with high pass of 10 Hz and low pass of 400 Hz was applied. The first and fifth second of each EMG signal was eliminated, being analyzed 3s of each collected signal.

The analysis was performed: 1) in the frequency domain, to obtain the values of average frequency (Hz) of the power spectral density of the EMG signal evaluated using the Fast Fourier Transform (FFT) algorithm with overlap of 50% (Hamming window processing) and 2) in the amplitude domain, to obtain the values of the integral of the electromyographic signal (IEMG), through a root mean square (RMS) window of 150 ms with later integration.

### Statistical analysis

To statistical analysis was used the SPSS 20.0 software, the *Shapiro-Wilk* test was used to evaluated the normality of data and the *Levene* test was used to the homogeneity of variances. When the data was normal, the Student's t-test for dependent and independent samples were used in the comparison of the neuromuscular variables, when the data were not normal, were used their corresponding *Mann-Whitney*. As the data were homogeneous, the three-way *ANOVA* (resisted x aerobic x monitoring time) with repeated measurements was used for intra and inter group comparisons in cardiorespiratory variables. When necessary, the *Tukey post-hoc* test was used to verify the differences. In all cases, a *P* value of less than 0.05 was considered statistically significant.

## RESULTS

To characterize the sample, the results of anthropometric and cardiorespiratory assessments are listed in Table 1.

The results of the means of SBP, DBP and HR in the pre-exercise, post-immediate and during 60 minutes of recovery after the different types of exercises are listed in Table 2. The SBP values after the resisted and aerobic exercises in the 30, 45 and 60 minutes of antecedent when compared

**Table 1.** Characterization of the sample, age, anthropometric and cardiorespiratory variables.

| Characterization of the sample (n=8) | |
|---|---|
| **Variables** | **mean ± standard deviation** |
| **Age(years)** | 28.7± 7.3 |
| **Body mass (kg)** | 89.3± 10.1 |
| **Height (m)** | 1.79± 0.3 |
| **BMI(kg/m²)** | 27.6± 2.5 |
| | **Ergometric Test** |
| **Time (min)** | 13.3±0.5 |
| **HRmax (bpm)** | 188.7± 7.3 |
| **$VO_{2peak}$ (ml/kg/min)** | 49.8± 2.3 |

Note: the values are presented in mean ± standard deviation. BMI: body mass index; HRmax: maximum heart rate; $VO_{2peak}$: peak oxygen consumption.

**Table 2.** Cardiovascular variables, systolic blood pressure (SBP), diastolic blood pressure (DBP), pre-exercise heart rate (HR), immediately after exercise (0 min) and during 60 min after the end of both types of exercises (aerobic and resisted), and variation delta (HRR60s).

| Variables | SBP (mmHg) Mean ± SD | DBP (mmHg) Mean ± SD | HR (bpm) Mean ± SD | HRC60s (bpm) Δ |
|---|---|---|---|---|
| **AEROBIC** | | | | 37.3±3.7 |
| Pre-exercise | 121.8±9.7 | 67±11.2 | 66.8±3.9 | |
| 0 min | 129.1±10.3† | 74±10.2† | 95.2±9.02† | |
| 15 min | 121.6±11.3 | 68.7±9.7 | 83.6±5.2† | |
| 30 min | 117.8±8.4* | 68.2±10.3 | 79.5±5.4† | |
| 45 min | 114.5±11.7* | 66.6±10.5 | 78.2±5.5† | |
| 60 min | 115.3±10.7* | 66.7±10.4 | 74.7±4.4† | |
| **RESISTED** | | | | 21.6±1.9‡ |
| Pre-exercise | 121.5±8.3 | 67.2±8.5 | 69.2±9.3 | |
| 0 min | 132±15.3† | 62.2±8.4*‡ | 101.5±15.2† | |
| 15 min | 120.1±10.2 | 58.6±10.2*‡ | 85.6±11.9† | |
| 30 min | 114.8±7.3* | 59.1±6.5*‡ | 81.2.2±13.4† | |
| 45 min | 117.5±10.6* | 62.8±10.1* | 77.5.2±10.2† | |
| 60 min | 116.1±11.5* | 63.4±10* | 77.2±10† | |

Note: * Significant decrease (p<0.05) in relation to pre-exercise; † significant increase (p<0.05) in relation to pre-exercise; ‡ significant difference (p<0.05) in relation to aerobic; HRR60s: delta of the HR of recovery after the exercise.

to the pre-exercise moment (p<0.05). The DBP did not present significant difference after the aerobic exercise and recovery period in relation to the initial pre-exercise values. However, there was a significant difference in relation to resisted exercise, DBP values remained lower than pre-exercise values in all the recovery periods (p<0.01). The results also showed significant differences after the exercise in the DBP in relation to the types of exercise and recovery periods. The DBP in the resisted exercise was lower when compared to the aerobic in the 0, 15 and 30 min of recovery (p<0.05).

The HR remained elevated after resisted and aerobic exercise, in all recovery periods (p<0.01) with relation to the pre-exercise values. Whereas the HRR 60s was higher after the aerobic exercise (p<0.01) in relation to the resisted exercise.

The results of neuromuscular, maximal strength and electromyographic signals variables, in the amplitude (IEMG) and frequency (Fmed) domain, pre-exercise and 60 min of recovery after the different types of exercises are in the Table 3 and 4. Regarding the values of maximum strength, IEMG and Fmed, no significant differences were observed after the two types of exercise and recovery period in relation to the pre-exercise values for all muscles evaluated.

**Table 3.** Neuromuscular, integral of the electromyographic signal (IEMG) and median frequency (Fmed) variables of the rectus femoris (RF), vastus medialis (VS) and vastus lateralis (VL) muscles in the pre-exercise and after 60 minutes at the end of the exercises (aerobic or resisted).

| Variables | IEMG(RF) (µV/s) Mean ± SD | IEMG(VM) (µV/s) Mean ± SD | IEMG(VL) (µV/s) Mean ± SD |
|---|---|---|---|
| **AEROBIC** | | | |
| pre-exercise | 395.11±222.4 | 1049±526.9 | 532.37±183.9 |
| 60 min | 386.36±158.3 | 795.09±301.5 | 590.41±254.3 |
| **RESISTED** | | | |
| pre-exercise | 446.32±248 | 1004.4±533.5 | 633.5±312.4 |
| 60 min | 415.67±222.1 | 1001.9±571.2 | 667.15±432.2 |
| | **Fmed(RF) (Hz)** | **Fmed(VM) (Hz)** | **Fmed(VL) (Hz)** |
| **AEROBIC** | | | |
| pre-exercise | 75.12±6.8 | 65.05±7.91 | 66.6±7.7 |
| 60 min | 73.28±8.39 | 74.94±14.9 | 72.09±16.1 |
| **RESISTED** | | | |
| pre-exercise | 76.45±10.6 | 66.87±9.3 | 65.75±6.01 |
| 60 min | 74.86±8.6 | 66.04±8.67 | 75.15±19 |

**Table 4.** Neuromuscular variable, maximal muscle strength in the pre-exercise and after 60 minutes at the end of the exercises (aerobic and resistance).

| Variables | AEROBIC Mean ± SD | RESISTED Mean ± SD |
|---|---|---|
| **Maximal strength (Kg)** | | |
| pre-exercise | 78.8±11.9 | 79.1±14.9 |
| 60 min | 77.4±9.89 | 78.8±15.6 |

## DISCUSSION

The results obtained in the present study demonstrated the occurrence of PEH in normotensive men after aerobic and resisted exercise. MacDonald et al.[17] observed a decrease in SBP during 60 minutes, after performing 15 minutes of exercise on a cycle ergometer with $VO_2$max intensity of 65%, similarly, Jones et al.[18] also verified a decrease in the SBP after 30 minutes of exercise on a cycle ergometer with $VO_2$peak intensity of 70%, however, found no decrease in DBP after aerobic exercises. On the other hand, Fisher et al.[19] analyzing the PEH effect in resisted exercise (5 exercises, 3 sets, 15 repetitions at 50% 1RM), observed only a decrease in SBP and no decrease in DBP.

Some studies available in the literature have pointed out that BP can be reduced after a single exercise session[20,21], however, the SBP seems to be more sensitive to the modifications imposed by the exercise when the sample are composed of normotensive, as well as in the present study. In this way, many studies involving aerobic and resisted exercise[1,19,21-22] in normotensive patients, identified PEH only in SBP, with little change in DBP for the resisted exercise. However, in the Figueredo et al.[20] observed that after the resisted exercise of 70%1RM occurred PEH in the DBP, this fact was confirmed in the present study, in which the DBP response was altered in the resisted exercise and the magnitude of this response was greater than in the aerobic exercise.

In relation to HR, was observed a significant increase after the aerobic and the resisted exercise, which can be explained by the compensatory increase in cardiac output and HR post-exertion, leading to a possible cardiovascular adjustment to compensate for the decrease in peripheral vascular resistance in aerobic exercise[23].

However, some evidence shows a reduction in cardiac output after resisted exercise, followed by increased peripheral vascular resistance and HR [24]. These results suggest that HR increases to provide compensatory adjustments in the baroreflex system, since after exercise there is a decrease in BP and an increase in HR to compensate for this decrease in BP, in agreement with the results of Ruiz et al.[21] that verified an increase in the HR after aerobic and resisted exercise.

Even with similar results in post-exercise hypotensive response, aerobic and resisted activities should have differentiated mechanisms. In the present study, the differentiation in the vagal behavior between activities was verified through the analysis of the HRR60s, which showed greater amplitude in aerobic training. These data suggested that the HR recovery was accelerated after aerobic exercise, suggesting greater sympathetic discharge in the activities of the resisted exercises[21].

Regarding the neuromuscular analyzes, no significant changes were observed when comparing pre-exercise data with those obtained after 60 minutes at the end of the exercises (aerobic or resisted). The findings of the present study corroborate with those of McCaulley et al.[25], in which the authors did not observe changes in quadriceps muscle strength (MIVC) and IEMG (RF and VM muscles), after 60 min recovery after squatting exercises in relation to pre-exercise. On the other hand, Baretta[26] analyzing the 15 min effect of sit-up exercise, observed that 20 min of recovery was sufficient to re-establish the electromyography activity of the RF, MV and VL muscles, but observed a reduction in muscle strength (knee extension (MIVC)) pre-exercise. Similarly, Izquierdo et al.[27] analyzed 30 min of recovery, after leg-press exercise (5 series and 10 maximal repetitions (MR)) and observed a decrease in the muscular strength (knee extension (CVMI)), but the electromyographic behavior of the Fmed of the RF, VM and VL muscles remained the same in relation to pre-exercise.

Despite the interesting results of the aforementioned studies, the protocol used was different from the present study, since the authors observed the neuromuscular behavior of only one type of exercise, not in relation to a resisted or aerobic exercise session, another difference is in recovery time which was lower than in the present study. Thus, further studies would be required using an exercise session for comparison.

Some limitations were found and deserved comments, autonomic function tests that could be associated with the cardiovascular behavior after exertion were not performed. Another limitation was the reduced number of volunteers, which may have reduced the power of the statistical tests of the study.

With the findings of the present study, it can be suggested that both types, aerobic and resisted, can be used in the prescription of physical exercise for the prevention of the development of hypertension and/or maintenance of BP in normotensive men. Therefore, health and fitness professionals could adopt these training programs. However, further studies with hypertensive individuals would be important to evaluate the cardiovascular and neuromuscular responses in this population.

## CONCLUSION

Through the methodology used, it is concluded that both aerobic and resistive exercise promote PEH and increase of HR. However, both exercises did not promote alteration of musculoskeletal variables. Therefore, the initial hypotheses of the study were rejected.

### AUTHOR'S CONTRIBUTION

RJR: acquisition of data, statistical analysis and writing of the manuscript; PFP: acquisition and processing of data; EBP and EMC: acquisition of data; FFM: acquisition of data and revision of the manuscript; MAP: co-orientation and revision of the manuscript; DRB: study orientation and revision of the manuscript.

### CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

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