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Effects of the alternance between aerobic and resistance exercise in different concurrent exercise sessions on blood pressure responses of healthy adults: a controlled and randomized study

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Abstract

Aerobic exercise (AE) and resistance exercise (RE) have shown benefits in preventing and / or controlling blood pressure (BP), although the influences of these two models (concurrent exercise) in a single session of exercise on BP are still unknown to the individual. Therefore, the aim of the present study was to verify the effects of the alternating between AE and RE in different concurrent exercise sessions on BP responses. In order to do so, ten young male athletes (22.6 ± 3.78 years, 70.3 ± 5.89 kg, 175.96 ± 5.83 cm, 6.8 ± 2.38 % body fat) participated in the study. The tests consisted of four randomized protocols, the sessions consisted of AE followed by RE (AR), RE followed by AE (RA), circuit (CC) (ER and EA alternating intermittently) and control session (CO) (without exercise). AE was performed on a treadmill at 90% of indirect minimum lactate and RE was performed on a circuit at 90% of 12 RM, alternating muscle segments in six exercises. BP was measured in all protocols and post-exercise recovery period (PERP) every 15 minutes during one hour. Results showed a significant decrease in systolic blood pressure (SBP) at the 45th minute of recovery (R45) and one-hour mean values of the PERP in the RA protocol when compared to its value at rest. Diastolic and mean BP showed no significant differences. Thus, the RA session promoted a more accentuated decrease in SBP when compared to the other sessions.

Key Words: Blood pressure; Post-exercise hypotension; Concurrent exercise; Exercise prescription; Health.

Introduction

Epidemiological and clinical studies have shown the benefits of exercise to the cardiovascular system and total health[1-4]. This benefic cardiovascular effect is related to the decrease of blood pressure, after performing an exercise session, to values lower than when at rest. A phenomenon named post-exercise hypotension (PEH)[5-7], which can help to control and maintain blood pressure at normal levels[8-10].

It is known that sedentary behaviors, among other factors, are related to the development of hypertension. In Brazil, for instance, only 33.8% of the young adults are physically active, and approximately 24.1% of this population already present hypertension[11].

In this scenario, exercise appears as an alternative to the prevention and development of cardiovascular diseases, being considered a low cost, non-pharmacological intervention[12] which can be performed by individuals in every age group[13].

Several authors have reported the presence of PEH after one session of aerobic (AE) and resistance (RE) exercise[8-10]. However, there is more evidence of PEH after AE when compared to RE, since AE promotes a PEH of higher magnitude and duration[14]. Nonetheless, there is still little evidence on the effect of the combination of AE and RE on blood pressure, being this combination named concurrent exercise (CE)[14].

Recently, some authors have referred that CE promotes PEH[14-16]. However, there is a gap in literature when it comes to providing information about which order of execution would result in a more accentuated decrease in blood pressure. Such findings would be of extreme importance to health professionals who prescribe exercise to hypertensive individuals. Therefore, the aim of the present study was to verify if the post-exercise blood pressure response depends on the order of exercise execution.

Method

Sample

Ten male young adults (22.6 ± 3.78 years; 70.3 ± 5.89 kg; 175.96 ± 5.83 cm; 6.8 ± 2.38 %body fat), jiu-jitsu athletes with regional and Pan-American results, who trained at least three times per week, participated in the study. The study was approved by the Ethics Committee of the Catholic University of Brasília (protocol n. 126/2010).

General procedures

Before the experimental sessions all volunteers were submitted to an electrocardiogram and measurement of blood pressure in order to verify if they were able to participate in the study. The exams were performed by a cardiologist at the Physical Evaluation and Training Laboratory of the Catholic University of Brasília.

The exclusion criteria adopted were: any cardiovascular impairment that would compromise performing the experimental sessions; any kind of bone or muscle injury; and presence of hypertension (systolic blood pressure at rest higher than 140 mmHg and diastolic blood pressure at rest higher than 90 mmHg), heart disease or other cardiovascular commitment.

After medical clearance, each volunteer visited the laboratory seven times, in alternated days with at least 48 hours of interval, in order to perform the tests and experimental sessions.

Visits

Each subject performed a total of seven trials, on separate days, at the Physiology and Strength Exercise Laboratory, as follows: 1st Visit - anthropometric measurements[17] and familiarization on resistance exercise equipment and with the 12 repetition maximum test (RMs); 2nd visit - aerobic fitness evaluation; 3rd visit - 12 RMs test, 4th, 5th, 6th and 7th visits - experimental sessions performing AE and RE in different orders in the same session. Volunteers were instructed to refrain from PE, and not to change their daily diet 24 h before the experimental sessions.

Minimum lactate prediction tests and maximum oxygen uptake

In these tests the volunteers ran a distance of 1600 m, in the lowest time possible, in a 400 m athletics track. The mean velocity in the 1600 m (mV1600) obtained in the test was applied in the predictive equation of VO_{2max} (VO_{2max}(mL.kg^{-1}.min^{-1}) = [0,177 * Vm1.600(m.min^{-1})] + 8,101) and minimum lactate [LAC= (0.7507 * 1600mV) + 21.575], proposed by Almeida et al.[18] and, Sotero et al.[19] respectively. The results of these tests were used to indirectly determine the intensity of the aerobic exercise.

Blood pressure monitoring

Blood pressure was measured with a digital oscillometric device (Microlife BP3A1C) before, during and after the experimental sessions. Initially, the volunteers remained seated at rest for 15 min. Blood pressure measurements were performed at the 5th, 10th and 15th min of rest, being the mean value considered as the resting blood pressure value. Values of blood pressure and heart rate were measured at the end of each type of exercise (AE and RE). Immediately after the experimental sessions blood pressure measurements were performed every 15 min during a 60 min period of post-exercise recovery. All experimental sessions followed the same protocol for blood pressure measurements.

Rate of perceived exertion

Two distinct scales were used to measure this variable. The first, for AE, used the Borg Scale with values ranging from 6 to 20[20]. For RE, the OMNI-RES scale with a 0 to 10 range of values was utilized[21-22].

12 RM familiarization and test

Before the 12 RM test, the volunteers underwent a familiarization session with all equipments used in the study. After an interval of 48 hours the volunteers were submitted to the 12 RM test in the following equipments: leg extensor, seated bench press, leg press, lat pull-down, leg curl and seated row, using the minimum weight available. Each volunteer had four attempts to reach the maximum load for each exercise with 3 to 5 min of rest between each attempt.

Experimental sessions

All volunteers performed four experimental sessions in a randomized order with an minimum interval of at least two days between experimental sessions, in a room with a controlled temperature between 20-24 ºC and at the same time of day (between 3:00 pm and 4:45 pm), as follows:

- Aerobic + Resistance session (AR): AE was performed before RE.
- Resistance + Aerobic session (RA): RE was performed before AE.
- Circuit training session (CT): AE and RE were performed alternatively during the full session, beginning with AE. This session consisted of 5 laps. Each AE lasted 3 min, and RE in the 1st and 3rd laps consisted of two sets of two exercises; the 2nd llap consisted of 1 set of 4 exercises, and the 5th lap consisted of one set of two exercises. This exercise session presented the same work load as the other sessions, but with exercises performed in different orders.
- Control session (CO): This session had the same duration as the others, but instead of exercise, the participants remained at rest in a sitting position.

Resistance exercise at 90% of 12 RM

Resistance exercise was performed alternating upper and lower limb exercises at an intensity of 90% of 12 RM. In total, three sets of each exercise were performed in a circuit training method, therefore, each lap of the circuit was equivalent to performing one set in the six previously cited exercises. Each repetition lasted for approximately 2 s (concentric and eccentric phase). The total duration of resistance exercise was 14 min and 24 s.

Aerobic exercise

Aerobic exercise was performed in a treadmill (Movement®) at a constant intensity of 90% of the indirect minimum lactate for 15 minutes

Statistical analysis

Values are presented as mean ± standard deviation. Rate of perceived exertion, heart rate, velocity (aerobic), repetitions (resistance) and blood pressure values during the post-exercise recovery period were analyzed through a repeated measure ANOVA (4 sessions x 5 recovery moments) with Bonferroni as "post hoc". The level of significance adopted was $p \leq 0.05$ and the software used was the Statistical Package for the Social Sciences (SPSS) v. 20.0.

Results

The main characteristics of the volunteers, the indirect values of VO_{2max} and minimum lactate, which were used to determine the intensity of the aerobic exercise, are show in TABLE 1.

The values referring to the intensity of the experimental protocols, such as: heart rate, rate of perceive exertion, running speed in AE, number of repetitions in RE and blood pressure values during and immediately after exercise are exhibited in TABLE 2. In this scenario, significantly higher values of rate of perceived exertion were found during the AE in the RA session when compared to the AR and CT sessions. On the other hand, the rate of perceived exertion during the RE of the RA session was significantly lower than in the AR session.

Regarding the blood pressure values measured during and immediately after the exercises, systolic blood pressure increased significantly after finishing the first exercise in all sessions (AR, RA and CT) when compared to the control session. Diastolic blood pressure showed an increase, when compared to the control session, only after finishing the first exercise in the AR session. Mean blood pressure increased significantly at the end of the first exercise in AR and RA when compared to the control session. In addition, after finishing the second exercise of the AR session, the mean blood pressure showed to be significantly lower than when measured immediately after finishing the first exercise.

Blood pressure values before exercise and during the post-exercise recovery period are shown in TABLE 3. In the 45th min of recovery in the AR and RA sessions, the systolic blood pressure values were significantly lower when compared to their values at rest. The 1-hour mean values of systolic blood pressure also reduced when compared to rest in AR ($p < 0.01$), RA ($p < 0.02$) and CT ($p < 0.02$), demonstrating the occurrence of PEH.

TABLE 1 - Sample's main characteristics.

Variables	Mean ± SD
Age	22.60 ± 3.78
Body mass (kg)	70.30 ± 5.89
Stature (cm)	175.00 ± 5.83
Body mass index (kg/m²)	22.64 ±1.37
Body fat percentage	6.80 ± 2.38
Indirect VO_{2max}	50.23 ± 4.35
Indirect minimum lactate	12.30 ± 1.48

VO_{2max}: indirect maximum oxygen uptake.
Values expressed in mean ± standard deviation (SD).

TABLE 2 - Intensities during exercises and blood pressure values.

Protocols		AR	RA	CT	CO
Aerobic exercise	RPE	11.1 ± 2.00**	14.26 ± 2.66	11.12 ± 1.63**	-----------
	HR (bpm)	171.37 ± 10.00	179.18 ± 8.77	175.84 ± 8.86	-----------
	Speed	11.59 ± 1.38	11.05 ± 1.51	11.45 ± 1.42	-----------
Resistance exercise	RPE	7.37 ± 1.29	6.40 ± 1.39*	5.10 ± 1.85	-----------
	Repetitions	11.59 ± 0.65	11.92 ± 0.24	12.00 ± 0.00	-----------
Systolic blood pressure	After Ex1	153.0 ± 21.1#	154.8 ± 13.2ω	145.9 ± 11.5ω	118.9 ± 7.1
	After Ex2	128.0 ± 12.8	144.1 ± 25.8	138.0 ± 19.6	116.6 ± 8.2
Diastolic blood pressure	After Ex1	80.3 ± 13.0	83.7 ± 11.0	77.3 ± 16.8	70.6 ± 13.1
	After Ex2	74.9 ± 9.7	74.7 ± 18.0	77.9 ± 14.2	67.3 ± 8.3
Mean blood pressure	After Ex1	104.7 ± 7.7ω	101.8 ± 20.0ω	100.1 ± 12.0	86.7 ± 9.2
	After Ex2	92.8 ± 9.65α	92.9 ± 24.0	98.0 ± 12.0	83.7 ± 7.0

RPE: rate of perceived exertion;
HR: heart rate;
After Ex1: immediately after finishing the first exercise of the session;
After Ex2: immediately after finishing the second exercise of the session;
AR: aerobic-resistance exercise session;
RA: resistance-aerobic exercise session;
CT: circuit training session;
CO: control session;
*$p < 0.05$ to AR;
**$p < 0.01$ to RA;
#$p < 0.05$ to CO;
ω: $p < 0.01$ to CO;
α: $p < 0.05$ to After Ex1 in the same session.

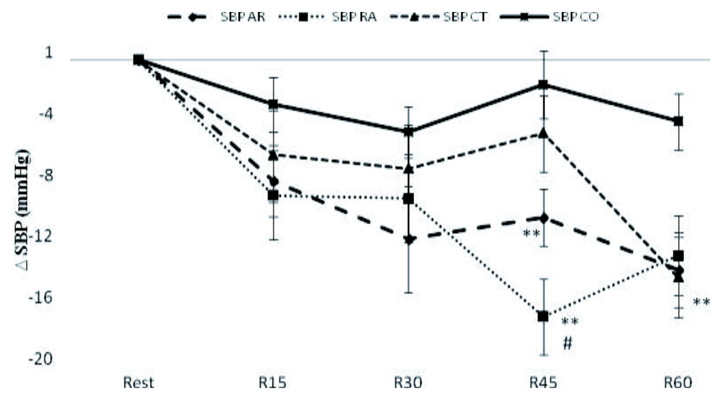
TABLE 3 - Blood pressure values before and during the post-exercise recovery period.

	Protocols	Rest	R15	R30	R45	R60	1h Mean
Systolic blood pressure	AR	122.0 ± 4.0	113.7 ± 7.9	109.9 ± 10.0	111.3 ± 6.2*	107.9 ± 8.5	111.0 ± 6.0**
	RA	122.0 ± 4.1	113.4 ± 11.0	113.2 ± 10.2	105.5 ± 9.4*	109.5 ± 9.8	110.0 ± 9.0**
	CT	119.0 ± 5.4	113.0 ± 10.4	112.1 ± 6.45	114.4 ± 12.0	105.0 ± 7.0	111.0 ± 7.0**
	CO	117.0 ± 4.7	114.3 ± 8.2	112.5 ± 7.5	115.6 ± 9.6	113.2 ± 5.0	114.0 ± 7.0
Diastolic blood pressure	AR	68.85 ± 7.7	69.1 ± 7.8	67.7 ± 5.0	65.2 ± 4.8	64.0 ± 8.5	66.5 ± 4.1
	RA	69.5 ± 4.3	68.8 ± 9.5	66.1 ± 10.3	70.1 ± 9.1	67.4 ± 7.1	68.1 ± 8.3
	CT	68.0 ± 5.3	61.6 ± 8.0	63.9 ± 10.0	65.6 ± 10.0	62.8 ± 13.0	63.4 ± 9.4
	CO	67.9 ± 8.0	70.1 ± 10.9	68.4 ± 7.7	64.9 ± 7.6	69.7 ± 8.7	68.3 ± 7.6
Mean blood pressure	AR	85.7 ± 7.5	83.9 ± 6.4	81.7 ± 5.5	80.2 ± 6.2	78.6 ± 7.2	81.1 ± 4.7
	RA	86.3 ± 5.5	83.6 ± 9.6	81.8 ± 9.5	81.9 ± 8.2	81.4 ± 6.8	82.2 ± 8.0
	CT	84.3 ± 5.1	78.7 ± 7.4	79.8 ± 7.9	81.8 ± 9.3	77.2 ± 11.5	79.4 ± 8.0
	CO	83.3 ± 8.4	84.8 ± 8.8	83.1 ± 6.9	81.8 ± 7.4	84.2 ± 6.7	83.5 ± 6.6

AR: aerobic-resistance exercise session;
RA: resistance-aerobic exercise session;
CT: circuit training session;
CO: control session;
*$p < 0.05$ to rest in the same session;
**$p < 0.02$ to rest in the same session.

FIGURE 1 shows the variations of systolic blood pressure between rest and the post-exercise recovery periods in all experimental sessions. PEH was observed at the 45th min of recovery in AR and RA ($p < 0.001$), and at the 60th min in CT ($p < 0.009$) and a tendency to PEH in AR ($p < 0.062$). In the comparison between sessions, RA presented a significantly lower systolic blood pressure at the 45th min of recovery when compared to CT ($p < 0.006$) and to the control session ($p < 0.008$).

FIGURES 2 and 3 show the variations of diastolic blood pressure and mean blood pressure between rest and the post-exercise recovery periods. No significant differences were found between the distinct moments and sessions.



**p < 0.05 to rest in the same session;
#p < 0.05 to the same moment in CO and CT.

FIGURE 1 - Variations of systolic blood pressure (SBP) between rest and the post-exercise recovery periods.

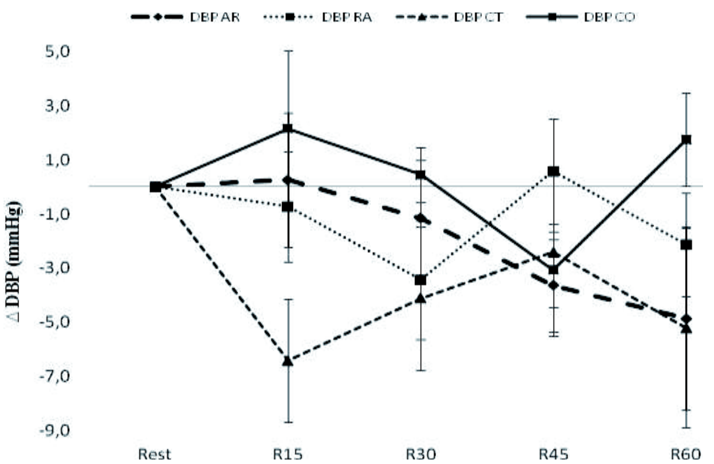


FIGURE 2 - Variations of diastolic blood pressure (DBP) between rest and the post-exercise recovery periods.

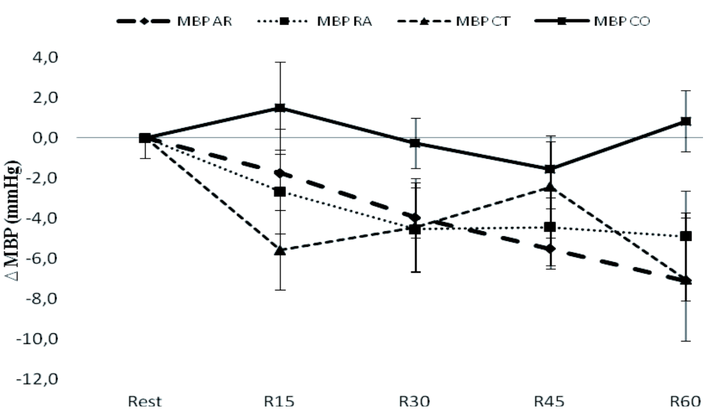


FIGURE 3 - Variations of mean blood pressure (MBP) between rest and the post-exercise recovery periods.

Discussion

The mais purpose of the present study was to verify if there was an order of exercise execution that would promote a higher PEH. In this scenario, the results suggested that the RA session promoted a more accentuated decrease in blood pressure when compared to the other protocols.

Regarding the systolic blood pressure values, it is possible to observe that both the AR and RA sessions were effective in promoting PEH. However, when analyzing the 1-hour mean values, all exercise protocols significantly decreased the systolic blood pressure when compared to their values at rest. Nonetheless, only the RA session promoted a significant reduction of systolic blood pressure variation when compared to the control session (at the 45th min of the post-exercise recovery period).

No significant decreases were found in diastolic blood pressure when compared to values at rest in the distinct sessions. However, reductions of 5.0 mmHg (AR and CT) and 2 mmHg (RA) were observed in the 60th min of the post-exercise recovery period, while there was an increase of 2 mmHg in the control session. These are important results, since the literature states that decreases of 2 mmHg in systolic or diastolic blood pressure are able to reduce the incidence of stroke and heart disease in the general population[23].

Other authors have reported PEH in concurrent exercise when AE is performed before RE. Ruiz et al.[16] observed PEH in normotensive individuals from the 15th to the 60th min of post-exercise recovery period. However, no significant decreases were found in diastolic blood pressure. This partially agrees with the findings of the present study, where PEH was only found at the 45th min and 1-hour mean values of recovery in the AR session.

Shaw et al.[11] studied the chronic effects of concurrent exercise and AE on the risk factors associated with developing heart disease and observed that concurrent exercise was as efficient as aerobic exercise in promoting a decrease on these risk factors.

The literature also refers to PEH in concurrent exercise when RE is performed before AE. Keese et al.[14] observed PEH in young adults with decreases in systolic blood pressure for until two hours of post-exercise recovery and reductions in diastolic blood pressure for 50 min after concluding the exercise session.

In another study Keese et al.[15] found PEH in three different concurrent exercise sessions (RE before AE), with different AE intensities (50%, 65% and 80% of VO_{2peak}), and found a significant decrease in systolic blood pressure in all three sessions. However, the authors stated that the more intense the session was performed, the longer was the PEH effect. The present study also found PEH, nonetheless, this effect was only observed at the 45th min of post-exercise recovery after the RA session, and in the 1-hour mean values ($p < 0.02$).

Santiago et al.[24] found results that differed from the ones shown in the present study. They performed two different models of CE in 15 young adults (men and women), being: 1) AE (80% of heart rate reserve) followed by RE (3 sets of 8 repetitions at 75% of 1RM); and 2) RE followed by AE using the same intensities. The authors reported PEH of SBP in AE + RE at the 30th and 60th min of post-exercise recovery, and in RE + AE only at the 60th min of post-exercise recovery. When comparing both models, AE + RE showed significantly lower values of SBP and DBP at the 15th, 45th and 60th min after exercise.

The mechanisms surrounding PEH in concurrent exercise sessions are still unknown, and the gap increases when it comes to studying different orders of exercise execution. Nevertheless, some inferences can be made about the topic. According to Teixeira et al.[25], the decreases in blood pressure after exercise have been attributed to a decrease in stroke volume, leading to a reduction in cardiac output that was not compensated by an increase in systemic vascular resistance.

In addition, Halliwill et al.[26] stated that PEH is mediated by the inhibition of the neuroreceiver Neurokinin-1 (NK-1) which acts in the regulation of sympathetic activity, in the activation of histamine and in the H1 and H2 receptors, which are associated with a higher expression and maintenance of endothelial vasodilatation. The activation of histamine is mediated by the masts, therefore evidencing that the release of histamine is associated with blood flow and with the muscle mass involved in exercise.

It is also said that performing RE before AE can result in an increase of the post-load in the left ventricle[27-28], resulting in an abrupt increase of blood flow and, therefore, in a higher shear stress of the endothelium[11, 29]. This could induce in a bigger dilation of the vessels, since several muscle groups are being used in exercise. In addition, performing AE secondly would promote the maintenance of the blood flow (due to the constant cardiac output), reduce peripheral vascular resistance (especially in the lower limbs), reestablish vascular caliber and reduce the relative flow to the upper limbs[30].

The findings from the present study do not allow the formulation of mechanisms of hypotension to explain our results. However, several studies have reported PEH after a single exercise session and, to our knowledge, this is the first research to approach concurrent exercise as made in the present study. Nevertheless, some limitations can be highlighted, such as: the low number of volunteers and the fact that they are athletes. Still, the fact that the individuals have the same training routine and frequency reduces the chances of drastic variations in the experimental sessions' results.

In conclusion, the results from the present study suggest that concurrent exercise sessions are able to promote PEH and that performing RE before AE seems to enhance this effect. New studies are always welcome in order to elucidate the mechanisms that encompass PEH, especially in hypertensive individuals, since a PEH of higher magnitude is found in this population[6, 31].

Resumo

Efeitos da alternância entre exercícios aeróbicos e resistência exercício em diferentes sessões de exercício concorrente em respostas pressão arterial de atletas: um estudo randomizado

O exercício aeróbico (AE) e exercícios resistidos (ER) têm demonstrado benefícios na prevenção e/ou controle da pressão arterial (PA), embora as influências destes dois modelos de exercícios (exercício concorrente) em uma única sessão sobre a PA ainda são desconhecidos. Desta forma, o objetivo do presente estudo foi verificar os efeitos da alternância entre EA e ER em diferentes sessões de exercícios concorrente sobre as respostas da PA. Participaram do estudo 10 jovens atletas do sexo masculino (22,6 ± 3,78 anos, 70,3 ± 5,89 kg, 175,96 ± 5,83 centímetros, 6,8 ± 2,38 % de gordura corporal). Os testes consistiram de quatro protocolos randomizados, sendo a sessão AR composta por EA seguido do ER, a sessão RA por ER seguido do EA (AR), a sessão circuito (CC) (ER e EA alternando de forma intermitente) e a sessão de controle (CO) (sem exercício) . EA foi realizado em uma esteira a 90% do lactato mínimo indireto e o ER foi realizado em forma de circuito a 90% de 12 RM, alternado por segmento em seis exercícios. A PA foi mensurada em todos os protocolos, durante o momento repouso e no período de recuperação pós-exercício (REP). Observou-se uma redução da pressão arterial sistólica (PAS) aos 45 e 60 minutos de recuperação do protocolo RA em relação aos valores pré-exercício. A PA diastólica e média não apresentaram diferenças significativas. A sessão RA foi mais eficaz em demonstrar respostas hipotensoras em relação aos outros protocolos experimentais.

Palavras-chave: Pressão arterial; Hipotensão pós-exercício; Exercício simultâneo; Prescrição de exercícios; Saúde.

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