Effects of Different Rest Intervals between Circuit Resistance Exercises on Post-exercise Blood Pressure Responses in Normotensive Young Males

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Abstract

Purpose: **To investigate the blood pressure responses during recovery after two protocols of circuit resistance exercises (CRE) with different rest intervals (RI).**

Methods: **Eleven normotensive males (aged 19.5 ± 1.0 yrs, height 172.8 ± 5.7 cm and weight 65.1 ± 8.1 kg) performed two CRE with RI of 30 (RI30s) and 40 (RI40s) seconds between the exercises randomly, as well as a control session without exercise. The protocols consisted of 3 circuits of 6 exercises with 10 repetitions maximum (10RM) and 2 minute rest between circuits, followed by an 80 minute recovery period. Measurements were taken before exercise and at each 10 min of post-exercise recovery. The Analysis of Variance (ANOVA) with Repeated Measures (group × time) was used to analyze data, followed by post-hoc Bonferroni test, for $P \leq 0.05$.**

Results: **Post-exercise hypotension of systolic blood pressure was observed after both CRE with RI30s and RI40s (at R40, R50, R60, R70 and R80), whereas diastolic blood pressure did not differ from that measured at rest. In all measured moments, there was no significant difference between exercise trials in post-exercise levels of systolic and diastolic blood pressure.**

Conclusion: **CRE with RI30s and RI40s between the exercises can lead to occurrence of PEH similarly in magnitude and duration. Our findings suggest a potentially positive health benefit of strength training.**

Key Words: Post-exercise Hypotension; Resistance Exercise; Systolic Blood Pressure; Diastolic Blood Pressure

INTRODUCTION

Physical exercise is a relevant non-pharmacologic option for the prevention and treatment of blood pressure (BP) disorders. Scientific evidence in the literature have demonstrated that after an acute exercise bout, BP levels are reduced for minutes or hours in relation to pre-exercise levels [1-3]. This phenomenon is called post-exercise hypotension (PEH) and considered as an important strategy in the control and reduction of BP [1,3,4]. The mechanisms responsible for PEH remain unclear. This phenomenon may occur due to a reduction of sympathetic nervous activity, cardiac output and peripheral vascular resistance, apart from changes in the release of vasoactive substances [2,4]. PEH has been demonstrated after aerobic exercise [4] However, whether or not resistance exercise results in a post-exercise hypotensive response is relatively unknown. Only a few studies have investigated the BP responses following resistance exercise, and these have shown increase [5], maintenance [6-8], and even decrease [9-12] in post-exercise BP. Although occurrence of PEH in resistance exercises is demonstrated by some studies, however there is still no consensus on an ideal protocol to enhance this effect [1,13]. According to results of some studies, resistance exercise intensity affects the duration (longer PEH in the protocol with the highest intensity), but not the magnitude of PEH [14,

[15], and different training methodologies (set repetition vs. circuit format) does not affect the magnitude or duration of the post-resistance exercise hypotensive response [15]. In addition to exercise intensity, volume and sequence that were previously studied, other variables such as the amount of muscular mass involved, number of repetitions, type of training and rest interval (RI) between the exercise sets can affect the hemodynamic responses to a bout of resistance exercises [16,17]. However, RI is considered as one of the main variables of resistance exercises [18,19], there are few studies in the literature regarding investigation and comparison of the effects of different RI on the BP responses to resistance exercises. Also, to our knowledge, there has been no study to date which has investigated the comparison of the effects of different RI between circuit training exercises on post-exercise BP. RI length influences the removal of metabolites produced during muscle contraction [18]. The use of a shorter RI may lead to increased accumulation of metabolites and ions with vasodilator effects (e.g. nitric oxide, prostaglandins, adenosine, hydrogen and potassium); and this can influence the reduction in peripheral vascular resistance [2]. Therefore, one might hypothesize that if PEH is mediated by some peripheral factors, resistance exercise with lower RI would be expected to result in a greater decline in BP.

Thus, the objective of the present study was to investigate and compare the effects of different RI

between circuit training exercises (30s and 40s; the ratio of exercise to rest was approximately 1 to 1.5 and 1 to 2, respectively) on post-exercise BP responses in non-hypertensive young males.

METHODS AND SUBJECTS

Subjects:

Eleven healthy sedentary males volunteered to participate in this study. All of the participants were non-smokers, had no history of cardiovascular disease in themselves and their families, were not taking any medication and engaged in regular physical activity < 2 h per week. Subjects who presented a body mass index $\geq$ 24 kg/m^2 and fat mass > 20% were excluded. Complete advice about possible risks and discomfort was given to the participants, and all of them gave their written informed consent to participate. Their physical and cardiovascular characteristics are shown in table 1. All procedures were in accordance with the declaration of Helsinki and the study was approved by the faculty ethics committee in the University of Guilan.

Procedures:

Before initiating the tests, the participants underwent an anamnesis, a clinical evaluation and BP, body fat

Table 1: Physical and cardiovascular characteristics of the participants

Participants characteristics	Mean (SD)
Age (y)	19.5 (1.0)
Weight (kg)	65.1 (8.1)
Height (cm)	172.8 (5.7)
Body mass index (kg/m^2)	21.8 (2.1)
Body Fat (%)	13.7 (2.5)
Systolic blood pressure (mmHg)	113.5 (5.6)
Diastolic blood pressure (mmHg)	77.1 (4.7)
10 RM leg press (kg)	110.9 (29.2)
10 RM lat pull dawn (kg)	47.3 (6.5)
10 RM knee flexion (kg)	38.2 (7.8)
10 RM bench press (kg)	54.1 (9.7)
10 RM knee extension (kg)	32.7 (4.1)
10 RM cable biceps curl (kg)	27.2 (6.8)

SD: Standard Deviation

mass, body mass index, weight and height measurements. Then all of them underwent familiarization session and participated in 10RM test. Afterwards, participants carried out three experimental sessions with a minimum of 72 h intervals: (1) circuit resistance exercises (CRE) with 30s RI between exercises (RI30), (2) CRE with 40s RI between exercises (RI40) and (3) a control session (CON). The RI30 and RI40 sessions were performed in a randomized order. Pre and post-exercise values of BP were measured and analyzed.

The participants were instructed not to ingest alcoholic or caffeinated drinks, not to perform strenuous physical activity in the previous 48 h and to have their last meal 2 h before the beginning of the experimental sessions, which occurred at 2:00-4:00 PM to control diurnal variation in BP. The laboratory had a mean temperature of $21^{\circ C}$ and mean relative air humidity of 41%.

Blood pressure measurements:

After a 5-min rest in the seated position, BP was measured three times during two different visits to the laboratory. On the occasion of each visit, BP was measured by the same experienced observer using a standard mercury sphygmomanometer (ALPK2, Japan), taking the first and the fifth phases of Korotkoff sounds as SBP and DBP values, respectively. Participants were excluded if the average of the last two values obtained during each visit for SBP and DBP was greater than 139 and 89 mmHg, respectively.

10RM test:

at least 7 days prior to the experiments, participants performed a maximal 10 repetitions test (10RM) in the leg press, lat pull-down, knee flexion, bench press, knee extension, and biceps curl after 15 min warm-up consisted of 5 minutes of slow running, 5 minutes of static stretching and 5 minutes of dynamic exercise. Each individual was given up to five tries, in order to determine the load, with a five minute interval between them. Also, before the 10RM tests, participants underwent a familiarization session and became familiar with Standard exercise techniques.

Exercise protocols:

Initially, the volunteers remained seated in a comfortable chair for 20 min, with BP being measured each 5 min from the 10th min to obtain average resting values. The experimental session was postponed to another day, if the pre-exercise BP of volunteers was abnormal (SBP>139, DBP>89). Then, the subjects who were randomly selected for one of the two protocols underwent 15 min warm-up consisting of 5 minutes of slow running, 5 minutes of static stretching, and 5 minutes of dynamic exercise and performed CRE with 30s (The ratio of exercise to rest ~ 1 to 1.5) or 40s (The ratio of exercise to rest ~ 1 to 2) active and passive RI between each exercise in which time the participant moved between each station and then began the next exercise. In each session the circuit of resistance exercises was performed in the following sequence: leg press, lat pull-down, knee flexion, bench press, knee extension, and biceps curl. The subjects performed 3 circuits of 10 repetitions (1 complete movement in ~ 2s) with 2 min passive rest in the sitting position after each complete circuit. After exercise trials, participants rested in the sitting position for 80 min, with BP being measured at each 10 min of post-exercise recovery (R10, R20, R30, R40, R50, R60, R70, and R80). BP was recorded by the same observer in all exercise trials, using a standard mercury sphygmomanometer.

Control session:

To determine any potential diurnal variations in blood pressure, all of the participants performed a non-exercise control trial three days after the exercise trials. During this trial, the participants were submitted to the same experimental protocol used in the exercise trials, they rested in the seated position for 80 min.

Statistical analysis:

All data were expressed as mean ± SD and were analyzed using SPSS software (v. 16.0). The Analysis of Variance (ANOVA) with repeated measures (group × time) was used to analyze data and when the difference presented was significant, the Bonferroni pos-hoc test was used for multiple comparisons, with a value of $p \leq 0.05$.

Table 2: Changes in systolic blood pressure and diastolic blood pressure during recovery after circuit resistance exercises with different rest intervals (n=12)

Period	Systolic Blood Pressure (mmHg)			Diastolic Blood Pressure (mmHg)		
	Control	Rest Interval of 30 Seconds	Rest Interval of 40 Seconds	Control	Rest Interval of 30 Seconds	Rest Interval of 40 Seconds
At rest	113.0 (2.5)	113.8 (8.4)	113.6 (4.82)	77.5 (3.8)	76.4 (2.2)	77.5 (7.1)
R10	111.1 (4.5)	111.4 (5.3)	112.8 (4.75)	77.8 (3.3)	78.1 (2.2)	78.4 (5.1)
R20	111.5 (2.9)	110.2 (10.1)	112.3 (7.95)	78.7 (3.5)	78.6 (3.7)	78.0 (5.5)
R30	112.5 (1.8)	107.6 (8.5)	109.7 (7.32)	77.6 (4.1)	76.0 (5.1)	75.9 (4.9)
R40	112.5 (1.9)	103.6 (۷٫۱)†*	108.4 (٦٫۳٦)*	76.8 (4.8)	75.5 (5.1)	76.0 (4.6)
R50	111.7 (2.1)	106.4 (۹٫٥)*	105.9 (٥٫٤۹)*	74.6 (3.9)	75.6 (4.4)	76.4 (4.9)
R60	112.3 (1.7)	104.8 (٤٫۸)†*	104.8 (٤٫۸)†*	75.0 (3.5)	74.7 (5.3)	76.6 (6.1)
R70	111.6 (1.7)	106.2 (٦٫۱)†*	106.2 (٦٫۱)†*	75.0 (3.4)	74.9 (4.8)	75.9 (6.0)
R80	111.5 (1.5)	107.1 (٥٫٥) *	104.8 (٦٫٤)†*	75.6 (2.7)	76.2 (4.6)	76.5 (5.5)

R10 to R80 - period after the protocol up to 80 minutes
*Significant difference in comparison to rest ($P \leq 0.05$) / † Significant difference in comparison to the control ($P \leq 0.05$)

RESULTS

BP responses during the different experimental sessions are shown in table 2. Regarding SBP measurements compared to rest values, there were significant decreases at R40 ($P=0.005$, $P=0.03$), R50 ($P=0.02$, $P=0.005$), R60 ($P=0.005$, $P=0.002$), R70 ($P=0.029$, $P=0.001$) and R80 ($P=0.031$, $P=0.001$) for both RI30s and RI40s. Whereas when compared with the CON session, observed significant differences at R40 ($P=0.004$), R60 ($P=0.002$) and R70 ($P=0.02$) for RI30s and at R60 ($P=0.003$), R70 ($P=0.01$) and R80 ($P=0.01$) for RI40s.

DBP did not differ from that measured at rest after CRE with RI30s and RI40s. Also, in all measured time, there was no significant difference between RI30s or RI40s and CON session.

In all measured time, no significant differences were observed between CRE with RI30s and RI40s in pre and post-exercise level of SBP and DBP. Also these variables did not significantly change during CON session.

DISCUSSION

The aim of the present study was to investigate and compare the SBP and DBP during recovery after a single bout of CRE with different RI between them (30s and 40s; the ratio of exercise to rest was approximately 1 to 1.5 and 1 to 2, respectively). Our results have shown that, both CRE with RI30s and RI40s were effective in promoting reductions in post-exercise blood pressure. The main finding was that CRE with RI30s and RI40s elicited PEH of SBP and no change of DBP in young healthy males, so that, there was no significant difference between CRE with RI30s and RI40s in post-exercise blood pressure responses. The absence of BP changes during the non-exercise control trial shows that, in fact, the decreased SBP levels after exercise are due to the exercise effect and not to the normal diurnal variations.

Based on previous studies, the data about PEH and resistance exercise is still scarce and controversial results have been reported. Increase [5], maintenance [6-8] or even decrease [9-12] in post-resistance exercise BP has been observed. The present study found a significant PEH of SBP compared to pre-exercise measurements in the protocols tested. The reductions in blood pressure levels after a single exercise session is in agreement with the results obtained by other studies that observed PEH after resistance exercises [9,10,15,20]. In a study conducted by de Salles et al [20], volunteers performed 3 sets of 10 repetitions per exercise at 70% 10RM, with 1 or 2 minutes RI between sets and observed PEH of SBP after both 1 and 2 minute sessions. Simão et al [15] compared the effect of intensity, volume and session format on post-resistance exercise hypotensive response and observed significant reduction of SBP after the protocols. mohebbi et al [9]

and Rezk et al [10] also reported significant reduction of SBP after two resistance exercise sessions with different intensities in normotensive young individuals. Mota et al [11] observed PEH of SBP after circuit model for resistance exercise composed of 13 resistance exercises that were performed with 20 repetitions at 40% 1RM and 30 seconds rest interval between exercises. In contrast to the results of the present study, Veloso et al [7] observed no change in SBP after three resistance exercise protocols with RI of 1, 2 and 3 minutes between the sets, that consisted of three sets of eight repetitions in six exercises. The loads used in the 1st, 2nd, and 3rd exercise sets were 80%, 70% and 60% 1RM, respectively. Simões et al [8] did not find significant differences between post-exercise measurements and rest measurements of SBP in type-2 diabetic and nondiabetic subjects after performance of a resistance exercise session at 23% of 1RM. Rodriguez et al [21] observed no significant variance in the SBP after both of traditional multiple set and tri-set methods that six upper limb exercises were used for two distinct muscular groups (chest and back). Also Polito et al [22] failed to induce a hypotensive response in SBP following three series of 12 maximal repetitions of knee extension unilaterally and bilaterally.

The differences between the results found in the present study and those reported by Veloso et al [7] and Simões et al [8] may be attributed to the differences in the protocols used as well as differences between subjects. Veloso used a protocol in which the load decreased at each set, with the purpose of maintaining the same work volume (load × repetitions) in all protocols. On the other hand, the differences between the results found in the present study and those reported by Rodriguez et al [21] and Polito et al [22] may be related to the amount of muscle mass involved in exercise. In the present study that performed 3 circuit of 6 exercises for upper and lower limbs, exercising muscle mass were more than Rodriguez et al [20] and Polito et al [22] studies that used lower and upper limb exercises, respectively. One of the physiological mechanisms that could explain the influence of muscle mass on blood pressure after resistance exercise is the reduction in vascular resistance, caused by the liberation of vasodilating endothelial substances (e.g. nitric oxide and prostaglandins).

Regarding DBP, compared to pre-exercise values there was no significant PEH of DBP observed in all measured moments during recovery period of exercise trials.

In the Simão et al [15] study, significant post-exercise decrease in DBP was also observed 10 minutes after completion of a protocol of 12 repetitions with a load of 50% of 6RM. Rezk et al [10] also found significant post-exercise decrease in DBP; however, the duration of PEH was longer (30 minutes) than that found by Simão et al [15]. In contrast, Rodriguez et al [21] and Polito et al [22] did not observe significant variation in the DBP after resistance exercise. Also, Veloso et al [7] observed no changes in DBP after resistance exercise with 2 min RI between resistance exercise sets but, significant reduction in DBP occurred after 1 and 3 min RI. De Salles et al [20] reported no changes of DBP after resistance exercise with 2 min RI between sets but observed significant reductions after a 1 min RI session.

Similar to the results of the present study, mohebbi et al [9], Polito et al [23] and MacDonald et al [24] observed significant PEH of SBP and no changes of DBP following resistance exercise. One of the possible explanations for SBP's higher sensitivity to PEH would be the posture subjects adopt after the exercise. Although all mentioned studies have chosen the seated position to assess arterial pressure, it was observed that the post-exercise SBP declines more deeply in the seated position rather in the supine position due to decrease in venous return and cardiac output [25,26]. Resistance protocols typically differ among studies, and these differences may likely be responsible for some of the variations seen in the results. The resulting differences in the degree of metabolic stress produced by differences in exercise intensity, number of sets, rest intervals and stations of resistance exercise may be enough to affect recovery blood pressure.

Possible mechanisms involved in mediating post-exercise reductions in arterial blood pressure include decreased stroke volume and cardiac output; reductions in limb vascular resistance, total peripheral resistance and muscle sympathetic nerve discharge [2]. Rezk et al [10] assessed some mechanisms of BP control after a resistance exercise session and observed decrease in the systolic volume and cardiac output, no change of

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the peripheral vascular resistance and, consequently, a reduction in BP. Teixeira et al [27] reported decrease in cardiac output, stroke volume and BP after a bout of resistance exercise despite the increase in systemic vascular resistance.

Additionally, there may be a reduction in vascular resistance influenced by an accumulation of metabolites and ions (e.g. nitric oxide, prostaglandins, adenosine, H^+ and K^+) produced in muscle contraction, which, according to MacDonald et al [2], is one of the factors accounting for vasodilation and subsequent decrease in peripheral vascular resistance. RI length influences the removal of metabolites produced during muscle contraction. A greater accumulation of metabolites in the protocol with lower RI had been demonstrated by previous studies [18,28]. The use of shorter RI may lead to increased accumulation of metabolites and ions with vasodilator effects that are produced in muscle contraction, and this can influence the reduction in peripheral vascular resistance and BP [2]. However, this effect was not observed in the present study.

In this study no significant differences were observed between CRE with RI30s and RI40s in post-exercise level of SBP and DBP. In our study, rest interval differences between the two protocols were 2.5 minutes. Probably this time is low and not sufficient to make significant differences in removal of metabolites and vascular resistance. However, in consistent with the results of this study, Veloso et al [7] observed no significant differences between three resistance exercise protocols with RI of 1, 2 and 3 minutes between the sets in the post-exercise responses of SBP and DBP. Similarly, de Salles et al [20] reported no significant differences between two resistance exercise protocols with 1 and 2 minutes RI between sets in the post-exercise responses of SBP and DBP. Regardless of the occurrence or non-occurrence of PEH, the results of studies show no significant differences between resistance exercises with different RI in post-exercise BP responses. Although in the present study potential causes of PEH were not measured, but based on the results of studies it doesn't seem that metabolites produced from cellular activity to be the main cause of post-exercise decrease in BP.

CONCLUSION

The present findings have shown that the CRE with RI30s and RI40s led to significant post-exercise decrease in SBP and no change of DBP. Although it has been suggested that RI length influences the removal of metabolites produced during muscle contraction that may be involved in PEH by vasodilator effects, we found no significant differences between exercise trials in post-exercise level of SBP and DBP in all measured moments. We suggest further studies to evaluate the effects of other RE variables on PEH in different populations such as those of elderly and hypertensive individuals. Additionally, the physiological mechanisms involved in post resistance exercise hypotension need to be better explained.

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