Isolated and Combined Effects of Aerobic and Strength Exercise on Post-Exercise Blood Pressure and Cardiac Vagal Reactivation in Normotensive Men

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Abstract

Ruiz, RJ, Simão, R, Saccomani, MG, Casonatto, J, Alexander, JL, Rhea, M, and Polito, MD. Isolated and combined effects of aerobic and strength exercise on post-exercise blood pressure and cardiac vagal reactivation in normotensive men. *J Strength Cond Res* 25(3): 640–645, 2011—The purpose of this study was to examine blood pressure (BP), heart rate (HR), and cardiac vagal reactivation (VR) after an aerobic training session (ATS), a strength training session (STS), and a combined aerobic and strength training session (ASTS) in normotensive men. Eleven healthy men (age 26.8 ± 2.9 years, body mass index 24.3 ± 1.6 kg·m^{-2}) with at least 6 months of strength and aerobic training experience performed an STS, an ATS, and an ASTS in a counterbalanced crossover design. Blood pressure and HR were measured at rest and at 15-minute intervals post-training for 1 hour. Vagal reactivation was measured during the first minute immediately post-exercise. After STS and ASTS, systolic BP (SBP) and mean arterial BP (MAP) remained significantly lower than at rest at all time intervals ($p < 0.05$). After ATS, SBP was significantly lower than at rest at 30 minutes and beyond ($p < 0.01$); however, no significant differences were observed for MAP. Post-training HR remained high after STS and ASTS at all intervals ($p < 0.01$). However, after ATS, the HR remained high only at the 15-minute post-exercise interval ($p < 0.01$). Vagal reactivation was significantly less pronounced after the first 30 seconds post-exercise ($p < 0.01$) in ASTS (531.3 ± 329.6 seconds) than in ATS (220.7 ± 88.5 seconds) and in STS (317.6 ± 158.5 seconds). The delta of the HR decrease at 60 seconds post-exercise was greater ($p < 0.00$) in ATS (33.4 ± 12.7 b·min^{-1}) than in STS (14.1 ± 7.2 b·min^{-1}) and in ASTS (11.4 ± 7.1 b·min^{-1}). In conclusion, post-exercise BP reduction was independent of the type of exercise; however, HR remained significantly greater after combination of strength and aerobic exercise, implying a reduction in cardiac VR after this type of training. Therefore, strength and conditioning professionals may prescribe aerobic, strength, or a combination of aerobic and strength exercise to assist individuals concerned with BP control, thus allowing for variety in training while similarly impacting post-exercise SBP regardless of desired exercise modality.

Key Words cardiovascular physiology, physical exercise, post-exercise hypotension

Introduction

Physical exercise is a relevant nonpharmacologic option for prevention and treatment of blood pressure (BP) disorders. There is evidence that aerobic exercise is effective in reducing BP at rest and can be considered a relevant nonpharmacologic intervention. Moderate BP decreases have been reported after an aerobic training session (ATS) (24). The effects of this decrease have been shown to last from 1 to 12 hours after exercise (18). The magnitude of the post-exercise hypotensive response might be associated with whether or not an individual is hypertensive or normotensive. Decreased BP after an ATS has been observed in both populations (26). Some studies have reported the post-exercise hypotensive response to be more evident in hypertensive than in normotensive individuals (12), whereas others have shown no significant difference in the post-exercise response between hypertensive and normotensive participants (5,8).

Strength training is prescribed for the control of resting BP in hypertensive and normotensive individuals (1). Meta-analytical data suggest that strength training of varying

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prescriptions can decrease mean resting BP by as much as 3–4 mm Hg (6). However, BP also drops acutely after strength training as a post-exercise hypotensive response (25). In this case, the reductions found in the literature vary considerably due to differences in prescription variables, health status of the sample, and training volume (7,17,21,23,25).

The involved mechanisms in the reduction of the BP seem to be different in relation to the type of exercise performed (aerobic or strength). Indeed, the decrease in BP after a session of aerobic exercise seems to be primarily related to a reduction in peripheral vascular resistance (5,10,11), whereas a reduction in BP after a session of strength training has been associated with a decrease in cardiac output (22). Considering the mechanistic differences of BP reduction after aerobic and strength training and that the recommendations of physical exercise include the association of the cited activities (13), the knowledge of the hemodynamic behavior after such training becomes important. However, information regarding BP response after a combination of aerobic and strength training session (ASTS) is lacking in the current literature. For example, it is not known if post-exercise cardiovascular alterations induced by an exercise could present a somative or an inhibitory effect when another type of exercise is performed immediately. Such information may be useful for exercise prescription when the exercise is intended to control BP after effort.

The purpose of this study was to observe the behavior of BP, heart rate (HR), and post-exercise cardiac vagal reactivation (VR) after an aerobic exercise session, a strength training session (STS), and a combination of both aerobic and strength exercise in normotensive men. We hypothesized that the combination of aerobic and strength exercise would result in a greater post-exercise BP reduction effect than each exercise modality alone.

Methods

Experimental Approach to the Problem

To investigate the effect of different training modalities on the post-exercise hypotensive response, participants performed an aerobic exercise session, an STS, and an ASTS. The experimental procedures were performed on 5 nonconsecutive days with 48 hours separating days in which experimental procedures were performed. On the first day, submaximal variables were monitored and recorded during a maximal stress test conducted on a cycle ergometer (2). On the second day, a 12 repetition maximum (12RM) for each exercise comprising the STS was determined. On the third, fourth, and fifth days, a counterbalanced crossover design was used to determine the exercise training sequence. Blood pressure was measured before and at 15-minute intervals for 60 minutes after training sessions.

Subjects

Eleven normotensive men (age 26.8 ± 2.9 years, weight 76.4 ± 9.7 kg, height 179.7 ± 10.4 cm, body mass index 24.3 ± 1.6 $kg \cdot m^{-2}$, systolic BP [SBP] < 140 mm Hg, diastolic BP [DBP] <90 mm Hg) with at least 6 months of strength and aerobic training experience participated in the present study. All participants signed an informed consent, and anonymity was expressly assured. The experimental protocol was approved by the research ethics committee of the institution. According to the Declaration of Helsinki, the following exclusion criteria were adopted: (a) use of medication affecting participants' cardiovascular responses and (b) existence of osteomioarticular and cardiovascular problems that might influence the performance of the proposed exercises. Participants did not ingest caffeine or alcohol during the 24-hour period before any of the testing protocols and did not perform any rigorous physical activity during the 48 hours before any testing protocols.

Procedures

During the first testing session, anthropometric values of weight and height were obtained. Each individual remained standing and barefoot on a digital scale (Welmy, Santa Bárbara, Brazil), dressing only in swimwear and keeping as motionless as possible. Weight was recorded in kilograms (to the nearest 100 g). Height was measured during breath holding after a deep inspiration (to the nearest 0.1 cm), observing the distance between the sole of the feet and the highest point on the head (vertex). After participants had remained seated and calm for 10 minutes, BP was measured. The mean of 2 BPs measured separated by 2 minutes was used as the baseline for each session. Immediately after the resting BP measure, the subjects performed an effort test. For the ergometric test (2), a continuous incremental protocol on a cycle ergometer (Model Monark, São Paulo, Brazil) was used, with the participant maintaining the cadence of 60–70 rpm. The participants completed a 2-minute warm-up consisting of pedaling without load. After the warm-up, the test was initiated with a load of 25 W, and new loads of 25 W were added every 2 minutes until voluntary exhaustion or incapacity to keep the cycle cadence between 60 and 70 rpm. Heart rate was measured by cardiofrequencimeter (Polar S610i; Polar Electro Oy, Kempele, Finland).

During the second testing session, 12RM testing was performed (24) in the following exercise sequence: bench press, leg press at 45°, shoulder press, leg extension, seated row, leg curl, biceps curl, and seated calf raise. The bench press, leg press at 45°, and biceps curl were performed with free weights. During the 12RM test, each participant performed a maximum of three 12RM attempts for each exercise with 5-minute rest intervals between attempts. After the 12RM load for a specific exercise was determined, an interval not shorter than 10 minutes was allowed before the 12RM determination of the next exercise. Standard exercise techniques were followed for each exercise.

Training Sessions

The 3 training sessions were performed on nonconsecutive days with at least 48–72 hours between experimental sessions in a counterbalanced crossover design. In the STS, all participants performed 3 sets of 12RM for each exercise (bench press, leg press at 45°, shoulder press, leg extension, seated row, leg curl, biceps curl, and seated calf raise), with 2-minute rest intervals between sets and exercises. No pause was allowed between the eccentric and concentric phase of a repetition or between repetitions. During all STS, participants were asked to not perform a Valsalva maneuver. In the ATS, the participants performed 40 minutes of cycling between 60 and 70% of $HR_{Reserve}$ on a cycle ergometer (Monark, São Paulo, Brazil). A 5-minute warm-up before exercise and 5-minute cool down after exercise were performed for both the ASTS and the STS. In the ASTS, the participants performed aerobic and strength training in a sequence exactly similar as the other training sessions.

Before the beginning of each training session, the participants rested quietly in a seated position for 10 minutes after which resting SBP and DBP were measured. The BP rest measure was determined through the average of 2 consecutive measures separated by a 2-minute interval. After each training session, the subjects remained seated for 60 seconds for the VR measure. Vagal reactivation was determined by the extent of the reduction of the HR during the first 30 seconds after the effort (T30) and also by the delta of HR recovery (HRR) 60 seconds after exercise (HRR60). T30 was calculated using the negative reciprocal of the inclination of the straight line obtained in the 30 initial seconds of HRR. HRR60 was the difference between the ending exercise HR and 60-second post-exercise HR. After the VR measure, the subjects were moved to a noise (ambient)- and temperature-controlled (23°C) location and remained seated for 60 minutes for all BP measures. Blood pressure was measured at 15-minute intervals for 60 minutes, resulting in a total of 4 readings after each training session. Before and after each session, participants were fitted using the auscultatory method, and this fitted equipment was used for all pre- and post-session BP measurements. The procedures for BP measurement followed the American Heart Association guidelines (19). Reliability of the BP measure was tested previously (intraclass correlation coefficient = 0.94, $p < 0.000$). The mean arterial BP (MAP) was calculated using the following equation: MAP = DBP + ([SBP − DBP]/3). Heart rate was recorded immediately before BP measurement.

Table 1. Comparison of systolic blood pressure, diastolic blood pressure, mean blood pressure, and heart rate at rest and post-exercise between training sessions.*†

Variables	ATS	STS	ASTS
SBP (mm Hg)			
Rest	121.8 ± 9.0	122.0 ± 6.9	123.5 ± 8.1
15 min	118.4 ± 9.1	114.2 ± 9.6‡§	116.0 ± 10.7‡
30 min	115.6 ± 7.0‡	114.0 ± 8.6‡	111.8 ± 8.8‡
45 min	114.6 ± 7.4‡	114.4 ± 6.4‡	112.4 ± 9.6‡
60 min	117.0 ± 9.1‡	117.5 ± 5.7‡	115.5 ± 7.6‡
DBP (mm Hg)			
Rest	74.4 ± 9.5	78.5 ± 6.5	76.7 ± 9.4
15 min	74.2 ± 10.3	76.4 ± 9.6	76.2 ± 10.1
30 min	72.6 ± 9.1	74.7 ± 10.4	74.9 ± 7.4
45 min	75.8 ± 8.0	75.6 ± 7.9	73.5 ± 8.2
60 min	77.2 ± 7.9	78.4 ± 8.3	76.7 ± 6.3
MAP (mm Hg)			
Rest	90.2 ± 8.9	93.0 ± 5.7	92.3 ± 8.6
15 min	88.9 ± 9.0	88.9 ± 9.2‡	89.4 ± 8.8
30 min	86.9 ± 7.1	87.8 ± 9.1‡	87.2 ± 7.2‡
45 min	88.7 ± 6.7	88.5 ± 6.8‡	86.4 ± 8.5‡
60 min	90.4 ± 6.9	91.4 ± 7.2	89.6 ± 6.5
HR ($b \cdot min^{-1}$)			
Rest	76.3 ± 10.0	71.5 ± 5.7§	74.6 ± 6.5
15 min	88.3 ± 12.3‡	92.9 ± 10.1‡§	96.2 ± 11.4‡§
30 min	79.7 ± 10.4	85.6 ± 8.7‡§	92.3 ± 8.8‡§¶
45 min	80.1 ± 11.8	81.0 ± 8.9‡	86.5 ± 8.6‡§¶
60 min	78.3 ± 10.8	80.3 ± 10.5‡	86.2 ± 10.5‡§¶

*ATS = aerobic training session; STS = strength training session; ASTS = aerobic and strength training session; SBP = systolic blood pressure; DBP = diastolic blood pressure; MAP = mean blood pressure; HR = heart rate.
†Data presented as mean ± *SD*.
‡Significant difference in relation to the rest ($p < 0.05$).
§Significant difference in relation to ATS ($p < 0.05$).
¶Significant difference in relation to STS ($p < 0.05$).

Statistical Analyses

Repeated-measures analysis of variance (RM-ANOVA) was used to determine possible changes in SBP, DBP, MAP, and HR for each exercise session. One-way ANOVA was used in the analysis of the T30 and HRR60 variables. Mauchly test of sphericity was employed because of the use of ANOVA. Post hoc least significant difference test was applied to delineate between significant differences. Alpha was set at $p \leq 0.05$. Statistica software was utilized to complete the analysis (version 6.0, Statsoft, Tulsa, OK, USA).

Table 2. Comparison of cardiac vagal reactivation between training sessions.*†

Variables	ATS	STS	ASTS	*F*	*p*
T30 (s)	220.7 ± 88.5‡	317.6 ± 158.5‡	531.3 ± 329.6	76.5	<0.000
HRR60 ($b \cdot min^{-1}$)	33.4 ± 12.7§	14.1 ± 7.2	11.4 ± 7.1	124.8	<0.000

*T30 = extent of the reduction of the heart rate during the first 30 seconds after the effort; HRR60 = delta of heart rate recovery during 60 seconds after exercise; ATS = aerobic training session; STS = strength training session; ASTS = aerobic and strength training session; HR = heart rate.
†Data are presented as mean ± *SD*.
‡Significant difference in relation to ASTS ($p < 0.05$).
§Significant difference in relation to STS and ASTS ($p < 0.01$).

Results

Average values for all variables (SBP, DBP, MAP, and HR in rest and after 60 minutes of recovery) for the different exercises modalities are listed in Table 1. Systolic BP remained significantly reduced in comparison to rest values after the STS, ATS (except at 15 minutes), and ASTS in all analyzed moments. Post-exercise MAP was not significantly different from that rest after the ATS. On the other hand, MAP remained significantly lower in relation to rest values at 15, 30, and 45 minutes and 30 and 45 minutes after the STS and ASTS, respectively. Finally, DBP values did not differ after any of the exercise sessions in relation to the rest values.

Heart rate remained significantly elevated compared with rest values for both the STS and the ASTS in all measurements post-exercise and only at 15 minutes post-aerobic exercise session.

Significant differences between session are shown in Table 1. Systolic BP in the STS was significantly lower than in the ATS at 15 minutes post-exercise. Heart rate was greater after STS in relation to the ATS at rest and at 15 and 30 minutes post-exercise. The ASTS resulted in higher HR values post-training compared with the ATS in all post-exercise measures. Heart rate was also significantly higher in the ASTS compared with the STS at 30, 45, and 60 minutes post-exercise. Diastolic BP and MAP did not differ significantly between the types of exercise post-exercise.

Comparison data of cardiac VR between training sessions are illustrated in Table 2. In regard to the T30 component, the greatest value was for the ASTS, which differed significantly from that for the ATS and STS. The highest value for HRR60 was for the ATS, which was significantly different from that for the 2 other training sessions.

Discussion

This study examined the post-exercise hypotensive response in normotensive, healthy men after isolated and combined exercises sessions of aerobic and strength training. A few studies have demonstrated that post-exercise SBP is reduced in normotensive participants after both aerobic and strength training in different sessions (3,4,16). However, a number of studies involving aerobic exercise (14,16,18) and strength exercise (7,16,25) in normotensive individuals found post-exercise hypotensive response only in SBP, with little or no alteration in DBP. The current study yielded similar results in that DBP was not altered with either type of exercise session.

This is the first study to examine the combined effect of aerobic and strength training in a single training session on BP. The larger training volume imposed by both activities may have influenced the decrease of SBP after this combined exercise. This thought is supported by studies examining the impact of increased training volumes in both aerobic exercise and strength exercise alone. For example, aerobic exercise sessions of long duration (45 minutes) have resulted in post-exercise hypotensive responses of greater magnitude and duration (9). Similarly, yet with strength exercise, recent comparison data demonstrated that strength exercise involving a high volume (sets = 10) resulted in a significantly greater post-exercise hypotensive SBP response than strength exercise involving a low volume (sets = 6) (20).

The results of the present study suggest that increasing the duration of distinct exercise training modalities does not automatically result in a greater post-exercise hypotensive response. One plausible explanation for this is the knowledge that the physiological mechanisms for the post-exercise hypotensive responses between aerobic and strength exercise differs significantly. Indeed, in regard to aerobic exercise, previous studies have shown that the post-exercise hypotensive response is due to a reduction in peripheral vascular resistance, which occurs compensatory to an increase in cardiac output and HR during exercise (8,15,24). In regard to strength exercises, relatively few studies have examined possible mechanisms for the post-exercise hypotensive response. However, some evidence has shown a reduction in cardiac output followed by an increase in peripheral vascular resistance and HR (22). Thus, even though the post-exercise hypotensive response is similar after aerobic and strength exercise, physiological mechanisms must be different. In fact, in the present study, differentiation in vagal behavior between the aerobic and strength exercise was verified through the analysis of HR and VR. T30 values were higher with combined aerobic and strength training than with aerobic training alone, suggesting a more rapid HR recovery after aerobic exercise. This demonstrates a potentially greater sympathetic inhibition after strength exercise.

Post-exercise HR behavior differed in the 3 experimental training sessions. These results suggest that HR recovery behavior depends more on the total work completed than on the type of exercise performed. Thus, this post-exercise HR increase may be due to a possible cardiovascular adjustment to compensate for the decrease in cardiac output (22). After the ATS, HR was higher than at rest only at 15 minutes. On the other hand, after the STS, HR was higher than at rest in all time measures. Moreover, HR at 15 and 30 minutes after STS was higher than the respective values after the ATS. In addition to this, the fact that resting HR before the STS was significantly lower than that before the ATS. The fact that the resting HR was higher before the aerobic exercise session suggests an anticipatory response to the effort, mediated by the autonomic nervous system, because the execution order of the sessions was randomized. Therefore, the magnitude of HR change was relatively larger after strength training than after aerobic training. In regard to the ASTS, post-exercise HR was greater at 30, 45, and 60 minutes than at the post-ATS alone. This suggests that the sympathetic activity is greater both in magnitude and in duration after strength exercise, even though aerobic exercise preceded strength exercise. Thus, during the post-exercise hypotensive response, the impact of post-exercise HR due to strength exercise prevailed over the impact of the aerobic exercise.

The current study is not without limitations. For example, in every case, aerobic exercise preceded strength exercise in the ASTS. Therefore, it is possible that the order of this training influenced the post-exercise physiological mechanisms that resulted in the manifested HR and BP response. Additionally, because this study employed normotensive, young male participants, it is not generalizable to hypertensive young men, normotensive or hypertensive older men, young women, and older women; therefore, further research is needed to examine the post-exercise BP response in these populations.

Practical Applications

The findings of the present study suggest that there is a post-exercise hypotensive response in normotensive men after aerobic, strength, and combined training modalities. Therefore, strength and conditioning professionals may prescribe either of these 3 exercise modalities to assist individuals concerned with BP control, thus allowing for variety in training while similarly impacting post-exercise SBP regardless of desired or chosen exercise modality. However, strength and conditioning professionals must keep in mind that the results from this study cannot be extended to older adults and/or hypertensive individuals. Further research is warranted to compare the impact of all 3 exercise modalities on post-exercise SBP with such populations.

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