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Influence of exercise order on blood pressure and heart rate variability after a strength training session

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Aim. **The purpose of this study was to compare the effects of two different strength training (ST) exercise sequences on blood pressure (BP) and heart rate variability (HRV) after a ST session.**

Methods. **Ten male subjects participated in the study. After determining the one repetition maximum load (1RM) for the bench press (BP), lat pull down (LPD), shoulder press (SP), triceps extension (TE), biceps curl (BC), leg extension (LE), leg curl (LC) and leg press (LP), participants performed two different exercise sequences. During sequence 1 (SEQ1) subjects performed 3 sets of 12 repetitions at 80% 1RM, with 3 minutes rest between sets and exercises with the following order: BP, LPD, SP, TE, BC, LE, LC, and LP. After 72 hours, subjects performed the SEQ2 with the same volume of exercise, but the order of exercises was reversed. BP and HRV were measured before and after the training sessions.**

Results. **The systolic blood pressure and mean arterial pressure were significantly higher for SEQ2 when compared to SEQ1. HRV showed significant differences between exercises orders, as SEQ1 presented higher values of low frequency normalized units band, lower values of high frequency normalized units band and lower values of the standard deviation of differences between adjacent normal R-R intervals when compared to SEQ2.**

Conclusion. **The order of ST exercises has a significant impact on the cardiac autonomic nervous system and on post-exercise blood pressure response. ST beginning with lower body exercises and progressing toward upper body exercises are more likely to produce a lower cardiovascular stress.**

KEY WORDS: Resistance training - Hypotension - Autonomic nervous system.

Strength training (ST) is an important part of a well-rounded physical exercise program and there is evidence that a single strength training session (STS) promotes acute modifications in blood pressure (BP) and heart rate variability (HRV) of normotensive and hypertensive individuals.[1, 2]

Blood pressure response after ST is an important topic of study, because post exercise hypotension, *i.e.*, a BP reduction to levels below those observed at rest or prior to exercise, has a significant role in the management of BP.[1] Several studies have examined blood pressure behavior from ST performed with different volumes and intensities.[2-5] However, the influences of these ST-related variables on BP after a STS are scarcely known.[2]

To the best of our knowledge, only three studies have investigated the physiological pathways of BP control derived from a STS,[2, 6, 7] while other studies have focused on the manipulation of methodological variables of ST such as training intensity, rest interval or concurrent training.[5, 8, 9] Until now, one study

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has investigated the acute response of BP and HRV associated with a STS and its relationship with ST intensity.[2] In light of this observation, it is necessary to better understand the mechanisms of BP control from this type of exercise performed with different exercise orders since exercise order can influence repetition performance and different physiological mechanisms during ST.[10, 11] Furthermore, current literature does not provide significant information about the physiological pathways of STS and the impact on BP and HRV.

Since previous studies analyzing the effect of exercise order on BP and HRV after a STS are scarce, the purpose of this study was to compare the effect of two different exercise orders in a STS on the BP and HRV.

Materials and methods

Participants

Ten normotensive men with previous experience in ST participated in this study (age: 26.6±4.5 years; height: 173.8±8.1 cm; body mass: 77.6±8.3 kg; BMI: 25.4±2.4 kg/m^2; resting systolic blood pressure (SBP): 126.5±8 mmHg; resting diastolic blood pressure (DBP): 74.7±4 mmHg). According to the criteria established by the Seventh Joint National Committee [12] the following criteria were adopted for subject recruitment: (a) nonsmokers; (b) absence of any kind of metabolic disease; (c) no articular or bone injury; and (d) absence of any medication. Participants were informed about the study procedures, possible risks and benefits, and signed an informed consent form. This study was approved by the Ethics Committee of the Rio de Janeiro Federal University. Participants were instructed to maintain their usual activities and eating habits throughout the study period.

Procedures

One repetition maximum (1RM) testing

During the first laboratory visit, the participants' height and body mass were measured by means of an analogical scale (Filizola, Brazil) and a stadiometer followed by 1RM testing. The 1RM testing began with a warm-up at 50% of the predicted 1RM. After five minutes rest, each subject was encouraged to perform one repetition with a heavier load. If the attempt was successful, the load was increased and the attempt repeated. After 72h a second visit occurred and the 1RM test was repeated, with the highest successful lift being recorded as the 1RM.[13] The exercises performed were the bench press (BP), front lat pull down (LPD), shoulder press (SP), triceps extension (TE), biceps curl (BC), leg extension (LE), leg curls (LC) and leg press (LP). The 1RM assessments were divided over a four day period. On the first and third day BP, LE, BC and LC were tested and retested, on second and fourth days LPD, LP, SP and TE were performed. To minimize the error during 1RM tests, standardized strategies were adopted.[13]

Exercise sessions

Seventy two hours after the last 1RM assessment, participants performed one of the two exercise sequences in a counterbalanced crossover design. The second session was performed 72 hours after the first session. The exercise order for SEQ1 was BP, LPD, SP, TE, BC, LE, LC and LP. The exercise order for SEQ2 was reversed. The warm-up consisted of 10 repetitions of the first exercise at 40% of 1RM. A 3-minute rest interval was allowed after the warm-up before participants performed the assigned exercise sequence. Both exercise sequences consisted of 3 sets of each exercise (80% of 1RM) with 3-minute rest intervals between sets and exercises. During the exercise sessions, subjects were verbally encouraged to perform 10 to 12 repetitions in all sets. During all training sessions participants were asked to avoid the Valsalva maneuver.

Measures of heart rate and heart rate variability

A heart rate monitor (Polar RS800sd, Finland) was continuously used for 30 minutes before and for 60 minutes after the sessions for monitoring HR and HRV. Data were recorded on the equipment and then immediately downloaded to the computer to be analyzed by the Polar Precision Performance Software (Release 3.00, Kempele, Finland). The HRV parameters were analyzed according to the components of low frequency in normalized units (LF-nu), high frequency in normalized units (HF-nu) and the standard deviation of differences between adjacent normal R-R intervals (RMSSD) after Fourier transformation and noise filtering through the program Kubios HRV Analysis Software version 2.0 (Kuopio, Finland). Data were collected at rest and after the ST sessions. Subjects remained at rest in a supine position in a quiet room with temperature maintained between 20 °C and 22 °C.

Arterial blood pressure assessment

Systolic blood pressure (SBP), diastolic blood pressure (DBP) and mean arterial pressure (MAP) were measured using an automatic oscillometric device (PM50 NIBP/Spo2, CONTEC, EUA). The resting BP value was averaged over three consecutive measurements with an interval of 5 minutes after the individual remained in a supine position for 10 min. Afterwards, BP was assessed every 10 minutes over a 60 minute period. Measurements were performed in the left arm, following the recommendations of the American Heart Association.[14]

Statistical analysis

Data for all variables were analyzed using the Shapiro-Wilk normality test and the Bartlett criterion for homocedasticity. An intraclass coefficients correlation (ICC) was used to test the reliability of 1RM tests. A paired Student t-tests were applied to compare the following parameters: 1RM test and retest and total number of repetitions performed in SEQ1 and SEQ2. The resting values of SBP, DBP, MAP, HR, RMSSD, LF-nu and HF-nu were analyzed separately using one-way ANOVA. Subsequently, a two-way repeated measures ANOVA was used to compare the resting values and post-exercise measures within and between sessions. In all cases, the post-hoc Bonferroni was used. Additionally, effect sizes (ESs; the difference between pretest and posttest scores divided by the pretest SD) were calculated for the SBP, DBP, MAP and RMSSD for both exercise orders. The scale proposed by Rhea [15] was used to determine the magnitude of the ES. Alpha was set at P<0.05 and all analyzes were performed with the Prisma (v. 5.0, Graphpad).

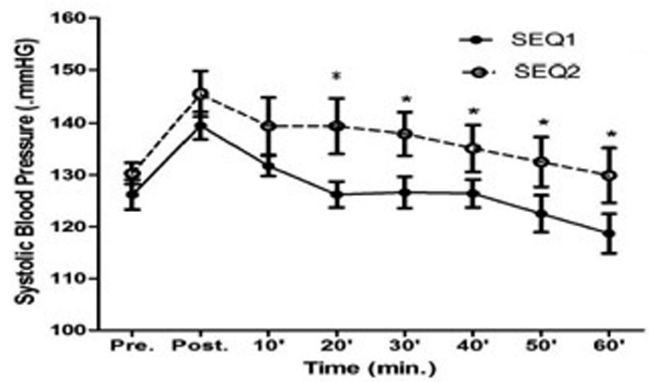

Figure 1.—Systolic blood pressure response to two strength training exercises sessions (mean±SD).

Results

All tested variables followed a normal distribution (P>0.05). The data of 1RM test were analyzed using intraclass correlation coefficients (BP r=0.95, LPD r=0.96, SP r=0.90, TE r=0.98, BC r=0.97, LE r=0.98, LC r=0.97 and LP r=0.96) and showed high reliability.

Average values at rest and during 60 minutes post-exercise for the SBP at different exercise orders are showed in Figure 1. No significant differences were found between rest values (P>0.05). There were significant differences between the two exercise sequences from 20 to 60 minutes in SBP (P<0.05). For the DBP, there were no differences in the measures between rest and after exercise and between the two exercise sequences (P>0.05). Post-exercise MAP was significantly different between SEQ1 and SEQ2 at 20 minutes (87±4 *vs.* 94±4 mmHg; P<0.05) and 30 minutes (87±7 *vs.* 94±6 mmHg; P<0.05).

Table I shows the systolic, diastolic, mean arterial pressure and RRmed ES after STS with different exercise orders. SBP and DBP effect sizes presented different classifications on all time values, with the exception of DBP at 10 minutes which showed small modifications on blood pressure control in SEQ1. Additionally, lower SBP and DBP ES were consistently observed for the SEQ1 condition at all time points.

Compared to the pre intervention, RMSSD value was reduced throughout the one hour period after both ST sequences, with significant differences be-

TABLE I.—*Effect Size: SBP, DBP, MAP and RRmed after both sequences of strength training.*

			10 min	20 min	30 min	40 min	50 min	60 min
SBP	SEQ1	Magnitude	1.10	0.60	0.37	0.40	1.10	1.13
		Classification	Mod.	Sm.	Sm.	Sm.	Mod.	Mod.
	SEQ2	Magnitude	2.08	2.04	1.50	0.90	1.30	1.80
		Classification	Large	Large	Large	Mod.	Large	Large
DBP	SEQ1	Magnitude	0.51	0.94	1.30	1.34	1.95	1.58
		Classification	Sm.	Mod.	Mod.	Mod.	Large	Large
	SEQ2	Magnitude	0.12	0.39	0.35	0.33	0.59	0.91
		Classification	Sm.	Sm.	Sm.	Sm.	Mod.	Mod.
MAP	SEQ1	Magnitude	1.38	1.06	1.03	1.21	1.00	0.60
		Classification	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.
	SEQ2	Magnitude	1.30	0.62	0.86	0,85	1.41	1.25
		Classification	Mod.	Mod.	Mod.	Mod.	Mod.	Mod.
RMSSD	SEQ1	Magnitude	4.97	7.39	6.96	6.47	5.14	4.50
		Classification	Large	Large	Large	Large	Large	Large
	SEQ2	Magnitude	1.27	1.72	1.50	1.12	1.25	1.20
		Classification	Mod.	Large	Mod.	Mod.	Mod.	Mod.

Legend: Sm. Small; Mod. Moderate; SBP. Systolic blood pressure; DBP. Diastolic blood pressure; MAP. Mean arterial pressure; RMSSD. Standard deviation of differences between adjacent normal R-R intervals.

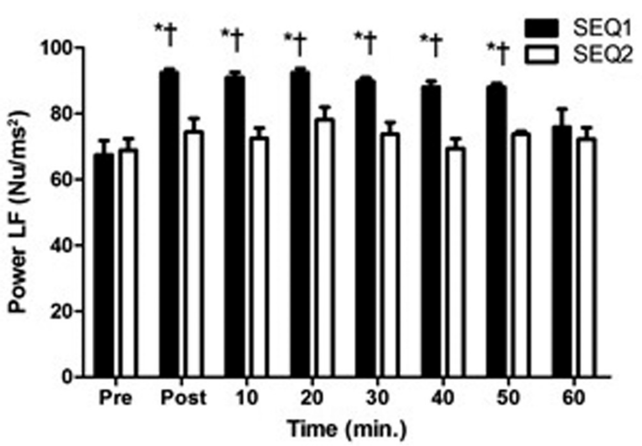

Figure 2.—Power LF standardized at rest, immediately after strength training and for one hour divided in ten minutes periods. *Significant difference between sequences at that time point (P<0.05). †Significant difference for intragroup rest (P<0.05).

tween sequences (P<0.05). However, a major magnitude of ES was found for the SEQ1 (4.97) when compared with the SEQ2 (1.29) (Table I).

LFun band during 50 minutes after ST demonstrated a significant increase when compared to SEQ1 rest values, and when SEQ1 was compared with SEQ2 (P<0.05) as illustrated in Figure 2.

HF band showed significant differences between SEQ1 and SEQ2 at 30 minutes (23.4±7.0 *vs.* 37.9±8.7), 50 minutes (22.2±4.5 *vs.* 34.7±10.0), and 60 minutes (20.0±5.6 *vs.* 33.4±7.9) (P<0.05).

Discussion

The major findings of this study include the following: (a) exercise order influenced HRV and cardiac autonomic control after ST, demonstrating an increased sympathetic tone and a reduced parasympathetic tone after the session, particularly when SEQ1 was performed; (b) exercise order influenced SBP after ST but did not elicit a significant post-exercise hypotensive response in normotensive, physically active men; and (c) blood pressure response was higher in SEQ2 which incorporated lower body exercises at the beginning of the session and progressed toward upper body exercises. In the present study the subjects performed two different STS containing the same exercises and the same total work volume. Our results showed that SEQ1 promoted major alterations in cardiac autonomic control when compared with SEQ2. A major increase in sympathetic tonus and a reduction in parasympathetic tonus observed in SEQ1 can be probably attributed to a concentric failure that occurs in upper body exercises at the beginning of the sequence.[2] On the other hand, a possible muscular fatigue at the beginning of the sequence may reduce plasma volume and, in consequence, the cardiac output and systolic volume which promotes a major cardiovascular imbalance after the session.[2, 16] Additionally, concentric failure increases the recruitment of additional motor units requiring a progressive activation of the sympathetic nervous system to maintain training intensity.[17] Finally, a greater activation of metaboreceptors, mechanoreceptors and arterial baroreflex may occur due to a reduction in blood flow promoted by a plasma volume decrease to the active muscles and an increase in peripheral vascular resistance induced by a mechanical occlusion of blood flow promoted by muscular contraction.[2]

The results of this study are in agreement with two previous studies. Both studies demonstrated greater sympathetic activation after ST suggesting that ST elicits important changes in the cardiac autonomic control after the session and these responses may be related to training intensity and total volume.[2, 18] Resk *et al.*[2] investigated the effect of two different intensities (40% and 80% of 1RM) on HRV and did not found significant differences between intensities on cardiac autonomic control after a STS. On the other hand, Lima *et al.*[18] found significant differences between different intensities after ST and concluded that major alterations occur after high intensity STS when compared with moderate or low intensity training. The differences in the total training volume potentially influence the magnitude and duration of increased sympathetic activity after ST. However, studies analyzing the cardiovascular response after STS performed with different volumes are not reported, as this is the first study to examine the influence of exercise order on cardiovascular responses after STS.

Recently, Lima *et al.*[18] demonstrated that cardiac sympathetic activation remains higher than resting values after upper body STS. Their results partially corroborate the current study's results. For example, in SEQ1 there was a similar increase in sympathetic activation; however, the reduction of parasympathetic activity observed by the HF band and RMSSD index in SEQ1 when compared with SEQ2 has an important practical application. For instance, an increase in the sympathetic activation combined with a reduction of parasympathetic activity increases the risk of cardiovascular events in both healthy individuals and patients with cardiovascular disease.[19]

In relation to SBP, DBP and MBP the present study demonstrated that exercise order influences both the magnitude and duration of BP response. Effect size data demonstrates a smaller magnitude and duration of SBP increase in SEQ1 when compared with SEQ2. On the other hand, SEQ1 ES data presented a longer duration of hypotensive response in DBP for SEQ1 compared with SEQ2. The results also show a small increase or a reduction in SBP and DBP when SEQ1 was performed. Previous studies examined different aspects of post exercise hypotension and some demonstrated that ST is capable of reducing SBP, DBP and MBP.[2, 5] As observed in this study, the SBP response after strength training, specifically in SEQ1, demonstrated a small reduction in normotensive male subjects, although other studies demonstrated a hypotensive response after single bouts of training.[5] A possible explanation for the excessive BP response in SEQ1 attributable to the cardiac stress may be the high intensity of training at the beginning of the session which can result in plasma reduction and an increased cardiac contractile effort to maintain cardiac output.[2] On the other hand, the influence of the parasympathetic nervous system in SEQ2 does not allow for the complete restoration of BP to resting values.

Although this study did not demonstrate a significant PEH in DBP after a STS, other have found differences in isolated sessions, which may be partially explained by the methodological dissimilarity that may have influenced the results. For example, major and longer hypotensive responses to ST were found in individuals that had previous experience in ST with sessions that were performed at moderate to high intensity (*i.e.*, 6RM, 12RM, 70% of 10RM and 80% of 1RM).[3, 5] Ruiz *et al.*[20] analyzed physically active men and adopted distinct protocols in exercise sessions; strength training was performed with slightly higher intensities, and the subjects performed 12 maximum repetitions. In this study, subjects had more frequent, intense sessions that may have contributed to the onset of PEH. Therefore, the authors of this study have concluded that high intensity training (80% of 1RM) combined with longer rest interval between sets and exercises (3 minutes) does not contribute to PEH in trained subjects.

Beyond the findings presented here, it is important to consider some limitations of this study. The blood pressure assessments were done in a supine position, which does not contribute to a reduction in SBP.[21] On the other hand, HRV can be affected during a prolonged seated position which can lead to a reduction in venous return and increased baroreflex activity.[22] Due to a lack of studies reporting the influence of exercise order on HRV after a STS, and how to perform the two measurements together, a supine position was adopted. Additionally, because this study investigated normotensive young subjects, the results presented here are may not be generalizable to other populations. Further research is needed to examine the PEH response related to the manipulation of ST methodological variables.

Conclusions

The findings of this study demonstrated different HRV behavior in trained normotensive men after high-intensity strength training performed with two different exercise orders. Therefore, one may conclude that strength training composed of upper and lower body exercises beginning with lower body exercises and progressing toward upper body exercises are more likely to produce a lower cardiac stress when compared to the reverse order. Therefore, professionals should prescribe lower body exercises first if the goal is to reduce cardiac stress. Since the results of this study are likely to only be applied to trained normotensive male individuals, further research testing other populations is warranted.

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