



Effects of Strength Training Sessions Performed with Different Exercise Orders and Intervals on Blood Pressure and Heart Rate Variability

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ABSTRACT

International Journal of Exercise Science 11(2): 55-67, 2018. This study compared the effect of a strength training session performed at different exercise orders and rest intervals on blood pressure and heart rate variability (HRV). Fifteen trained men performed different upper body exercise sequences [large to small muscle mass (SEQA) and small to large muscle mass (SEQB)] in randomized order with rest intervals between sets and exercises of 40 or 90 seconds. Fifteen repetition maximum loads were tested to control the training intensity and the total volume load. The results showed, significant reductions for systolic blood pressure (SBP) for all sequences compared to baseline and, post-exercise: SEQA90 at 20, 30, 40, 50 and 60 minutes; SEQA40 and SEQB40 at 20 minutes and SEQB90 at 10, 20, 30, 40, 50 and 60 minutes. For diastolic blood pressure (DBP), significant reductions were found for three sequences compared to baseline and, post-exercise: SEQA90 and SEQA40 at 50 and 60 minutes; SEQB40 at 10, 30 and 60 minutes. For HRV, there were significant differences in frequency domain for all sequences compared to baseline. In conclusion, when performing upper body strength training sessions, it is suggested that 90 second rest intervals between sets and exercises promotes a post-exercise hypotensive response in SBP. The 40 second rest interval between sets and exercises was associated with greater cardiac stress, and might be contraindicated when working with individuals that exhibit symptoms of cardiovascular disease.

KEY WORDS: Resistance training, exercise order, rest interval, post exercise hypotension, hypotensive effect, autonomic behavior

INTRODUCTION

Strength training (ST) is recommended as part of an exercise program for increasing muscle strength and hypertrophy, and can be considered an important non-pharmacological tool for prevention and treatment of some risk factors related to cardiovascular disease such as hypertension (1, 2, 3). After a ST session, systolic blood pressure (SBP) and diastolic blood pressure (DBP) can be reduced below baseline values, an effect known as post-exercise

hypotension (PEH), which is considered an important response for acute blood pressure (BP) control in hypertensive individuals (1,12). A greater magnitude, frequency and duration of PEH may increase the likelihood for chronic reductions in resting BP (1, 18, 21).

Several ST variables can be manipulated to promote PEH, such as: training volume (15), load intensity (16), exercise order (13, 22), rest interval between sets and exercises (10, 17, 34) amount of muscle mass involved (27), method used (i.e., circuit fashion, reciprocal supersets or traditional) (5, 7, 31) and execution speed (23, 24, 33). Previous studies have analyzed the influence of these variables on PEH however, studies analyzing the PEH with manipulation of rest interval lengths and exercise order are scarce (12).

Veloso et al. (34) evaluated the effect of three different rest intervals between ST sets and exercises on PEH in sedentary, normotensive men. The protocols consisted of upper and lower body exercises with three sets of eight repetitions with one, two and three minutes' rest interval between sets and exercises. The results of this study showed that when the total workload was equated, varying at rest interval did not influence the magnitude of the PEH. On the other hand, De Salles et al. (10) compared the PEH after a ST session performed with two different rest intervals between sets and exercises (i.e., 1 minute vs. 2 minutes) in a sequence composed by upper and lower body exercises for three sets of 10 repetitions in normotensive elderly men. The results of this study showed a PEH for 60 minutes' post-exercise. Based on the effect sizes the authors suggest that 2-minute rest interval is more effective to promote greater and longer PEH.

Jannig et al. (22) analyzed the influence of three different ST protocols performed with different exercise orders on PEH of eight elderly hypertensive subjects (i.e., sequence1: lower to upper body exercises; sequence2: upper to lower body exercises and; sequence3: alternating upper and lower body exercises). Three sets with a 12 repetition maximum (RM) load for all exercises, and rest intervals of 2-3 minutes between sets and exercises. The sequence1 showed no significant differences from baseline; sequence2 showed significant differences in SBP from baseline at the 20 and 40-minute time-points post-exercise; and sequence3 showed significant differences from baseline at all SBP time points post-exercise and at 10, 20, 30 and 60 minutes' post-exercise in DBP.

Conversely, Figueiredo et al. (13) investigated the influence of different exercise orders on BP and heart rate variability (HRV) after a ST session in normotensive men. Two different exercise sequences were used: upper to lower body exercises (SEQ1) and the reverse order (SEQ2). The authors did not found PEH and observed that HRV was significantly impacted by exercise order. SEQ1 elicited an increase in sympathetic tonus and decrease parasympathetic tonus.

The mechanisms of PEH in relation to ST are still not well elucidated. It may involve an acute reduction in sympathetic neural activity (26), which can be measured as HRV, describing the sympathetic-vagal balance (32). Abnormal changes in the sympathetic-vagal balance are associated with heart disease (32).

Regarding the rest interval between sets during ST, there is a gap in the literature without studies utilizing rest intervals less than one minute between sets and exercises on PEH response (10, 12, 17) and this length is suggested to hypertrophy and muscular endurance (9), besides to be the most used at fitness centers. In addition, regard to exercise order, the literature is scarce comparing its effects on the PEH response (6, 13, 22). Thus, the purpose of this study was to investigate the effect of ST performed with different exercise orders and rest intervals on BP and HRV in men. The hypothesis is that begin with small muscle groups and progress to large muscle groups, associated with a longer rest interval between sets and exercise promotes greater and longer PEH.

METHODS

Participants

Fifteen trained men with at least 12 months of recreational experience in ST participated in this study (table 1).

The inclusion criteria were: a) agree not to perform any physical activity beyond the prescribed protocols of the study; b) should not present conditions that could influence data collection or interpretation; c) not use ergogenic substances or medicines to control BP; d) absence of any kind of cardiovascular or metabolic disease; e) not consume caffeinated or alcoholic beverages; f) be normotensive (BP \leq 140/90 mmHg) and; g) no articular or bone injury. The study's details were explained verbally and in writing, and subjects signed an informed consent form according to the Declaration of Helsinki and answered the PAR-Q questionnaire (Shephard, 1988). The study protocol was approved by the Institutional Ethics Committee of the University.

Table 1. General characteristics of participants (Values in mean \pm standard deviation).

Age (years)	25 \pm 4.5
Body Mass (Kg)	77 \pm 8.3
Height (cm)	173 \pm 8.1
Body Mass Index (kg/m ²)	25 \pm 24

Protocol

During the first laboratory visit, subjects' weight and height were measured by analogical scale (Filizola, Brazil) and stadiometer (Sanny, Brazil) followed by 15RM testing. The test and retest procedures were conducted at least 72 hours apart. The test procedure was limited to four attempts with a 5-minute interval between them to achieve the highest 15RM load. After each successive attempt an additional load was added. After obtaining the 15RM load for an exercise, 10-minute rest intervals were given before proceeding to testing for the next exercise.

All tests were conducted at the same time of day. The exercises performed were: chest press (CP), front lat pulldown (FLP), seated row (SR), upright row (UR), triceps curl (TC) and biceps curl (BC), selected due to their common use in fitness centers. To minimize error during the 15RM testing, the following strategies were adopted: a) standardized instructions concerning the procedures and exercise technique performance were given to subjects before the test; b)

subjects received verbal encouragement during the testing procedure; d) the mass of all weights and bars used were determined using a precision scale (9, 17).

The intraclass correlation coefficients for the 15RM tests-retest for each exercise were: (CP: $r = 0.95$; FLP: $r = 0.96$; SR: $r = 0.92$; UR: $r = 0.98$; TC: $r = 0.97$; BC: $r = 0.98$) and showed high reliability.

Blood pressure and HRV were measured before (after 10 minutes of rest as soon as subjects arrived at the laboratory) and at intervals of 10 minutes for 60 minutes after each of the four ST protocols.

After the assessment of 15RM loads for CP, FLP, SR, UR, TC and BC; subjects performed four different exercise sequences in a random order and 72 hours apart. During sequence A (SEQA) the exercise order was performed from large to small muscle group (i.e., CP, FLP, SR, UR, TC and BC) with either 40 (SEQA40) or 90 seconds (SEQA90) between sets and exercises. During sequence B (SEQB) the exercise order was performed from small to large muscle group (i.e., BC, TC, UR, SR, FLP and CP) and with the same rest intervals (SEQB40 and SEQB90). All exercises were performed with Rotech® exercise machines (Goiás, Brazil).

The warm-up procedure consisted of one set of 10 repetitions of the first exercise in the sequence at 60% of the 15RM. A 2-minute rest interval was allowed between the warm-up and the exercise sequence. During each protocol, subjects were verbally encouraged to perform 15 repetitions for all sets. Successful repetitions utilized a complete range of motion as defined during 15RM testing. No pause was allowed between the eccentric and concentric phases of each repetition. During all protocols, subjects were asked to avoid the Valsalva maneuver. No attempt was made to control the velocity with which repetitions were performed. The total number of repetitions for each exercise of each set was recorded to calculate the total volume of work performed.

The SBP and DBP measures were measured using an automatic oscillometric device (Contec PM50 NIBP/Spo2, Qinhuangdao, Hebei, China) with range of 10 - 290 mmHg, with a resolution of 1mmHg. The equipment was auto calibrated before each use. All records occurred pre- and immediately post-exercise over 60 minutes, with 10-minute intervals between each record. Measurements were performed on the left arm, following the American Heart Association recommendations (4).

For baseline measurements, subjects rested in a seated position for 10 minutes in a temperature controlled room without any noise or distractions. The resting BP was determined by average of three measurements performed on non-consecutive days during the subjects' familiarization and testing sessions. At the end of each protocol, BP was recorded in 10-minute cycles over a 60 minutes' period, resulting in a total of six measurements.

Subjects were fitted with a heart rate (HR) monitor (Polar RS800cx, Kempele, Finland) for acquisition of RR intervals from each heart beat cycle. The HR and HRV, beat-to-beat, were

assessed for 10 minutes' before ST session and for 60 minutes' after ST session. Data were collected with subjects seated in a quiet room with temperature maintained between 20 to 22°C.

The RR interval data were downloaded to a computer for further analysis. The interpolation method was used to edit the sounds in all R waves pre- and post-exercise. After this procedure, the data were digitized in *Matlab* (*Matlab version 6.0 Mathworks* - Massachusetts - USA) for analyses of the frequency domain, which was performed using the Fourier transform algorithm.

The frequency bands were divided as follows: low frequency component (LF - 0.04 to 0.15Hz); and high frequency component (HF - 0.15 to 0.4Hz). The normalized power of the LF and HF components calculated in normalized units (nu) from the equations: LFnu = LF/(Total power - VLF) x 100; HFnu = HF/(Total power - VLF) x 100 (24), where VLF means very low frequency.

Statistical Analysis

Data were analyzed using Shapiro-Wilk normality test and homoscedasticity test (Bartlett criterion). For normally distributed variables, a two-way ANOVA was used to compare differences at each time point in SBP, DBP and HRV. In all cases, Bonferroni post-hoc comparisons were used to locate statistically significant differences. Additionally, to determine the magnitude of the SBP and DBP findings, effect sizes (difference between pre-test and post-test scores divided by the pretest standard deviation) were calculated and delta values (difference of post-exercise BP and rest BP) were used to verify the differences found in SBP and DBP.

Statistical analyses were performed using Prism software (v. 5.0, Graphpad) and all data are presented as mean and standard deviation (mean \pm SD). The adopted statistical significance level was $p < 0.05$.

RESULTS

All variables followed a normal distribution. No differences were found between 15RM test and retest ($p > 0.05$). The total volume for SEQA90 was $10,565.4 \pm 1,286.3$ kg, the total volume for SEQA40 was $10,024.3 \pm 1,277.6$ kg, the total volume for SEQB90 was $10,090.1 \pm 1,303.4$ kg and the total volume for SEQB40 was $9,613.9 \pm 955.4$ kg. The total load volume did not differ significantly between protocols, therefore the total amount of work performed in all sequences were similar ($p > 0.05$).

BP data were compared at rest (pre) and over 60 minutes (each 10-minute periods) post-exercise between ST sequences (SEQA90, SEQA40, SEQB90 and SEQB40). For SBP, significant reductions were found for all ST sequences compared to baseline; and post-exercise: SEQA90 at 20, 30, 40, 50 and 60 minutes ($p < 0.05$); SEQA40 and SEQB40 at 20 minutes ($p < 0.05$); and SEQB90 at 10, 20, 30, 40, 50 and 60 minutes ($p < 0.05$) (Figure 1).

For DBP, significant reductions were found for three sequences compared to baseline; and post-exercise: SEQA90 and SEQA40 at 50 and 60 minutes ($p < 0.05$); and SEQB40 at 10, 30 and 60 minutes ($p < 0.05$) (Figure 1). These findings were confirmed via the delta values (Figure 2).

The HRV data in frequency domain (LF, HF and LF/HF) were analyzed at baseline (pre) and over 60 minutes (in periods of 10 minutes) post-exercise between ST sequences. There were significant differences in frequency domain for all sequences compared to baseline (SEQA90 - 10, 20, 30, 40, 50 and 60 minutes; SEQA40 - 10, 20, 30, 40, 50 and 60 minutes; SEQB90 - 10, 20, 30, 40, 50 and 60 minutes and; SEQB40 - 10, 20, 30, 40, 50 and 60 minutes).

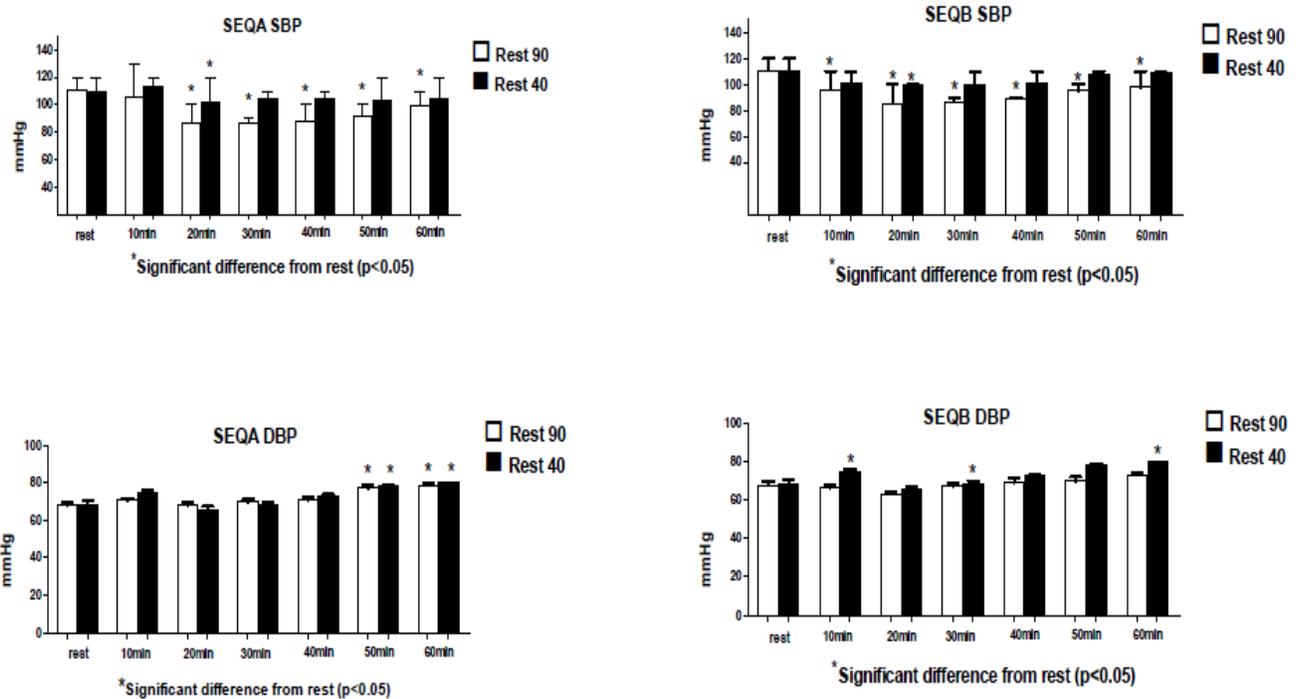


Figure 1. SBP and DBP after each sequence; SEQA = exercises performed from large to small muscle mass; SEQB = exercises performed from small to large muscle mass.

DISCUSSION

The purpose of this study was to compare the effect of a ST session performed with different exercise orders and rest intervals on BP and HRV in normotensive trained man. The major finding of this study was that a comprehensive upper body ST session, using rest intervals of 90 seconds between sets and exercises, promoted a longer PEH, specifically in SBP, when compared the exercises sequences that using a rest interval of 40 seconds between sets and exercises regardless of exercise order. In addition, the results of HRV showed variations independent of the exercise order or rest interval between sets, promoting an overall increase in sympathetic tonus and a decrease in parasympathetic tonus for 60 minutes' post-exercise. HRV is a tool that registers the activity of the autonomic nervous system on the sinus node, thus allowing the evaluation and identification of health commitment. For example, a high

HRV is a sign of a good functioning of the autonomic mechanisms, whereas the low variability is an indicator of an abnormal and insufficient adaptation of the autonomic nervous system (4).

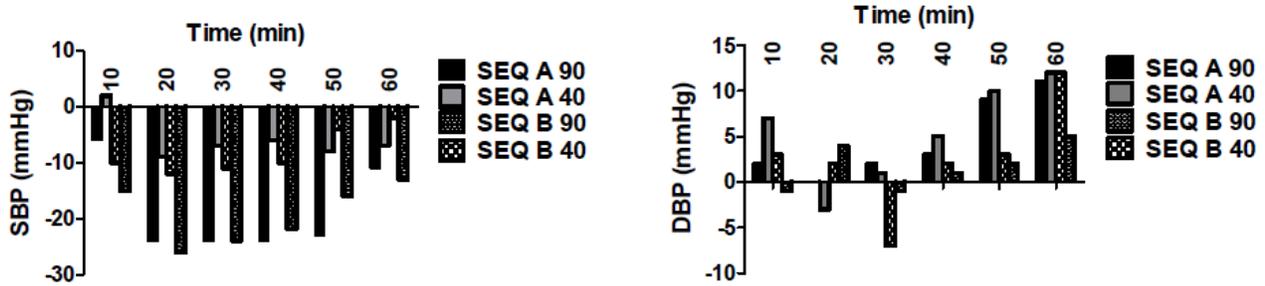


Figure 2. Delta variation of SBP and DBP after each sequence; SEQA = exercises performed from large to small muscle mass; SEQB = exercises performed from small to large muscle mass.

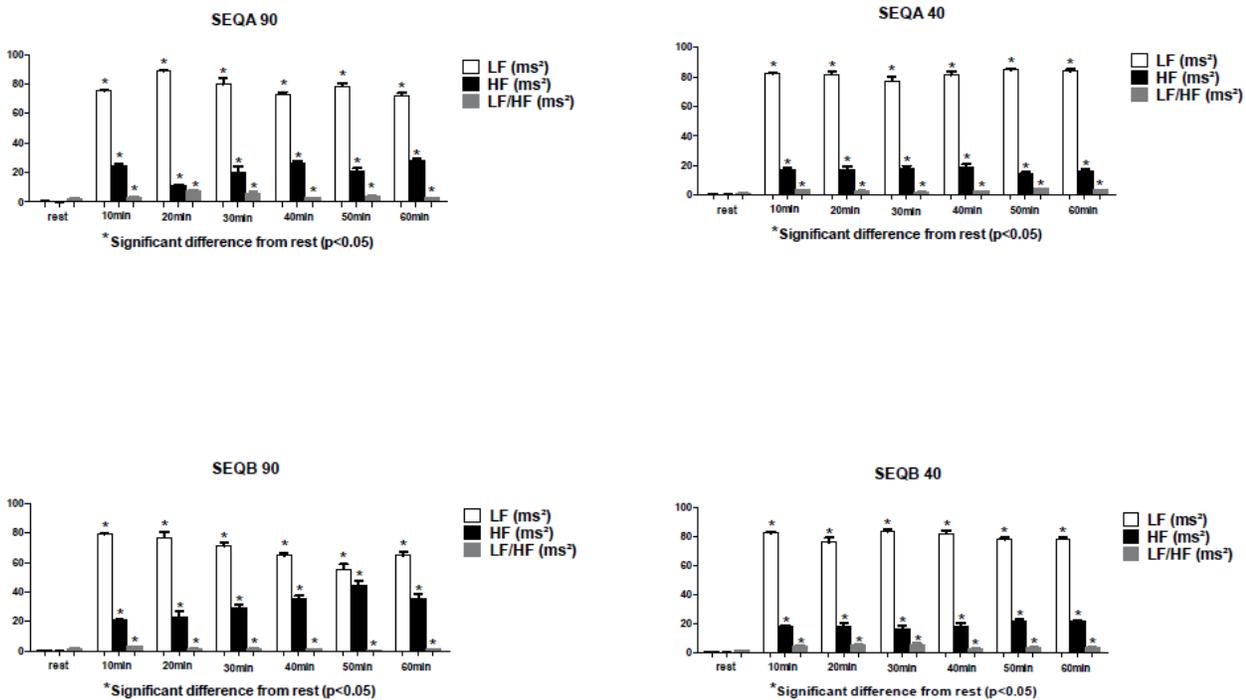


Figure 3. Frequency domain after each sequence; SEQA = exercises performed from large to small muscle mass; SEQB = exercises performed from small to large muscle mass.

These findings were consistent with previous studies which the larger rest interval (90 seconds) elicited a greater PEH response in SBP. De Salles et al. (10) compared the PEH of different rest intervals between sets and exercises (i.e., one and two minutes) using upper and lower body exercises for three sets of 10 repetitions in normotensive elderly men. It was found that both protocols elicited a PEH until 60 minutes'. However, the effect size statistics

indicated that SBP and DBP decreased to a greater extent after the session that utilized the two-minute rest interval.

On the other hand, Veloso et al. (34) evaluated the effect of different rest intervals (i.e., 1, 2 and 3 minutes) between sets on BP in normotensive, untrained men. The protocols consisted of upper and lower body exercises, with three sets of eight repetitions at 60, 70 and 80% of 1RM. The results showed that when the total workload was equated between load intensities, the rest interval between sets and exercises did not influence the magnitude of the PEH response. However, greater magnitude and duration of PEH was found in the DBP after the protocol that utilized the one-minute rest interval between sets. The ST sessions performed in this study differed from Veloso et al. (34) for SBP results. Whereas, in the Veloso et al. (34) study, the rest interval between sets differed, but the rest interval between exercises was consistently two minutes across protocols, in the present study, the same rest interval length was used between sets and exercises. So, the total exercise time and the total volume might be a key factors in promoting the PEH response (15).

In relation to exercise order, Jannig et al. (22) analyzed the influence of three different ST protocols with different exercise orders in PEH of elderly hypertensive subjects. The subjects performed a ST protocol beginning with upper body exercises and progressed toward to upper body exercises, a second ST protocol beginning with lower body exercises and progress toward to upper body exercises and a third ST protocol with alternate segments (i.e., one exercise for upper body and one exercise for lower body). The results of this study showed greater and longer PEH when ST were performed with alternate segment method. The results of this study were different from the Jannig et al. (22) study, because the results did not show any influence of exercise order on duration and magnitude of the PEH. These differences might have been due to the present study utilizing strictly upper body exercises and relatively limited muscle mass compared with Jannig et al. (22) that utilized both upper and lower body exercises. Figueiredo et al. (13) investigated the influence of different exercise orders on BP and heart rate variability (HRV) after a ST session in normotensive men. The authors did not found PEH and observed that HRV was significantly impacted by exercise order. The SEQ1 elicited an increase in sympathetic tonus and decrease parasympathetic tonus. It is true that lower limbs present larger amounts of blood vessels; on the other hand, upper limbs present a higher proportion of fast fibers, which can generate greater accumulation of metabolites and provide greater cardiovascular stress. However, further research is needed on this topic. The effect of muscle mass involved were previously described by Polito and Farinatti, (27).

In addition, Bentes et al. (6) compared the effect of two different exercise orders (i.e., alternate segments; one exercise for upper body and one exercise for lower body vs. upper body exercises and progress toward to lower body exercises) and two different load intensities (i.e., 60% and 80% of one repetition maximum) on SBP and DBP, in 13 healthy women. To compare the effect of exercise order on PEH, two ST sessions were performed that consisted of 3 sets of maximum repetitions and 2 minutes' rest intervals between sets and exercises. Significant BP decreases were found in all protocols, however, no significant difference were found between different load intensities and exercise orders. Although the Bentes et al., (6) study showed

significant decreases in SBP and DBP after different ST sessions, the modification of load intensity and exercise order, did not generate changes in the magnitude and duration of PEH.

The DBP increased in relation to baseline by the end of the observation period. The literature suggests some possible mechanisms that may be related to these findings regarding the reduction observed in SBP and an increase in DBP. Rezk et al. (29) suggested a decrease in ventricular pre-load while the peripheral vascular resistance (PVR) remains unchanged. Thus, there is a decrease in cardiac output and a decrease in BP. The decrease in ventricular pre-load can be influenced by decrease in venous return caused by a decrease in plasma volume, as apparently during ST, blood plasma is pressed into interstitial spaces, decreasing blood volume (8). Furthermore, there may be an increase in peripheral vascular resistance to maintain BP with the drop in stroke volume (26). In the current study, individuals remained in a seated position throughout the 60-minute post-exercise period; it is plausible to assume that the increase in DBP occurred due to reduced venous return and an increase in peripheral vascular resistance.

The findings of the current study showed that 40 second rest interval, although not significantly different, tended to have more of a negative impact on autonomic behavior versus 90 second rest interval. There was greater sympathetic stimulation and lesser parasympathetic stimulation associated with the 40 second rest interval between sets and exercises. Therefore, we can hypothesize that the shorter interval induced greater cardiac stress. Our results are partially corroborated by Figueiredo et al. (17) study that compared the effect of one and two minutes' rest interval between sets and exercises in an ST session performed by prehypertensive trained man. The results of this study showed that the rest interval between sets and exercises did not influence the PEH, however shorter rest intervals between sets and exercises (i.e., one minutes) promotes a greater cardiac stress.

The sequences that used the shorter rest interval produced a greater fatigue state versus the sequences with longer rest interval. It is possible to suggest that the shorter rest interval resulted in increased sympathetic cardiac activation. This response may have been due to greater activation of mechanoreceptors and chemoreceptors with the shorter rest interval, providing sensory feedback according to a higher level of exertion and ensuing state of metabolic acidosis, to promote greater sympathetic cardiac activation to increase cardiac output (17, 28).

Rezk et al. (29) investigated the effect of two different load intensities (40 and 80% of 1RM) on autonomic responses, using a 45 second rest interval between sets of 40% of 1RM and 60 second rest interval between sets of 80% of 1RM; and 90 second rest interval between all exercises in both protocols. Both protocols consisted of upper and lower body exercises. There were no significant differences in autonomic modulation between load intensities. Similarly, Lima et al. (25) compared the effect two different load intensities (50% and 70% of 1RM) on autonomic responses. Sessions were composed of only upper body exercises, with three sets of six, nine and 12 repetitions at each load intensity, respectively; and rest intervals of two minutes between sets and exercises. Significant differences were found between load

intensities, with greater changes in autonomic modulation demonstrated at 70% versus 50% of 1RM. In addition, Figueiredo et al. (16) compared the effect three different load intensities (60%, 70% and 80% of 1RM) on autonomic responses on pre-hypertensive trained men. The ST sessions were composed of upper body and lower body exercises, with three sets of 8-10 repetitions at each load intensity respectively; and two minutes' rest interval between sets and exercises. Significant differences were found between load intensities, with greater changes in autonomic modulation demonstrated at 80% of 1RM loads when compared to 60% and 70% of 1RM loads. The results of this studies showed that cardiac stress can be related to ST intensity.

Ultimately, it is important to consider some limitations of this study. SBP can be affected during a supine position following a ST session Farinatti et al. (11). HRV can be affected during a seated position Gotshall et al. (19). Due to a lack of studies reporting the influence of exercise order and rest intervals lengths on BP and HRV following a ST session, a seated position was adopted in the present study. We did not directly analyze cardiac variables closely related to PEH and this study did not have a control group. Thus, because this study utilized normotensive young subjects with previous experience in ST, the results presented here may not be generalizable to other populations, such as hypertensive subjects. Further research is needed to examine the PEH and HRV related to the manipulation of ST load variables like number of sets and training intensity and associated with other physical activities like aerobic training and flexibility training.

In conclusion, when performing upper body strength training sessions, it is suggested that 90 second rest intervals between sets and exercises promotes a post-exercise hypotensive response in systolic blood pressure. The 40 second rest interval between sets and exercises was associated with greater cardiac stress, and might be contraindicated when working with individuals that exhibit symptoms of cardiovascular disease. Further studies are recommended to verify the impact of rest interval length between sets and exercises to promote chronic reductions in BP in hypertensive populations.

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