Postexercise hypotension and heart rate variability responses subsequent to traditional, paired set, and superset resistance training methods.

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Running head: Strength training methods and hemodynamics.

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Abstract

The purpose of this study was to compare training volume, post-exercise hypotension (PEH) and heart rate variability (HRV) responses to different strength training methods. Thirteen trained men volunteered for this study. Three training methods were completed in a randomized design, which included: Traditional Set (TS) – three successive sets for the lying bench press (LBP), lat pulldown (LPD), incline 45º bench press (BP45), seated close-grip row (SCR), triceps extension (TE), and biceps curl (BC), with a 90 sec. rest interval between sets and exercises; Paired Set (PS) – three paired sets for the LBP-LPD, BP45-SCR, and TE-BC, with a 90 sec. rest interval between sets and exercises; and Super-Set (SS) – three super-sets for the LBP-LPD, BP45-SCR, and TE-BC. During the SS session, no rest was permitted between paired sets, followed by 180 sec. rest after each super-set. Ten repetition maximum (RM) loads were adopted for all exercises. Blood pressure and HRV were measured at baseline, immediately post-session, and at 10 min. intervals until 60 min. post session. Significantly greater training volume was noted under the SS method (8608.6 ± 2062.2 kg) versus the TS method (7527.5 ± 2365.1kg), respectively. Significantly greater training volume was also observed under the PS method (8262.3 ± 2491.2kg) versus the TS method (p ≤ 0.05). No main effects for HRV and PEH were noted between protocols (p > 0.05). However, similar PEH responses intra-protocol were observed for the TS, PS and SS methods (p ≤ 0.05). Considering the duration of the PEH intra-protocol, large effect sizes were noted for the SS and PS methods versus the TS method in diastolic and mean blood pressure. Therefore, both the PS and SS methods may be an alternative to the TS method to achieve greater total work and training volume with a tendency towards a longer PEH response.

Keywords: Blood pressure, strength training, cardiovascular response, autonomic control.
Introduction

Conditioning programs generally promote benefits in health for individuals of all ages, especially with the goal of controlling blood pressure (BP) (25). Strength training has been associated with acute reductions in post-exercise blood pressure, a phenomenon called post-exercise hypotension (PEH), which may play a key role in chronic blood pressure and cardiovascular risk reduction (5). Heart rate variability (HRV) is a reflection of autonomic modulation of the heart (30) and the study of this variable leads to greater understanding of the autonomic nervous system in cardiac vagal control (26).

Strength training methods are characterized by the manipulation of prescriptive variables with the goal to optimize muscle strength, power, localized endurance, and hypertrophy gains (21). Previous studies have examined PEH responses after strength training sessions performed in different formats such as a Paired Set (PS), Super-Set (SS) or Traditional Set (TS), while incorporating different numbers of sets (e.g., 1, 3 vs. 5 sets) (6), load intensities (e.g. 60%, 70%, and 80% of 1 repetition-maximum) (8), rest intervals between sets and exercises (4, 7, 32), and exercise sequences (e.g., multi and single joint exercises) (20).

In addition, decreased HRV in apparently healthy subjects or after myocardial infarction is a risk factor for mortality (24). To date, little is known about the impact of these different resistance training methods on HRV (6, 8, 10). Paired Sets are characterized by the performance of pulling and pushing exercises with or without agonist-antagonist relationship in an alternating manner (28). Paz et al. (20) investigated the PEH response in a sample of trained men following a strength training session composed of three sets to failure (e.g., bench press and wide-grip seated row) with 8 repetition maximum (RM) loads and 2-minute rest intervals between sets and exercises, adopting either the Tradition Set versus the agonist-antagonist Paired Set method.
Both methods provided long PEH responses (e.g. 40 min), although a larger magnitude was observed under the agonist-antagonist Paired Set method for systolic blood pressure (SBP) and diastolic blood pressure (DBP). Furthermore, Maia et al. (14) found significant increases in repetition performance and myoelectric activity of the knee extensors for an agonist/antagonist Super-Set protocol (e.g., without rest between sets) using 10-RM loads for the prone leg curl and leg extension exercises, and with shorter rest intervals (e.g., no rest, 30 seconds, or 1 minute) versus longer rest intervals (e.g., 3 minutes or 5 minutes) between paired exercises.

In this regard, previous studies have shown that set configuration, training volume, and intensity promote changes in cardiac vagal control and PEH (3, 11, 17, 19). Furthermore, the cardiovascular effects associated with strength training sessions performed with differing training methods may provide useful information for practitioners in designing programs. Therefore, the purpose of this study was to compare training volume, post-exercise hypotension and heart rate variability responses to different strength training methods (e.g. PS, SS, TS) in a sample of recreationally trained men. It was hypothesized that the PS and SS methods would result in greater training volume versus the TS method, and consequently promote longer hypotensive responses and an augmentation of HRV indices.

**Methods**

**Experimental approach to the problem**

The study was a randomized cross-over design. To compare training volume, PEH and HRV responses, subjects performed three different strength training methods (e.g. PS, SS, TS). The three training methods were randomly performed on non-consecutive days with at least 48 hours between experimental sessions.
The training methods implemented in this experiment were: Traditional Set – three successive sets for the lying bench press (LBP), lat pulldown (LPD), incline 45° bench press (BP45), seated close-grip row (SCR), triceps extension (TE), and biceps curl (BC) with a pulley, with a 90 sec. rest interval between sets and exercises; Paired Set (PS) – three paired sets for the LBP-LPD, BP45-SCR, and TE-BC, with a 90 sec. rest interval between sets and exercises; and SS – three super-sets for the LBP-LPD, BP45-SCR, and TE-BC. During the SS session, no rest was permitted between paired sets, followed by 180 sec. rest after each super-set. Ten RM loads were adopted for all exercises. Blood pressure and HRV were measured at baseline, immediately post-session, and at 10 min. intervals until 60 min. post session.

*** Insert Figure 1***

Subjects

Prior to participation and data collection, all subjects completed the Physical Activity Readiness Questionnaire. This study was approved by the Ethics Committee of the institution (nº 51654515.2.0000.5257). A counter-balanced, crossover design was used to compare the effects of strength training sessions between training methods on PEH and HRV responses. Thirteen men with at least five years of recreational strength training experience volunteered for this study (age: 26.2 ± 3.9 years, body mass: 81.2 ± 5.9 kg, height: 175.1 ± 10.9 cm, body mass index: 23.9 ± 3.1 kg.m⁻², SBP: 121.2 ± 10.1 mmHg and DBP: 82.2 ± 7.8 mmHg). Subjects did not have any recent history of upper or lower body injury. The exclusion criteria for the study were as follows: (a) the existence of musculoskeletal or cardiovascular problems that might influence the performance of the proposed exercises; (b) use of medication affecting cardiovascular responses;
Before the start of each experimental session, subjects were instructed not to consume any caffeinated or alcoholic beverage while maintaining their usual activities and eating habits, and to avoid any abrupt changes in resting metabolism throughout the study period. Height was measured by a wall stadiometer (Sanny, Sao Paulo, Brazil). Weight was measured on a digital scale (WelmyW110H, Sao Paulo, Brazil).

Ten repetition loads determination

During the first and second testing sessions, 10-RM loads were obtained (e.g. test-retest) for LBP, LPD, BP45, SCR, TE and BC exercises with at least 48 hours between testing sessions. The 10-RM test was performed following the protocol proposed by Paz et al. (21). The initial load was estimated according to the weight commonly used during strength training sessions. The objective of the 10-RM test was to carry out 10 consecutive repetitions at peak load. If the subject did not accomplish a 10-RM in the first attempt, the weight was adjusted by 4–10 kg and a minimum 5-minute rest period was given before the next attempt. Only three trials were allowed per testing session. The following strategies were adopted to reduce the margin of error in the data collection procedures (13): (a) standardized instructions were given before the tests such that the person being tested would be aware of the entire routine involved in the data collection; (b) the individual being tested was instructed on the proper exercise execution; (c) all subjects were given standardized verbal encouragement throughout the tests; and (d) all tests were conducted at the same time of the day for every session.

Strength training sessions

Before the experimental sessions, all subjects performed a standardized warm-up composed of two sets of 15 repetitions of the LBP exercise with 50% of 10-RM loads.
During the session, no pause was allowed between the eccentric and concentric phases of a repetition or between repetitions. Subjects performed each session at approximately the same time of the day. The number of successful repetitions completed was recorded during each set, exercise and protocol. Rating of perceived exertion (RPE) was also computed via OMNI-RES scale after the last set of each exercise during all experimental sessions (29). The session median of each experimental session was considered during statistical analyses.

**Perceived Exertion assessment procedures**

One week before the experimental protocols, instructions were provided on the nature and use of the OMNI-RES scale. The scale anchoring procedure provided the subject with an understanding of the range of perceptions that corresponded to the low- and high-rating categories. The anchoring procedures allowed the subjects to experience the two extremes of RPE: rating 1 (*extremely light*) and rating 9 (*extremely hard*). In the present study, the RPE was taken at the end of each set for all protocols.

**Measures of heart rate and heart rate variability**

The R wave to R wave interval (RR) of heart rate was recorded for 10 and 60 minutes before and after the experimental sessions with a heat rate (HR) monitor (Polar, Polar RS800CX, Finland). Recently, Hernando *et al.* (9) indicated that the RR interval provided by Polar device was useful to study the evolution of slow oscillations in HRV, such as the changes in mean HR or the low frequency (LF) component. For all visits, subjects reported to the research laboratory between 6 and 11 A.M. to control for diurnal variation. Heart rate and HRV data were collected with subjects in a seated position with palms facing up in a quiet room with temperature maintained between 20 and 22º C. All subjects breathed with a metronome set at 12 breaths per
minute to control for the respiratory effects on autonomic modulation. Eight small samples of beats were used (time points: Pre- and Post - 0-5 min; 10: 5-10 min; 20: 15-20 min; 30: 25-30 min; 40: 35-40 min; 50: 45-50 min; 60: 55-50 min) in the Fast Fourier transformation to generate spectral power.

Data were recorded on the equipment and then immediately downloaded to the computer to be analyzed. After this procedure, the data were digitized in Matlab (Matlab version 6.0; MathWorks, MA, USA) for analysis in the time and frequency domains. Kubios software version 2.0 (MathWorks, Natick, MA, USA) was used to calculate HRV indexes in the time and frequency domains. HR variability was calculated in both time and frequency domains. The spectral analysis in the frequency domain was performed by the Fast Fourier algorithm. For HRV analysis in the frequency domain, we used the spectral components of low frequency (LF: 0.04 to 0.15 Hz) and high frequency (HF: 0.15 to 0.4 Hz), in normalized units, in addition to the LF/HF ratio. The HFnu was used as indicative of cardiac parasympathetic modulation, while LFnu is sometimes used as more reflective of sympathetic modulation. Normalized units (LF or HF) are derived by dividing the power of a component by the total power minus the very low frequency power. The normalized values of LF (LFnu) and HF (HFnu) were used as measures of sympathetic and parasympathetic modulation, respectively. Time domains included the square root of the mean squared differences of successive R-R intervals (RMSSD). The RMSSD is usually referred as a measure of parasympathetic cardiac modulation (30).

**Arterial Blood Pressure Assessment**

The SBP, DBP, and mean blood pressure (MBP) were measured using an automatic oscillometric device (PM50 NIBP/Spo2; CONTEC, USA).
The equipment was auto calibrated before each use. The MBP was calculated based on
the equation: $\text{MBP} = \text{DBP} + ((\text{SBP} + 2 \times \text{DBP})/3)$ (20). During each experimental session, blood
pressure was assessed after a 10-minute passive rest period in a seated position on arrival at the
laboratory. The resting blood pressure values were averaged over two consecutive measurements
with five minutes between measurements at the end of the RR recording. Blood pressure was
then assessed immediately after each experimental session and then at 10-minute intervals for 60
minutes after each experimental session, resulting in a total of 6 measurements after each
experimental session. Measurements were performed from the left arm, consistent with the
recommendations of the American Heart Association (2). The SBP, DBP, and MBP were
considered for further analysis.

**Statistical analysis**

Normality of all variables was analysed by the Shapiro-Wilk test. Test-retest reliability
of 10-RM loads was conducted using the intraclass correlation coefficient ($\text{ICC} = (\text{MSb} - \\
\text{MSw})/[(\text{MSb} + (k-1)\text{MSw})]$), where $\text{MSb} =$ mean-square between, $\text{MSw} =$ mean-square within,
and $k =$ average group size. The cutoff points for classification of the ICC were defined
considering: weak reliability ($\text{ICC} \leq 0.40$); moderate reliability ($0.41 \leq \text{ICC} < 0.75$); and excellent
reliability ($\text{ICC} > 0.75$) (21). Resting day-to-day repeatability was also analyzed by ICC for HFnu
and LFnu. The coefficient of variation was also computed for HFnu and LFnu at rest. Total work
(repetitions x sets) and training volume (repetitions x sets x external loads) were computed for
each exercise and the sum of all exercises indices was considered to represent the total work and
training volume of each protocol. One-way repeated measures ANOVA was used to compare the
pre-intervention and the lowest value after training of SBP, MPB, DBP, total work and training
volume between conditions (e.g. traditional, paired set and superset).
A two-way repeated measures ANOVA (time [Rest vs Post- vs 10 min vs 20 min vs 30 min vs 40 min vs 50 min vs 60 min] x protocols [traditional vs paired set vs superset]) was used to analyze the blood pressure assessments (SBP, DBP, MBP) and HRV assessments (RMSSD, LF-nu and HF-nu). A two-way repeated measure ANOVA [protocols (3) x time-point (2)] was implemented to compare the pre-intervention and greatest individual decrease of SBP, DBP, and MBP between training methods. Multiple comparisons with Bonferroni correction were performed when necessary. Rating of perceived exertion was compared using the Friedman non-parametric test. An \( \alpha \)-level of \( p \leq 0.05 \) was adopted for all comparisons. SPSS version 20.0 (SPSS Inc., Chicago, Illinois, USA) was used for all statistical analyses. Additionally, to determine the magnitude of differences, effect size statistics (ES; the difference between pre-test and post-test scores divided by the pre-test standard deviation) were calculated for the SBP, DBP, MBP, LF-nu, HF-nu and RMSSD for all exercise sequences. The magnitude of the ES was interpreted using the scale proposed by Rhea (27) for recreationally trained individuals, where ES lower than 0.5, 0.50–1.25, 1.25–1.9, and higher than 2.0 are referred as trivial, small, moderate, and large effects respectively.

RESULTS

All tested variables followed a normal distribution. The ICC of 10-RM test and retest was LBP = 0.91, LPD = 0.92, BP45 = 0.97, SCR = 0.98, TC = 0.95 and BC = 0.97. Significant differences were noted between protocols for total work \( (F_{2, 24} = 5.569; p = 0.010, \text{see Table 1}) \) and training volume \( (F_{2, 24} = 7.168; p = 0.004) \), respectively. Post-hoc pairwise comparisons showed significantly greater total work \( (p = 0.009) \) and training volume \( (p = 0.002) \) for the SS protocol versus the TS protocol. Training volume \( (p = 0.002) \) and total work \( (p = 0.032) \) were also significantly greater for the PS protocol versus the TS protocol.
However, there was no significant difference between the PS protocol versus the SS protocol for total work ($p = 0.247$) and training volume ($p = 0.783$). No main effects between protocols were noted for RPE ($p = 0.061$).

**Insert Table 1**

There was no significant difference between protocols in SBP ($p = 0.759$), DBP ($p = 0.441$) and MBP ($p = 0.609$) (see Figure 2). There were no significant interactions among protocols and time-points for SBP ($p = 0.468$), DBP ($p = 0.435$) and MBP ($p = 0.278$). However, there was a significant main effect for time-points intra-protocol in SBP ($F_{7,84} = 19.943; \ p = 0.0001$), DBP ($F_{7,84} = 17.071; \ p = 0.0001$), and MBP ($F_{7,84} = 12.741; \ p = 0.0001$), showing significantly lower values after all protocols versus baseline values.

**Insert Figure 2**

Significant differences were observed between baseline and the lowest value post-session in SBP ($F_{1,12} = 7.925; \ p = 0.001$), MBP ($F_{1,12} = 33.927; \ p = 0.004$), and DBP ($F_{1,12} = 15.861; \ p = 0.0001$; see Table 2). The magnitude of difference (delta) between baseline and the lowest blood pressure value post-session was significantly different in SBP, MBP, and DBP for the SS protocol versus the TS protocol (SBP – $p = 0.0001$; MBP – $p = 0.0001$; DBP – $p = 0.0001$) and PS (SBP – $p = 0.041$; MBP – $p = 0.0001$; DBP – $p = 0.0001$).

**Insert Table 2**

No main effects for protocols were noted for RMSSD ($p > 0.05$; see figure 3). There were no significant interactions between protocols and time-points ($p > 0.05$). However, significant main effects intra-protocol for time-points were observed ($F_{7,84} = 49.773; \ p = 0.0001$).
The resting day-to-day ICCs for HFnu and LFnu were 0.91 and 0.89, respectively. The coefficient of variation was also calculated at 14% for HFnu and 15% for LFnu at rest. For HFnu, no main effects between protocols were observed ($p > 0.05$; see Figure 4). However, significant main effects were noted for time-points intra-protocol ($F_{7,84} = 4.653; p = 0.0001$). Additionally, no main effects for protocol were noted for LFnu ($p > 0.05$). However, significant main effects were observed for time-points ($F_{7,84} = 8.412; p = 0.0001$). There were no significant interactions between protocols and time-points ($p > 0.05$) for HFnu and LFnu.

No significant main effects for protocols ($p > 0.05$; see Figure 5), nor interactions between protocols and time-points ($p > 0.05$) were noted for the LF/HF index. A significant main effect was noted for time-points ($F_{7,70} = 172.484; p = 0.004$). Regarding the comparison between time-points, it was observed that the LF/HF index was higher at all time-points during recovery versus baseline values for the TS, PS and SS protocols.

The ES with respect to baseline values are reported in Table 3. Large ES were observed for DBP at 10, 20, 30, 40 and 60-min. after exercise for the PS protocol. Similar results were noted for MBP after the PS protocol. In general, large reductions in RMSSD were observed from the 10 to 60-min. time points after each protocol.
Discussion

The purpose of this study was to compare training volume, PEH and HRV responses to different strength training methods. The key findings of the current study were that higher training volume and total work were accomplished for the Super-Set and Paired Set methods versus the Traditional Set method, respectively. Thus, there were no differences between the Paired Set and Super Set methods for strength parameters. No main effect for protocols was observed for blood pressure and HRV variables. Furthermore, there were significant main effects intra-protocol for blood pressure and HRV indices for the post-session time points versus baseline.

In this study, subjects performed three different experimental sessions consisting of the same exercises, number of sets and training loads, but differing in the exercise order and total inter-set recovery period. The PEH responses among training methods were partial agreement with previous studies (6-8, 20, 32). Despite the lack of main effects for protocols, the Paired Set and Super-Set training methods provided moderate to large ES for all post-session time points versus baseline in DBP and MBP, while trivial or small ES were observed after the Traditional Set protocol.

Previous studies have indicated that higher training volume and intensity induces increased activation of metaboreceptors, mechanoreceptors, and the arterial baroreflex due to a reduction in blood flow (due to a reduction in plasma volume) to the active muscles (6, 7, 8, 10, 23). Additionally, several mechanisms have been suggested to mediate increases in arterial pressure during strength training, including: central neural mechanisms, an elevated intrathoracic pressure coincident with the Valsalva maneuver, and reflex neural responses from
chemosensitive and mechanosensitive nerve endings within exercising muscles, and mechanical compression of the skeletal muscle vasculature (15, 17, 18).

These above-mentioned studies showed greater and longer PEH responses when the strength training session contained higher training volume and/or load intensities [80% of 1-RM (8) and five sets (6)], respectively. Figueiredo et al. (7) compared the effects of two different rest intervals between sets and exercises during strength training on blood pressure and HRV in prehypertensive trained men. Each strength training session consisted of performing three sets of 8 to 10 repetitions at 70% of a 1RM for each exercise, with either 1-min. or 2-min. rest intervals between sets and exercises, respectively. Similar PEH were noted in both sequences, with a greater withdrawal in parasympathetic activity vs. baseline as noted in the HF band at 1, 10, and 20-min. post-exercise. Moreover, Teixeira et al. (31) evaluated the hemodynamic and autonomic responses comparing the following: Control (30 min of rest), Aerobic (30 min, cycle ergometer, 75% of VO2 peak), Resistance (6 exercises, 3 sets, 20 repetitions, 50% of 1 RM), and Concurrent training sessions with twenty health subjects. They noted that DBP decreased similarly after all the sessions, but this decrease lasted longer after the aerobic session. Cardiac output also decreased similarly after all the sessions, while systemic vascular resistance increased after the Resistance and Concurrent sessions in the recovery period, respectively. Teixeira et al. (31) associated the decreases in cardiac output observed after the three exercise sessions to a decrease in SV which might be related to a decrease in cardiac contractility and/or a reduction in pre-load. Similar mechanisms might account for the PEH response observed in the current study particularly following the Paired Set and Super-Set protocols.
In the current study, the longer rest between like sets might be one of the factors that could justify the greater total work and training volume observed under the Super-Set and Paired Set protocols versus the Traditional Set protocol. The rest interval adopted between like sets (e.g., bench press set to another bench press set) under the Super-Set and Paired Set protocols was 50 to 100% longer than the Traditional Set protocol, considering the passive rest plus the performance of the next paired set exercise. Regarding the total recovery period implemented during each experimental session (e.g., the total sum of each exercise rest interval block), the Super-Set allowed for greater inter-set rest (e.g., 1530 sec.) versus the Traditional Set and Paired Set protocols (e.g., 1440 sec.), respectively.

In the current study, no main effects were noted between protocols in HRV measures. The current results reflected a lower vagal cardiac modulation after each experimental session, which was consistent with previous studies which investigated the acute effects of strength training on HRV indices (10, 11, 17, 30). Additionally, no significant interaction between time and experimental protocols was detected. Therefore, it could be suggested that set configuration (e.g., TS, PS and SS) did not affect acute changes in autonomic cardiac modulation. This absence of significant differences could be attributed to the large variability in responses among subjects (1). In addition, the results for HRV showed that all experimental sessions elicited significant cardiac stress. Nicolino et al. (19) and Figueiredo et al. (8) demonstrated that cardiac sympathetic activation remains higher than resting values following an upper-body strength training protocol. Their results partially corroborate the results of this study. For instance, after all sessions, there was an increase in sympathetic activation and a reduction of parasympathetic activation observed by the RMSSD index. This finding may have an important clinical implication; an increase in sympathetic activation combined with a reduction in parasympathetic
activation may increase the risk of cardiovascular events in patients with cardiovascular disease (24).

On the other hand, the ES data presented a large magnitude in sympathetic tonus and a large decrease in parasympathetic tonus (e.g., RMSSD) for all experimental sessions. Unlike previous studies that used equalized volumes (e.g., fixed number of repetitions) (6-8); in the present study, all sets were performed to repetition failure, which may have activated a greater number of motor units with greater activation of the sympathetic nervous system to maintain consistent repetition performance over the sets and exercises, respectively (10, 26).

Mayo *et al.* (16) investigated the effects of three set configurations on cardiac autonomic control and baroreflex sensitivity. Seventeen trained subjects performed one control session and three experimental sessions of the leg-press exercise with the same volume (40 repetitions), total recovery time between sets (720 s), and load intensity (10RM load): (a) 5 sets of 8 repetitions with 3 min. rest between sets (8S), (b) 10 sets of 4 repetitions with 80 sec. rest between sets (4S), and (c) 40 sets of 1 repetition with 18.5 sec. rest between each repetition (1S). They noted that longer set configurations (8S and 4S) induced greater reductions of the vagal cardiac autonomic control and baroreflex sensitivity compared with a shorter set configuration (1S). However, in the current study, the Super-Set protocol presented the longer recovery period between like sets (e.g., BP followed by LPD exercise plus 180 sec. rest).

Thus, we can hypothesize that similar changes in cardiac autonomic control detected in our study can be partly explain by the fact that each set was performed leading to repetition failure in every session. In this regard, it has been previously suggested that strength training protocols lead to a reduction in plasma volume by a shift of plasma liquid from the blood to
interstitial spaces (26), and this decrease in plasma volume can lead to a deactivation of cardiopulmonary receptors, increasing the sympathetic activation to the heart (22).

Despite the reduction in parasympathetic cardiac modulation observed after resistance exercises, several studies have reported no changes in resting HRV of individuals with normal cardiac autonomic modulation (6, 7, 8). In addition, there is increasing support for the use of strength training in individuals with chronic diseases (11), including individuals with autonomic and endothelial dysfunction such as hypertension or fibromyalgia. Previous evidences indicated that the improvements in cardiovagal control after strength training in those with autonomic dysfunction may be due to greater physical deconditioning and adiposity (12, 16, 17). However, the duration of the training stimulus and the exercise prescription need to be further investigated to truly understand the effects of strength training on the autonomic nervous system.

Some limiting factors were not controlled, such as endothelium-dependent vasodilator agents, autonomic activity, cardiac output and the different recovery period between like sets during each training method adopted in the current study. Additionally, statistical power was limited by the sample size, so further studies should consider an a priori power analysis in order to overcome this limitation. It is also important to note that these data apply to young, healthy individuals and may not necessarily be true for other populations. Furthermore, future studies should implement strength training sessions with different configurations of load intensity, exercise order, and work-to rest ratio in order to investigate PEH and HRV changes between training methods.
In conclusion, the Super-Set and Paired Set methods provided greater total work and training volume than the Traditional Set method, respectively. No difference in total work and training volume was noted between the Paired Set and Super-Set methods. Additionally, the implementation of different training methods did not generate significant changes in the duration and magnitude of hypotensive effect and HRV responses. Despite this lack of difference, the Super-Set and Paired Set sessions showed a trend toward a longer PEH for DBP and MBP versus the Traditional Set method. A significant main effect intra-protocol was noted for HRV indices across time points, with an increase in sympathetic modulation and a decrease in parasympathetic modulation after all strength training sessions. These results have clear applicability in gym and training centers, and also add important knowledge regarding the potential benefits of strength training for prevention of hypertension, control of autonomic system and blood pressure levels in apparently health trained men. Furthermore, the training methods characterized by the performance of pushing and pulling exercises in an alternating manner with longer recovery periods between like sets (e.g., Paired Set and Super-Set methods) seem to be more effective to achieve greater acute total work and training volume than the Traditional Set method. Therefore, both the Paired Set and Super-Set methods might be an alternative to the Traditional Set method in order to achieve greater training volume with a trend towards longer PEH responses.
REFERENCES


Figures legends

Figure 1 – Study design

Figure 2 – Mean and SD (bar) of systolic (A), diastolic (B), and mean blood pressure (C) between protocols and time points.
* Significant difference from rest (main time effect); † Significant difference from postsession (main time effect) intra-protocol.

Figure 3 - Index RMSSD results (mean and SD).
* Significant difference from rest (main time effect); † Significant difference from postsession time point (main time effect).

Figure 4 - Index high and low frequency indices results (mean and SD).
* Significant difference from rest (main time effect); † Significant difference from postsession (main time effect).

Figure 5 - Values of HF/LF indexes in the frequency domain, in evaluated moments, expressed as mean (bar) and standard deviation (line). * Significant difference from baseline (main time effect); † Significant difference from post-session (main time effect).

Tables legends

Table 1 – Total work, training volume, and rating of perceived exertion (RPE) values between protocols.
Total work = repetition x sets x exercises; training volume = repetitions x sets x loads x exercises; * Significant difference from or traditional protocol (p ≤ 0.05);

Table 2 - Values as mean (SD) of pre-intervention, greatest individual decrease, and difference between pre-intervention and percentage decrease (Δ) of systolic (SBP), mean (MBP) and diastolic (DBP) blood pressure for traditional, paired set and superset training methods.
*P<005 versus pre-intervention. †Significant difference for Δ blood pressure versus traditional method; ¥ Significant difference for Δ blood pressure versus paired set method.

Table 3 - Effect size: SBP, DBP, MBP, and RMSSD after three methods of resistance training.*
*SBP = systolic blood pressure; Sm = small; Mod = moderate; DBP = diastolic blood pressure; MBP = mean blood pressure; RMSSD = SD of differences between adjacent normal.

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Table 1 – Total work, training volume, and rating of perceived exertion (RPE) values between protocols.

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Total work (repetitions)</th>
<th>Training Volume (kg)</th>
<th>RPE (median)</th>
<th>Session duration (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>128 (17.5)</td>
<td>7527.5</td>
<td>8</td>
<td>39 (2.8)</td>
</tr>
<tr>
<td></td>
<td>(2365.1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paired Set</td>
<td>138.2 (21.5)*</td>
<td>8262.3</td>
<td>8</td>
<td>39.5 (3.4)</td>
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<tr>
<td></td>
<td>(2491.2)*</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Superset</td>
<td>143 (13.3)*</td>
<td>8608.6</td>
<td>8</td>
<td>40.7 (2.0)</td>
</tr>
<tr>
<td></td>
<td>(2062.2)*</td>
<td></td>
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</tbody>
</table>

Total work = repetition x sets x exercises; training volume = repetitions x sets x loads x exercises; * Significant difference from traditional protocol (p ≤ 0.05);
Table 2 - Values as mean (SD) of pre-intervention, greatest individual decrease, and difference between pre-intervention and percentage decrease (Δ) of systolic (SBP), mean (MBP) and diastolic (DBP) blood pressure for traditional, paired set and superset training methods.

<table>
<thead>
<tr>
<th></th>
<th>Traditional</th>
<th>Paired set</th>
<th>Superset training</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SBP (mmHg)</td>
<td>MBP (mmHg)</td>
<td>DBP (mmHg)</td>
</tr>
<tr>
<td>Pre-intervention</td>
<td>130.8 (16)</td>
<td>88.8 (11.7)</td>
<td>77.5 (11.9)</td>
</tr>
<tr>
<td></td>
<td>134.2 (11.3)</td>
<td>94 (8.4)</td>
<td>78.5 (7.6)</td>
</tr>
<tr>
<td></td>
<td>129.4 (10.4)</td>
<td>90.3 (8.7)</td>
<td>76.3 (8.8)</td>
</tr>
<tr>
<td>Post-intervention</td>
<td>113.4 (11.1)*</td>
<td>69.6 (15.2)*</td>
<td>56.7 (8.5)*</td>
</tr>
<tr>
<td>Lowest value</td>
<td>113.9 (9.5)*</td>
<td>70.5 (9.8)*</td>
<td>55.8 (6.8)*</td>
</tr>
<tr>
<td></td>
<td>114.4 (8.2)*</td>
<td>71.6 (7.6)*</td>
<td>53.2 (8.2)*</td>
</tr>
<tr>
<td></td>
<td>12.6 (9.3)</td>
<td>22.2 (10.6)</td>
<td>25.6 (12.7)</td>
</tr>
<tr>
<td></td>
<td>14.9 (5.3)</td>
<td>25.6 (11.3)</td>
<td>28.2 (11.7)</td>
</tr>
<tr>
<td></td>
<td>25.2 (5.8)†</td>
<td>42.3 (10.9)†</td>
<td>51.1 (11.5)†</td>
</tr>
<tr>
<td>P value</td>
<td>0.001</td>
<td>0.002</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>0.001</td>
<td>0.023</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>0.001</td>
<td>0.001</td>
<td>0.002</td>
</tr>
<tr>
<td>%Δ, mmHg</td>
<td>12.6 (9.3)</td>
<td>22.2 (10.6)</td>
<td>25.6 (12.7)</td>
</tr>
<tr>
<td></td>
<td>14.9 (5.3)</td>
<td>25.6 (11.3)</td>
<td>28.2 (11.7)</td>
</tr>
<tr>
<td></td>
<td>25.2 (5.8)†</td>
<td>42.3 (10.9)†</td>
<td>51.1 (11.5)†</td>
</tr>
</tbody>
</table>

*P≤0.05 versus pre-intervention. †Significant difference for Δ blood pressure versus traditional method; ¥ Significant difference for Δ blood pressure versus paired set method.
Table 3 - Effect size: SBP, DBP, MBP, and RMSSD after three methods of resistance training.*

<table>
<thead>
<tr>
<th></th>
<th>Traditional</th>
<th>10 min</th>
<th>20 min</th>
<th>30 min</th>
<th>40 min</th>
<th>50 min</th>
<th>60 min</th>
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<tbody>
<tr>
<td>SBP</td>
<td>Magnitude</td>
<td>0.50</td>
<td>0.28</td>
<td>0.46</td>
<td>0.31</td>
<td>0.43</td>
<td>0.39</td>
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<tr>
<td></td>
<td>Classification</td>
<td>Sm.</td>
<td>Trivial</td>
<td>Sm.</td>
<td>Trivial</td>
<td>Sm.</td>
<td>Sm.</td>
</tr>
<tr>
<td>Paired set</td>
<td>Magnitude</td>
<td>0.79</td>
<td>0.98</td>
<td>1.11</td>
<td>0.77</td>
<td>1.17</td>
<td>0.92</td>
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<tr>
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<td>Classification</td>
<td>Sm.</td>
<td>Mod.</td>
<td>Mod.</td>
<td>Sm.</td>
<td>Mod.</td>
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</tr>
<tr>
<td>Superset</td>
<td>Magnitude</td>
<td>0.58</td>
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<td>0.95</td>
<td>0.40</td>
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<td>0.06</td>
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<td>Sm.</td>
<td>Trivial</td>
<td>Mod.</td>
<td>Sm.</td>
<td>Trivial</td>
<td>Trivial</td>
</tr>
<tr>
<td>DBP</td>
<td>Magnitude</td>
<td>1.28</td>
<td>0.76</td>
<td>1.17</td>
<td>1.07</td>
<td>0.99</td>
<td>0.50</td>
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<td>Mod.</td>
<td>Sm.</td>
<td>Mod.</td>
<td>Mod.</td>
<td>Mod.</td>
<td>Sm.</td>
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<tr>
<td>Paired set</td>
<td>Magnitude</td>
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<td>1.86</td>
<td>1.83</td>
<td>1.75</td>
<td>1.46</td>
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<td>Large</td>
<td>Large</td>
<td>Large</td>
<td>Mod.</td>
<td>Large</td>
</tr>
<tr>
<td>Superset</td>
<td>Magnitude</td>
<td>2.02</td>
<td>1.40</td>
<td>1.50</td>
<td>1.69</td>
<td>0.99</td>
<td>0.69</td>
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<td>Mod.</td>
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<td>Mod.</td>
<td>Large</td>
<td>Sm.</td>
</tr>
<tr>
<td>MBP</td>
<td>Magnitude</td>
<td>0.66</td>
<td>0.43</td>
<td>0.55</td>
<td>0.40</td>
<td>0.85</td>
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<td>Sm.</td>
<td>Sm.</td>
<td>Mod.</td>
<td>Trivial</td>
</tr>
<tr>
<td>Paired set</td>
<td>Magnitude</td>
<td>1.73</td>
<td>1.88</td>
<td>1.63</td>
<td>1.35</td>
<td>1.44</td>
<td>1.83</td>
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<td>Mod.</td>
<td>Mod.</td>
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<tr>
<td>Superset</td>
<td>Magnitude</td>
<td>1.61</td>
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<tr>
<td>RMSSD</td>
<td>Magnitude</td>
<td>-1.60</td>
<td>-1.61</td>
<td>-1.43</td>
<td>-1.04</td>
<td>-0.73</td>
<td>-0.60</td>
</tr>
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<td></td>
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<td>Large</td>
<td>Mod.</td>
<td>Mod.</td>
<td>Sm.</td>
<td>Sm.</td>
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<tr>
<td>Paired set</td>
<td>Magnitude</td>
<td>-1.97</td>
<td>-1.73</td>
<td>-1.52</td>
<td>-1.21</td>
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<td>Large</td>
<td>Mod.</td>
<td>Mod.</td>
<td>Mod.</td>
</tr>
<tr>
<td>Superset</td>
<td>Magnitude</td>
<td>-2.04</td>
<td>-1.79</td>
<td>-1.62</td>
<td>-1.53</td>
<td>-1.19</td>
<td>-1.07</td>
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<td>Large</td>
<td>Large</td>
<td>Mod.</td>
<td>Mod.</td>
<td>Mod.</td>
</tr>
</tbody>
</table>

*SBP = systolic blood pressure; Sm = small; Mod = moderate; DBP = diastolic blood pressure; MBP = mean blood pressure; RMSSD = SD of differences between adjacent normal.
Figure 1 – Study design using an example of bench press and lat pull down sets performed during each protocol. The arrow represents the insertion and duration of rest interval between sets. BP: bench press; LPD: lat pull down.
Figure 2 – Mean and SD (bar) of systolic (A), diastolic (B), and mean blood pressure (C) between protocols and time points. * Significant difference from rest (main time effect); † Significant difference from postsession (main time effect) intra-protocol.
Figure 3 - Index RMSSD results (mean and SD). * Significant difference from rest (main time effect); † Significant difference from postsession time point (main time effect).
Figure 4 - Index high and low frequency indices results (mean and SD). * Significant difference from rest (main time effect); † Significant difference from postsession (main time effect).
Figure 5 - Values of HF/LF indexes in the frequency domain, in evaluated moments, expressed as mean (bar) and standard deviation (line). * Significant difference from baseline (main time effect); † Significant difference from post-session (main time effect).