The Effects of Muscle Mass and Number of Sets During Resistance Exercise on Postexercise Hypotension

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Abstract

Polito, MD and Farinatti, PTV. The effects of muscle mass and number of sets during resistance exercise on postexercise hypotension. *J Strength Cond Res* 23(8): 2351–2357, 2009—The effects of muscle mass and number of sets on postexercise hypotension (PEH) following resistance exercises are barely known. The aim of the study was to compare systolic blood pressure (SBP), diastolic blood pressure, and mean arterial blood pressure (MAP) after biceps curl and leg extension with different number of sets. Twenty-four trained men (23 ± 1 year, 69 ± 4 kg, 173 ± 3 cm) were randomly assigned into control group, arm group, and leg group. On the first day, the 12 repetition maximum (12RM) workload was determined for both experimental groups. In the remaining days, arm group and leg group performed, randomly, 6 or 10 sets of 10 repetitions of the respective exercises at 12RM workload. Blood pressure was assessed before and every 10 minutes after the exercises for 1 hour. The 3-way analysis of variance identified a significant influence of the type of exercise (p = 0.000001), number of sets (p = 0.007), and postexercise period (p = 0.009) on SBP and of the type of exercise (p = 0.03) on MAP. No differences were found among the groups at rest. Postexercise hypotension was only observed for the leg group when 10 sets were performed. In this group, SBP was significantly ($p \leq 0.05$) lower than at rest during all the observation periods (120.6 ± 2.7 vs. 107.1 ± 3.2 to 113.4 ± 2.8 mm Hg) and MAP was significantly lower than at rest only for the 30-minute assessment (90.3 ± 2.1 vs. 85.1 ± 1.5 mm Hg). It is therefore possible that the muscle mass activated during resistance exercise has an influence on PEH, especially in high-volume multiple-set training sessions.

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23(8)/2351–2357

Journal of Strength and Conditioning Research

Key Words cardiovascular physiology, strength training, peripheral vascular resistance

Introduction

It is important to assess the cardiovascular responses associated with a given exercise program to define better prescription strategies for subjects with and without cardiovascular disease. In this context, postexercise hypotension (PEH) is important to help blood pressure (BP) controlling, especially in hypertensive patients (3,7). This effect may occur after an aerobic exercise, and there are several studies that tend to agree on the adoption of prescription models to optimize PEH, such as duration longer than 10 minutes (9) and intensity equal to or higher than 50% of $\dot{V}O_2$max (8). As of resistance exercise, however, there are still few studies available.

Most of the limited research on PEH because of resistance training investigated the role of training intensity and volume variables. Polito and Farinatti (17), for instance, have not identified any change in arterial BP after the leg extension performed either unilaterally or bilaterally. However, the volume of training applied was relatively small (3 sets of 12 repetition maximum [RM]), which may have reduced the possibility of PEH occurring. Another study (22) compared PEH following different training intensities (6RM and 12 repetitions using 50% of 6RM), volumes (6 and 12 repetitions), and methodologies (set repetition format and circuit training). Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were determined before and up to 60 minutes postexercise. The results showed that the training intensity did not affect the magnitude of the postexercise hypotensive response. Such data have been further confirmed by Rezk et al. (21) comparing hemodynamic responses in resistance exercises performed at 40 and 80% of 1RM.

In general, studies that have succeed to demonstrate the relationship between resistance training and PEH have adopted 12–18 sets if we consider the sum of all exercises performed (1,4,5,17,21,22). However, in those experiments, exercises for all muscle groups were included, what may have limited further considerations about the role played by the

muscle mass. Nevertheless, exercise performed with larger muscle mass would possibly lead to a higher PEH, maybe because of the production of vase dilating endothelial substances. Such possibility has been confirmed by MacDonald et al. (10) demonstrating that aerobic exercise performed in cycloergometer produced longer PEH than exercising in an arm ergometer, even though the absolute BP decline was similar. Unfortunately, we could not find any research specifically addressing this issue in resistance training.

Therefore, consistent information regarding the influence of muscle mass of the resistance exercise on PEH still lacks. In such context, although resistance training has been recognized by important agencies (15) as an auxiliary strategy to reduce BP levels, enough evidence is lacking about the influence of the muscle mass to produce this effect. Considering that in resistance training design there is a wide range of exercise options, information on the muscle mass influence on PEH can help planning better programs aiming to help in the BP control.

Hence, the purpose of the present study was to observe the BP after multiple-set and moderate- to high-intensity resistance exercises performed by small and large muscle groups. It has been hypothesized that exercising larger muscle groups would lead to a higher BP decline, regardless the number of sets.

Methods

Experimental Approach to the Problem

The present study observed BP after strength exercises performed with different number of sets, including small and large muscle groups. The subjects were randomly assigned into a control group and 2 experimental groups. The first experimental group performed the exercise biceps curl, while the second performed the leg extension. Subjects executed 6 and 10 sets of the respective exercises at a 12RM workload in alternate days. The BP was assessed before and for 1 hour following the exercises. Subjects assigned in the control group have remained seated, while the experimental group exercised.

Subjects

The sample size was calculated using the Primer of Biostatistics 4.0. The minimum difference regarding rest conditions for SBP in the last measurement was fixed at 1.40 mm Hg for an *SD* of the residuals of 0.83 mm Hg. The statistical power was set at 80% considering a significance level of $p \leq 0.05$. A minimum of 8 subjects were estimated to integrate each one of the observed groups. Therefore, 24 male participants have been equally and randomly assigned into 3 groups: control group, arm group, and leg group according to the exercises performed (Figure 1). All subjects were physically active and had 3–6 months of previous experience with the proposed exercises. The subjects were told to remain in postprandial fast for 3 hours, not to take caffeine during the 12 hours before data collection, and not to perform physical activities in the previous 24 hours of the exercise session day. Subjects were matched for age and weight as for some characteristics affecting BP by applying the following exclusion criteria: smoker; use of ergogenic substances or any kind or drugs that could alter the cardiovascular responses; bone, joint, or muscle problems that could limit the execution of the exercises; resting BP higher than 140/90 mm Hg; and cardiovascular or metabolic disease (especially hypertension and diabetes).

This study was approved by institutional ethical committee and was conducted according to the recommendations of the Declaration of Helsinki. All subjects were informed about the procedures and risks before giving written consent.

Experimental Procedures

Data were assessed during 4 days. On the first day, body mass and height measurements were taken, and 12RM workload was determined for the biceps curl (for the arm group) and leg extension (for the leg group) exercises, both using a specific device (Technogym, Gambettola, Italy). On the second day, the 12RM retest was performed by the experimental groups. The control group remained seated during this procedure.

The 12RM workload was determined after a maximum of 3 attempts were made for each exercise, with a minimum rest period of 3 minutes between each attempt. The highest 12RM workload obtained in the 2 tests was recorded. In the remaining days, subjects from the arm and leg groups have randomly performed 6 and 10 sets of 10 repetitions in each exercise at the 12RM workload, with a 2-minute rest interval between the sets. The control group has remained seated during all the periods in which the experimental group was exercising. All data assessments were made between 9 and 11 AM in a controlled temperature environment (22–24°C).

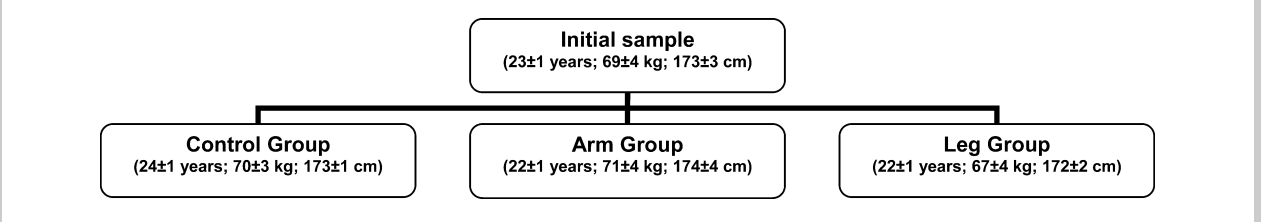

Figure 1. Sample distribution for the experimental and control groups (mean ± *SD*).

Table 1. Resting and postexercise systolic blood pressure for the different groups (mean ± *SD*).

	Control	Arm (6 sets)	Arm (10 sets)	Leg (6 sets)	Leg (10 sets)
Rest	117.3 ± 3.2	117.9 ± 1.1	118.8 ± 1.1	120.1 ± 1.4	120.6 ± 2.7
10 min	116.8 ± 2.9	117.1 ± 3.3	119.0 ± 1.3	116.3 ± 1.7	109.4 ± 2.0*
20 min	116.8 ± 2.9	117.5 ± 1.4	119.3 ± 2.2	116.1 ± 1.1	109.5 ± 2.5*
30 min	116.9 ± 3.3	117.0 ± 1.0	119.1 ± 2.2	116.1 ± 1.2	107.1 ± 3.2*
40 min	116.6 ± 3.6	116.6 ± 1.8	117.9 ± 1.5	116.2 ± 1.7	109.3 ± 2.8*
50 min	117.5 ± 3.7	116.8 ± 2.9	118.6 ± 1.3	115.8 ± 1.4	111.4 ± 3.2†
60 min	117.5 ± 3.6	117.5 ± 1.6	119.9 ± 1.7	120.3 ± 1.3	113.4 ± 2.8†

*Significant difference ($p < 0.001$) in relation to rest measurement.
†Significant difference ($p \leq 0.05$) in relation to rest measurement.

The choice of a 12RM workload must be justified because it could be claimed that it does not match up with conventional lifting. Considering the high number of sets, a 12RM workload should not be considered as light. Indeed, it is endorsed by the American College of Sports Medicine (ACSM) as indicated to well-trained subjects (advanced) and may be around 70–80% of the 1RM (6). On the other hand, conventional training programs are usually designed with submaximal workload and repetitions. In the present study, many sets of a given exercise have been performed at 12RM with a slightly lower number of repetitions (10 reps) to observe the independent effect of the muscle mass, which was very hard to achieve.

The volume and intensity of the sessions followed the recommendations of the ACSM (6). In the present study, however, emphasis was given to a single exercise to assess the influence of muscle mass. Because a single exercise has been performed, the experimental approach included many sets to the volume come up to the usually reported by studies that have observed PEH (1,4,5,11,19,21,22). Therefore, 10 repetitions were adopted in each set in view of the fact that it would be improbable that the subjects could keep 12RM of a same exercise along 6 or 10 sets. In this sense, it is worth mentioning that even performing 10 reps at 12RM, all subjects were exhausted at the end of the last sets. In practical terms, probably, it is not likely that someone normally performs so many sets of a single exercise, but the study approach seems to be adequate to clarify the influence of the muscle mass on the PEH.

Blood Pressure Assessment

Blood pressure measurement has followed the recommendations of the American Heart Association for arm assessment (16) using an indirectly semiautomatic equipment (HEM-431 CINT; Omron, Vernon Hills, IL) fixed at the left arm. The reliability of the obtained values was previously determined by test-retest approach in 10 subjects following 2 consecutive measurements with 2-minute interval. The intraclass correlation coefficients for each variable were as follows: SBP − ICC = 0.93 ($p = 0.0002$) and DBP − ICC = 0.94 ($p = 0.00001$).

To measure BP at rest, the subjects have remained seated for approximately 10 minutes in a quiet environment. After the end of each exercise session, they stayed in the same initial position and BP was assessed every 10 minutes for 1 hour in a total of 6 measurements. The control group was submitted to rest measurement, staying approximately 15 minutes in the place where the exercises were performed and then returning to the 60-minute assessment. The mean arterial pressure

Table 2. Resting and postexercise diastolic blood pressure for the different groups (mean ± *SD*).

	Control	Arm (6 sets)	Arm (10 sets)	Leg (6 sets)	Leg (10 sets)
Rest	74.9 ± 1.8	75.4 ± 2.1	75.6 ± 2.0	73.8 ± 2.4	75.1 ± 2.4
10 min	74.1 ± 1.6	72.9 ± 2.8	73.8 ± 1.8	71.6 ± 3.2	75.0 ± 2.1
20 min	72.0 ± 0.9	73.4 ± 3.4	74.0 ± 1.9	73.1 ± 2.8	74.0 ± 1.5
30 min	72.4 ± 0.9	73.5 ± 2.0	74.0 ± 1.7	72.4 ± 2.4	74.1 ± 1.4
40 min	72.5 ± 1.5	73.5 ± 2.5	75.5 ± 2.4	73.8 ± 2.7	74.8 ± 1.8
50 min	73.0 ± 1.6	75.1 ± 2.4	74.3 ± 1.8	75.0 ± 1.7	74.9 ± 1.3
60 min	72.5 ± 0.9	75.0 ± 2.7	74.1 ± 1.9	74.3 ± 2.7	75.1 ± 1.8

TABLE 3. Resting and postexercise mean arterial pressure for the different groups (mean ± *SD*).

	Control	Arm (6 sets)	Arm (10 sets)	Leg (6 sets)	Leg (10 sets)
Rest	83.4 ± 0.6	89.5 ± 1.4	90.0 ± 1.3	89.2 ± 1.8	90.3 ± 2.1
10 min	83.6 ± 0.5	87.2 ± 2.2	88.8 ± 1.2	86.5 ± 2.3	86.5 ± 1.5
20 min	83.3 ± 0.9	88.1 ± 2.3	89.1 ± 1.2	87.5 ± 1.9	85.8 ± 1.5
30 min	83.8 ± 1.3	88.0 ± 1.3	89.0 ± 1.3	87.0 ± 1.6	85.1 ± 1.5*
40 min	82.3 ± 1.1	87.9 ± 1.5	89.6 ± 1.8	87.9 ± 1.8	86.3 ± 2.0
50 min	82.1 ± 1.6	89.0 ± 2.1	89.0 ± 1.3	88.6 ± 1.1	87.0 ± 1.8
60 min	83.0 ± 0.9	89.2 ± 1.9	89.4 ± 1.4	89.6 ± 1.6	87.9 ± 1.9

*Significant difference ($p \leq 0.05$) in relation to rest measurement.

(MAP) was calculated based on the equation: MAP = DBP + ([SBP − DBP]/3). During the postexercise BP assessment, the subjects were allowed to read. No other sound or visual stimulus was provided.

Statistical Analyses

Data for SBP, DBP, and MAP were separately analyzed using a 3-way analysis of variance (ANOVA) (group × number of sets × time of assessment), with repeated measurements followed by the Tukey post hoc test whenever necessary. The absolute values for SBP, DBP, and MAP were converted to a percent variation of rest (Δ%) and treated the same way. The homogeneity of the variances and data normality were assessed using respectively the Levene's and Shapiro-Wilk's tests. In all cases, significance was set at $p \leq 0.05$. The Statistica 6.0 software was used for the calculations (Statsoft, Tulsa, OK).

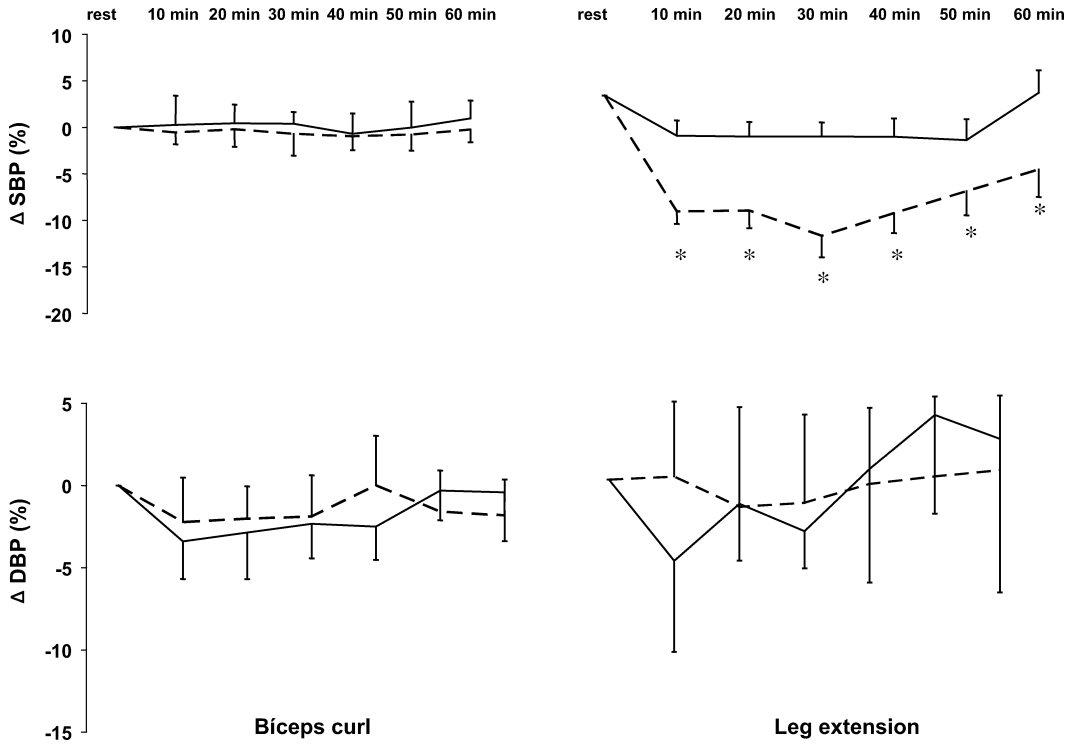

Figure 2. Difference from rest values (Δ%) (mean ± *SD*) for systolic blood pressure (SBP) and diastolic blood pressure (DBP) during the exercises and till 60 minutes postexercise. Solid lines refer to the exercises performed with 6 sets. Dashed lines refer to the exercises performed with 10 sets. Asterisk indicates significant difference ($p < 0.001$) in relation to rest measurement.

Results

The ANOVA identified a significant influence of the type of exercise ($p = 0.000001$), the number of sets ($p = 0.007$), and assessment period ($p = 0.009$) on the SBP values. A significant reduction of SBP was observed in all leg group measurements when 10 sets were performed. The execution of 6 sets by the leg group or both sets by the arm group has not produced any change in SBP (Table 1).

Regarding DBP, no influences were accounted for the exercise type ($p = 0.80$), number of sets ($p = 0.32$), or assessment period ($p = 0.89$). No significant change was identified for control group, arm group, or leg group regardless the sets performed (Table 2).

As far as MAP is concerned, a significant influence was found for the exercise type ($p = 0.03$) but not for the number of sets ($p = 0.85$) and observation period ($p = 0.28$). Mean arterial pressure was significantly lower when compared with rest only at 30 minutes postexercise in leg group when 10 sets were performed (Table 3).

Figure 2 finally shows the behavior of SBP and DBP comparing the percent variation to rest (Δ%). Similar to the data found for the absolute values, a significant difference for SBP variation was only identified in the leg group (10 sets).

Discussion

The present study investigated the possible differences of a multiple-set moderate- to high-intensity exercise performed by small and large muscle groups. The main result refers to the possibility that many sets of a single exercise performed at moderate-to-high workloads are capable to induce PEH if the muscle mass is larger enough.

Comparing the effects induced by the leg extension and biceps curl performed with different volumes (6 vs. 10 sets) but with same intensities (12RM), the PEH has been identified just for the situation that combined large muscle mass (leg extension) and high volume (10 sets). Hence, it is feasible to think that both variables can influence the PEH. In the case that the workload has been higher (for instance 5–6RM), we could speculate that the PEH would occur because the volume has also been elevated. In fact, there are previous studies that have reported significant reductions in the BP following exercises performed with high workloads and number of sets (22).

The relationship between exercise intensity and PEH is an issue frequently addressed in the literature. The current recommendations for exercise prescription aiming to reduce BP propose aerobic exercises performed at approximately 50% $\dot{V}o_2max$ (15). In general, hypotensive effects induced by lower intensities have been observed in hypertensive subjects, which are probably more susceptible to PEH response (15). As for strength training, data are scarcer than for aerobic exercises. Moreover, because of the many possibilities of interaction between the prescription variables (number of exercises, number of repetitions, workload, and recovery intervals), the available results are somewhat conflicting. Significant PEH has been observed by some experiments with normotensive subjects (5,22) and hypertensive subjects (1) as a result of many different exercise protocols. From this point of view, there is no inconsistency of the present results with the available data on the BP responses to resistance training.

Regardless the fact that a single exercise was performed in each situation, the volume and intensity relationship hereby proposed was similar to those found in previous research. Just to illustrate, Hardy and Tucker (4) have demonstrated PEH for SBP and DBP during the first hour following 7 resistant exercises performed for 3 sets of 8–12 repetitions using an 8–12RM resistance, thus a similar intensity and volume to ours but with several exercises. Other studies also reported short-lived but significant SBP postexercise decline up to 1 hour after resistant training sessions with light-to-moderate intensities and volumes, as in Fisher (1) (5 exercises performed for 3 circuits of 15 repetitions using 50% of the 1RM) or MacDonald et al. (11) (unilateral leg press exercise for 15 minutes at 65% of 1RM).

The studies that have successfully observed PEH and that have used training protocols that were more in tune with the reality of exercise prescription (5) have used 12 (5,13), 15 (1,22), and 18 (19,22) sets. In all these studies, the number of sets was higher than the one used in the present study. However, the selected exercises were applied to muscle groups of different sizes. Only 1 study tried to compare the BP taking into account the muscle mass activated during the effort (unilateral and bilateral leg extension) (18). However, a small quantity of sets was used, and probably, for this reason, PEH was not reported regardless the exercised muscle mass.

In the present study, the exercise protocol differs to some extent from what is normally applied in real resistance training. However, this was a necessary strategy to verify the specific influence of the muscle mass on the postexercise BP. This option is not uncommon, and other studies have applied similar procedures to observe the particular relationship of a given training variable on PEH. For example, MacDonald et al. (11) have assessed the BP after a single set of the unilateral leg press performed at 65% of 1RM. The set lasted 15 minutes nonstop, and the legs were interchanged alternately. Although this exercise requires considerable muscle mass, that design is not usually applied in training conditions.

A significant PEH was observed only for SBP. These results are in consonance with the literature because the majority of the studies that have identified the PEH caused by resistance exercise have reported more evident decreases for SBP (1,11,13,19,21,22) when compared with DBP (4,5,21). One of the possible explanations for SBP's higher sensitivity to PEH would be the posture subjects adopt after the exercise. Although all mentioned studies have chosen the seated position to assess arterial pressure, it was observed that the postexercise SBP declines more soundly in the seated position rather in the supine position (20).

One of the physiological mechanisms that could explain the influence of muscle mass on BP after resistance exercise is the reduction in vascular resistance, caused by the liberation of vase dilating endothelial substances (e.g., nitric oxide and prostaglandins). The stimulus for the liberation of such substances seems to be caused by an increase in blood flow (3). Therefore, it may be assumed that a larger muscle mass activated during the activity, if all the other variables are kept constant, would raise the need for blood in the active region thus favoring PEH.

The same mechanism related to muscle mass can be attributed to the influence of the number of sets on hypotension after resistance exercise. The higher the number of sets developed for a muscle group, the stronger must be the action of the blood flow over the endothelial region of the muscle groups. In fact, the relationship between the number of sets and PEH was described in a previous study (13). The authors have used 4 exercises (chest press, leg press, rowing, and triceps curl) performed at 10RM with 1 or 3 sets. The results have indicated a reduction in SBP and DBP, respectively, for 60 and 50 minutes following the exercises performed in 3 sets. However, the sample was composed of hypertensive subjects who are likely to be more sensitive to changes on BP after the activity (7). The extent to which those results can be applied to normotensive subjects is uncertain.

Even though the results obtained so far have provided relevant information on PEH, it is important to highlight some of the limitations of this study. For instance, it is not possible to extrapolate the results obtained for people with different training levels or clinic conditions. Furthermore, variables possibly related to PEH mechanisms (such as sympathetic activity, blood flow, cardiac output, and nitric oxide production) were not evaluated. Neither was analyzed the influence of other variables of resistance exercise (such as number of repetitions and workload). However, this experiment becomes relevant because it is the first to directly investigate the influence of muscle mass and number of sets of resistance exercises on PEH. These 2 variables are particularly important because they can be directly associated to the BP increase during resistance exercises (2,12,14). Hence, it is possible to develop strategies for resistance training based on the evidences related not only to what happens during effort but also to what happens after it is over.

In conclusion, the present findings have shown that SBP following resistance exercise performed at moderate-to-high workload is influenced by the muscle mass engaged in the effort and the number of sets performed. However, because resistance training allows great manipulation of volume and intensity, the possible interaction between the number of sets and repetitions, number and type of exercises, workload, recovering intervals, and speed of movement to produce PEH should be considered in future research.

Practical Applications

The present results revealed that exercising larger rather than smaller muscle groups should likely provoke postexercise hypotensive response if the given number of sets is high. It is therefore possible that the BP decline depends on the type of the exercise included in a program design. As a practical application, these results suggest that a resistance exercise program designed to help controlling arterial BP levels should include exercises involving large muscle groups performed in a multiple-set perspective.

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