Clinic and Ambulatory Blood Pressure Responses After Resistance Exercise

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Abstract

Queiroz, ACC, Gagliardi, JFL, Forjaz, CLM, and Rezk, CC. Clinic and ambulatory blood pressure responses after resistance exercise. J Strength Cond Res 23(2): 571–578, 2009—This study investigated clinic and ambulatory blood pressure (BP) responses after a single bout of low-intensity resistance exercise in normotensive subjects. Fifteen healthy subjects underwent 2 experimental sessions: control—40 minutes of seated rest, and exercise—6 resistance exercises, with 3 sets of as many repetitions as possible until moderate fatigue, with an intensity of 50% of 1-repetition maximum (1RM). Before and for 60 minutes after interventions, clinic BP was measured by auscultatory and oscillometric methods. Postintervention ambulatory BP levels were also measured for 24 hours. In comparison with preintervention values, clinic systolic BP, as measured by the auscultatory method, did not change in the control group, but it decreased after exercise (−3.7 ± 1.6 mm Hg, p < 0.05). Diastolic and mean BP levels increased after intervention in the control group (+3.4 ± 1.0 and +3.0 ± 0.8 mm Hg, respectively, p < 0.05) and decreased in the exercise group (−3.6 ± 1.7 and −3.4 ± 1.4 mm Hg, respectively, p < 0.05). Systolic and mean oscillometric BP levels did not change after interventions either in the control or exercise sessions, whereas diastolic BP increased after intervention in the control group (+5.0 ± 1.7 mm Hg, p < 0.05) but not change after exercise. Ambulatory BP behaviors after interventions were similar in the control and exercise sessions. Significant and positive correlations were observed between preexercise values and postexercise clinic and ambulatory BP decreases. In conclusion, in the whole sample, a single bout of low-intensity resistance exercise decreased postexercise BP under clinic, but not ambulatory, conditions. However, considering individual responses, postexercise clinic and ambulatory hypotensive effects were greater in subjects with higher preexercise BP levels.

Key Words: ambulatory blood pressure, clinic blood pressure, hypotension, strength exercise

Introduction

Aerobic training is recommended as a part of the nonpharmacological treatment of hypertensive patients (6) because of its important hypotensive effects (8,28,38). In fact, beyond its chronic effects, a single bout of aerobic exercise promotes an acute decrease in blood pressure (BP) that lasts for many hours during the recovery period (7,15,19,28,29). This phenomenon has been called postexercise hypotension (17) and has been assumed to have clinical significance (28). Recently, resistance exercise has been proposed as a complementary kind of training for hypertensive subjects because of its undeniable muscular benefits (28,39). However, the chronic and acute effects of this kind of exercise on BP have not been sufficiently studied.

In a previous study with normotensive subjects (32), we observed that single bouts of low- and high-intensity resistance exercises similarly decreased systolic BP during the recovery period; however, diastolic BP was only reduced by the low-intensity resistance exercise. To have clinical relevance, postexercise hypotension should be maintained for many hours after exercise and should be sustained when subjects are performing their daily activities (17). Nevertheless, in our previous study (32), data collection was limited to laboratorial conditions (which is called clinic BP) (37) and was stopped 90 minutes after exercise.

To our knowledge, only 2 studies have investigated ambulatory BP responses after resistance exercise in normotensive subjects. Roltsch et al. (33) did not observe any change, whereas Bermudes et al. (2) found a decrease only in asleep diastolic BP. However, these studies did not evaluate clinic BP because it was difficult to establish whether the resistance exercise protocol employed was adequate to induce acute hypotensive effects, at least under laboratorial conditions.

Therefore, scientific knowledge about the acute effects of resistance exercise on postexercise BP is still scarce and controversial. To help clarify this issue, the purpose of this study was to investigate BP response after a single bout of low-intensity resistance exercise in healthy normotensive
subjects, evaluating whether hypotensive effects were maintained for many hours after exercise.

**METHODS**

**Experimental Approach to the Problem**

We hypothesized that in inactive, normotensive, healthy subjects, a single bout of low-intensity resistance exercise would promote a significant decrease in BP during the recovery period and that this decreased BP would persist for many hours after exercise while subjects were engaged in their activities of daily living. These hypotensive effects would be greater in subjects with higher preexercise BP levels.

Although postexercise hypotension might have clinical relevance in hypertensive subjects, the present study was conducted with normotensive subjects to understand its physiological behavior without the influence of pathological alterations.

To check our hypothesis, the experimental protocol consisted of 2 sessions (control and exercise) in which variables were measured before and after interventions (rest or exercise). With this model, postexercise values were compared not only with preexercise ones but also with the control condition, which allowed for controlling the physiological alterations induced by experimental conditions other than exercise, such as sitting for many minutes.

Exercise intensity (50% 1-repetition maximum [1RM]) was established by its potential effect on BP lowering. Thus, this intensity was chosen on the basis of our previous study (32), which showed that low-intensity exercise promoted greater postexercise hypotensive effects in normotensive subjects than did high-intensity exercise, at least under laboratory conditions. To improve clinical applicability, session volume was established according to the American College Sports Medicine (1) recommendations for resistance training in hypertensive subjects.

**Subjects**

Fifteen nonobese, normotensive subjects, 18–35 years, participated in this study. They were informed of the risks, benefits, and objectives of the study and signed an informed consent previously approved by the ethics committee of the School of Physical Education and Sport, University of São Paulo, São Paulo, Brazil. Subjects were excluded if they had hypertension, cardiovascular disease, and/or obesity. None of the subjects practiced any regular physical activity, smoked, or took medications. Physical and functional characteristics of the subjects are shown in Table 1.

**Procedures**

As a preliminary evaluation, anthropometric measurements (height and weight) were used to calculate body mass index, and subjects were excluded if the value was equal or greater than 30 kg m⁻². Resting BP was measured 3 times after 5 minutes of seated rest, using the auscultatory method. This procedure was performed on 2 distinct days, and a mean value of all measurements was calculated. Subjects were excluded if their systolic and/or diastolic BP levels were equal or greater than 140 and 90 mm Hg, respectively (23).

All subjects who fulfilled the inclusion criteria underwent 2 adaptation sessions to assure the correct execution of the 6 resistance exercises included in the study: bench press, squat, lat pull-down, leg press, arm curl, and leg curl. In these sessions, subjects performed 2 sets of 20 repetitions of each exercise with the minimum load allowed by the equipment. Then, in another session, subjects underwent 1RM tests for each exercise. This test followed the Kraemer and Fry’s protocol (18). Briefly, for each exercise, subjects performed 1 set of 5–10 repetitions with an intensity of 40–60% of the estimated maximum load, 1 set of 3–5 repetitions with an intensity of 60–80% of the estimated maximum load, and then 1–3 attempts of reaching the maximum load with an interval of 3–5 minutes between attempts. Adaptation and testing sessions were conducted with an interval of at least 5 days.

The experimental protocol consisted of 2 experimental sessions (control and exercise) performed in random order with an interval of at least 5 days. Subjects were asked to refrain from formal exercise and alcohol ingestion for a minimum of 24 hours before the sessions. They also were instructed to take a similar light meal 2 hours before each experiment and to avoid caffeine and other substances that might influence BP. Subjects drank water ad libitum before the experiments, but no water ingestion was allowed during the experiments, which were initiated between 10 and 12 AM.

In each experimental session, subjects rested in the sitting position for 20 minutes each before intervention. During this preintervention period, systolic and diastolic BP levels were measured every 5 minutes by auscultation on the dominant
arm and by the oscillometric method on the nondominant arm. The preintervention mean value was calculated by the mean of all measures, excluding the first and the last ones. Then, the subjects underwent the intervention period, which consisted of 40 minutes of seated rest in the control session. In the exercise session, it consisted of 3 sets of as many repetitions as possible until achieving moderate fatigue (reduction of movement velocity) in 6 resistance exercises (bench press, squat, lat pull-down, leg press, arm curl, and leg curl) with an intensity of 50% 1RM. Intervals of 45 seconds were allowed between sets, and intervals of 90 seconds were allowed between exercises. After the interventions, the subjects remained seated for 60 minutes. During this postintervention period, BP was measured every 5 minutes, similar to preintervention. Mean postintervention values were calculated between 25 and 30 (30'), 40 and 45 (45'), and 55 and 60 (60') minutes. After this period, subjects had 30 minutes to shower and then return to the laboratory, at which point the ambulatory BP monitor was attached to the nondominant arm.

During the experimental sessions, auscultatory BP was measured by the same expert observer using an aneroid sphygmomanometer. Phases I (appearance) and V (disappearance) of the Korotkoff sounds were established, respectively, as the systolic and diastolic BP levels (23,36). Clinic oscillometric BP was measured by an ambulatory device (SpaceLabs 90207, SpaceLabs Medical, Inc, Redmond, Wash) (9), and ambulatory BP monitoring was performed with measurements taken every 15 minutes for 24 hours (23). Aneroid sphygmomanometer and oscillometric device calibrations were frequently checked during the study by comparison with a mercury column (4,30). Subjects were instructed to avoid exercise and alcohol while with the monitor, to report all activities carried out during the 24 hours, and to keep similar patterns of activity and sleep on both experimental days. Ambulatory data were analyzed for 24 hours (average of all measures taken before subjects reported to sleep), and asleep (average of all measures from the period during which subjects reported to be sleeping) periods.

Statistical Analyses
Preintervention values were compared between sessions by paired Student’s t-test. The BP responses in each experimental session were established by the differences between the values measured post- and preintervention. These responses were compared between sessions by a 2-way analysis of variance with repeated measures (Statistica for Windows release 4.3, Statsoft, Inc., 1993, Tulsa, Okla), establishing sessions (control and exercise) and stages (pre, 30', 45', and 60') as the main factors. The minimum size of the sample in the present study was calculated to be 7 subjects. Post hoc comparisons were made by Newman-Keuls test. Correlations were established by Pearson coefficient. p ≤ 0.05 was accepted as significant. Data are presented as mean ± SE.

RESULTS
Eight subjects began the experimental protocol with the control session, and 7 began with the exercise session. Resistance exercise characteristics are presented in Table 2. The number of repetitions decreased significantly throughout the sets in almost all of the exercises.

Preintervention values measured in both experimental sessions are shown in Table 3. Preintervention auscultatory and oscillometric BP levels, as well as heart rate, were similar in the control and exercise sessions. Preintervention oscillometric systolic BP was significantly higher than the auscultatory measurement in both sessions.

Auscultatory BP responses are shown in Figure 1. In comparison with the preintervention values, systolic BP did not change in the control session, but it decreased significantly after exercise (greatest difference = −3.7 ± 1.6 mm Hg, p < 0.05). Diastolic BP increased after intervention in the control session (+3.4 ± 1.0 mm Hg, p < 0.05) and decreased after exercise (−3.6 ± 1.7 mm Hg, p < 0.05). Mean BP also increased significantly after intervention in the control session (+3.0 ± 0.8 mm Hg, p < 0.05) and decreased after exercise (−3.4 ± 1.4 mm Hg, p < 0.05). Thus, in comparison with the control session, systolic, diastolic, and mean BP levels decreased significantly during the postexercise period.

Oscillometric BP responses are shown in Figure 2. In comparison with preintervention values, systolic and mean

<table>
<thead>
<tr>
<th>Resistance exercise</th>
<th>Number of repetitions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Load (kg)</td>
</tr>
<tr>
<td>Bench press</td>
<td>24.7 ± 2.4</td>
</tr>
<tr>
<td>Squat</td>
<td>51.0 ± 2.4</td>
</tr>
<tr>
<td>Lat pull-down</td>
<td>22.9 ± 1.9</td>
</tr>
<tr>
<td>Leg press</td>
<td>118.5 ± 9.3</td>
</tr>
<tr>
<td>Arm curl</td>
<td>14.8 ± 1.2</td>
</tr>
<tr>
<td>Leg curl</td>
<td>9.7 ± 0.9</td>
</tr>
</tbody>
</table>

*Significantly different from set 1 (p < 0.05); †significantly different from set 2 (p < 0.05).
Values are mean ± SE.
BP levels did not change after intervention in the control or exercise sessions. On the other hand, diastolic BP increased postintervention in the control session (greatest difference = +5.0 ± 1.7 mm Hg, \( p < 0.05 \)) but did not change after exercise. Thus, in comparison with the control session, systolic, mean, and diastolic BP levels after intervention decreased significantly in the exercise session.

In comparison with preintervention values, heart rate decreased significantly during the postintervention period in the control session (30' = -3.9 ± 0.9; 45' = -4.0 ± 0.7; 60' = -4.4 ± 1.1 bpm, \( p < 0.05 \)), and it increased after exercise (30' = +9.7 ± 1.7; 45' = +6.8 ± 1.6; 60' = +3.6 ± 1.2 bpm, \( p < 0.05 \)).

Positive correlations were observed between preexercise BP values and their reductions after exercise. These correlations were significant for auscultatory diastolic and mean BP levels measured 45 minutes after exercise (\( r = +0.546 \) and +0.599, respectively, \( p < 0.05 \)), for oscillometric systolic BP levels measured at 30, 45, and 60 minutes after exercise (\( r = +0.533, +0.723, \) and +0.703, respectively, \( p < 0.05 \)), and for mean BP levels measured at 30 and 45 minutes after exercise (\( r = +0.495 \) and +0.513, respectively, \( p < 0.05 \)).

Ambulatory BP responses are shown in Figure 3. Systolic, mean, and diastolic BP behaviors evaluated during the 24-hour, awake, and asleep periods did not differ between the control and exercise sessions. In both experimental sessions, awake systolic, diastolic, and mean BP levels were similar to the preintervention values, whereas asleep BP was significantly lower.

Positive correlations were observed between preexercise BP values and ambulatory BP decreases after exercise. These correlations were significant for 24-hour, awake, and asleep systolic BP levels (\( r = +0.701, +0.656, \) and +0.696, respectively, \( p < 0.05 \)) and for 24-hour and asleep diastolic (\( r = +0.554 \) and +0.652, \( p < 0.05 \)) and mean (\( r = +0.591 \) and +0.733, \( p < 0.05 \)) BP levels.

### DISCUSSION

The most important finding of this study is that, in normotensive subjects, a single bout of low-intensity resistance exercise promoted postexercise hypotension in the laboratory, but this response was not sustained when subjects...
in the control session and decreased in the exercise session, with the greatest net change (−6.3 ± 1.8 mm Hg) being observed at 30 minutes of recovery. These decreases show an important hypotensive effect of resistance exercise because their magnitudes are similar to the ones expected after aerobic exercise (5–7 mm Hg) (28). It is interesting to note that such falls were obtained with low-intensity exercise. In fact, many previous studies with high-intensity resistance exercise have not observed systolic or diastolic BP decreases during the recovery period (10,12,24,32,34), and some even have reported increases in systolic BP (3,12,24). Taking together, these results suggest that low-intensity resistance exercise is better than high-intensity exercise for inducing postexercise hypotension; however, in the present study, only one intensity was tested, and thus future studies might test this suggestion.

It is interesting to point out that although low-intensity training does not optimize strength and muscle mass gains, it can increase maximal dynamic strength (32%) and local muscular endurance (94%) in healthy young men (5). Moreover, it is the kind of training recommended for cardiac and hypertensive patients (1) and also for starting a resistance training program (11). Thus, when this intensity of training is employed, it might result in some muscle gains and decreased BP levels after each training session.

The increase in diastolic BP in the control session might seem odd at first. However, this behavior has already been reported extensively (13,14,31,32); it has been attributed to the orthostatic stress imposed by the sitting position (14), which might reduce venous return and deactivate cardiopulmonary reflex, resulting in increases in peripheral vascular resistance and diastolic BP (14,21).

The use of oscillometric devices for measuring BP has increased recently because of the new equipment and the advantage of eliminating any possible observer bias (25,27,35). Using this technique, the present study did not observe any changes in systolic BP after interventions in the control or exercise sessions. However, comparing the sessions, there was a significant difference showing a significant hypotensive effect, with greater magnitude at 60 minutes of recovery and a net value of −3.9 ± 1.7 mm Hg. Diastolic BP did not change after exercise, but it increased in the control session, which also resulted in a significant hypotensive effect, with greater magnitude at 45 minutes and a net value of −7.1 ± 2.1 mm Hg.

Comparing auscultatory and oscillometric data, it is possible to observe that behaviors in each isolated session are different. These differences might be explained by differences in methodologies, because with the auscultatory method systolic and diastolic BP levels were measured and mean BP was calculated. On the other hand, with the oscillometric technique, mean BP was measured and systolic and diastolic values were calculated by mathematical algorithms (20,26,35). One important point is that these algorithms must change if pulse pressure or arterial

returned to their activities of daily living. Nevertheless, clinic and ambulatory hypotensive effects were greater in subjects with higher preexercise BP levels.

Auscultatory measurement is the most common method used to measure BP (20). Using this technique, this study found a reduction in systolic BP after resistance exercise and a maintenance in the control session. The greatest net change was observed at 45 minutes of recovery, with a magnitude of −5.1 ± 1.7 mm Hg. Diastolic BP increased after intervention...
compliance changes (25,26), which might happen after resistance exercise (10,32). In fact, in the present study, the intraclass correlation coefficients between auscultatory and oscillometric systolic and diastolic BP levels were greater before (0.920 and 0.946, respectively) than after exercise (0.917, 0.720, 0.767, and 0.877, 0.857, and 0.915 at 30, 45, and 60 minutes of recovery, respectively). Thus, our results raise a question regarding the adequacy of the oscillometric method for measuring BP after exercise. Despite this consideration, it is possible to observe that although auscultatory and oscillometric responses after each session were not equal, the net results are the same. This convergence of results strengthens the notion that a single bout of resistance exercise produces significant postexercise hypotension in healthy subjects.

The sample employed in the present study included women and men. Differences in postexercise hypotension between genders have not been sufficiently studied in the literature and are outside the scope of the present study, which included only 6 women. Nevertheless, a complementary analysis, including gender as a between-group main factor, revealed that responses after interventions were similar between genders, supporting the combination of men’s and women’s data for the analysis. It is important to point out, however, that possible differences between genders should be investigated in more detail in the future with larger samples.

Mechanisms responsible for decreases in post–resistance exercise BP are outside the scope of this study. However, the similarity of this study’s results to the results of one of our previous studies (32) suggests that the mechanisms are the same. Thus, the reduction in BP after exercise might be attributable to a decrease in cardiac output that was not compensated for by an increase in peripheral vascular resistance. The decrease in cardiac output was determined by a decrease in stroke volume, because heart rate increased after exercise.

The novelty of this study is its demonstration that post–resistance exercise hypotension, although observed in the laboratory, was not maintained under ambulatory conditions in normotensive subjects. In fact, 24-hour, awake, and asleep BP behaviors were similar between the control and exercise sessions. These results are similar to the findings of Roltsch et al. (33), but those authors used high-intensity resistance exercise and did not observe BP responses in the laboratory, and thus they could not evaluate whether there was any hypotensive effect under clinical conditions. The present results are also different from the results of Bermudes et al. (2) that verified a reduction in asleep BP after low-intensity resistance exercise. However, differences in sample characteristics (middle-aged men vs. young subjects), a greater number of resistance exercises, and different data analysis methods might explain these discrepancies. Thus, the present results emphasize the importance of monitoring ambulatory BP to evaluate postexercise hypotension relevance, because laboratory results might be different from ambulatory ones.

Another important novelty of this study is that, as with aerobic exercise (7,29), clinic and ambulatory BP decreases after low-intensity resistance exercise were greater in subjects with higher preexercise values. This relationship increases the clinical relevance of the phenomenon because it is more important to reduce BP when it is high. This study did not evaluate hypertensive subjects, but the results suggest that such subjects would have greater BP decreases. In fact, in a previous study with hypertensive women receiving captopril (22), we observed a post–resistance exercise BP reduction that lasted for 10 hours. Increasing this knowledge, our findings suggest that this response might also be seen in hypertensive subjects without pharmacological treatment. In the literature, only 1 study (16) has evaluated ambulatory BP in untreated hypertensive subjects, and it did not demonstrate any change; however, that study employed high-intensity exercise. Thus, future studies might investigate clinic and ambulatory BP responses after low-intensity resistance exercise in untreated hypertensive subjects.

In conclusion, in a sample of healthy subjects, a single bout of low-intensity resistance exercise decreased postexercise BP under clinic but not ambulatory conditions. However, considering individual responses, the postexercise clinic and ambulatory hypotensive effects were greater in subjects with higher preexercise BP levels.

**Practical Applications**

Low-intensity resistance training is recommended to cardiac and hypertensive patients and also at the beginning of
resistance training programs (11). This type of training results mainly in muscle endurance enhancement, but it also promotes slight increases in strength (5). The findings of the present study show that, in normotensive subjects, each single bout of low-intensity resistance exercise produced a decrease in systolic and diastolic BP levels during the recovery period. However, these responses are not maintained during the daily activities, and they are proportional to the preexercise levels. Thus, the results show that this hypotensive response will not have hazardous effects in subjects with normal or low BP levels. Moreover, because BP levels are continuous, whereas hypertension is arbitrarily stated, it is possible that this hypotensive effect might be greater in hypertensive subjects.

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