

# Acute resistive exercise does not affect ambulatory blood pressure in young men and women

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## ABSTRACT

ROLTSCH, M. H., T. MENDEZ, K. R. WILUND, and J. M. HAGBERG. Acute resistive exercise does not affect ambulatory blood pressure in young men and women. *Med. Sci. Sports Exerc.*, Vol. 33, No. 6, 2001, pp. 881–886. **Purpose:** Resistive exercise elicits a pressor response that results in a dramatic increase in blood pressure (BP) during the exercise. However, it is not known if the BP elevation persists after resistive exercise. **Methods:** This study examined the effects of an acute resistive exercise session on 24-h ambulatory BP in sedentary (5 men, 6 women), resistance-trained (6 men, 6 women), and endurance-trained (4 men, 6 women) young subjects (age  $22 \pm 3.2$  yr) with normal BP. Two 24-h ambulatory BP recordings were made on each subject, one after two sets of resistive exercise on 12 weight machines and one after 48 h without prior exercise. **Results:** Systolic, diastolic, and mean arterial BP and heart rate (HR) were not different in the hours after and for up to 24 h after the single resistive exercise session compared with the control day. There also was no difference in the ambulatory BP or HR response after the single session of resistive exercise based on the training status of the subjects. **Conclusion:** Thus, the elevated BP that occurs during resistive exercise does not persist in the 24 h after acute resistive exercise in sedentary, resistance-trained, or endurance-trained, young, normotensive men and women. **Key Words:** STRENGTH TRAINING, HEART RATE, SEDENTARY, ENDURANCE-TRAINED

Public awareness of the numerous musculoskeletal and metabolic benefits of resistive exercise has led to its increasing popularity in recent years. However, although benefits clearly accrue from long-term resistive exercise training, blood pressure (BP) increases substantially above resting levels during resistive exercise (14,15,17,20), reaching levels as high as 320/250 mm Hg due to a pressor response (15). Furthermore, some evidence indicates that plasma norepinephrine levels are elevated for up to 24 h after a resistive exercise session, giving rise to the possibility that the sympathetic nervous system remains active after exercise, which could result in a prolonged increase in blood pressure (19). Only two previous studies have assessed whether BP is persistently elevated after an acute bout of resistive exercise (6,16), and these studies only measured BP for up to 2 h. One study by Hill et al. (6) examined blood pressure immediately after and for up to 60 min after 11–18 min of resistive exercise in six young men. Although this short resistive exercise period is not representative of a typical resistive exercise session, there was a significant decrease in diastolic BP for up to 1 h after resistive exercise. A second study by O'Connor et al. (16) investigated ambulatory blood pressure for 120 min after a bout of six resistive exercises on three separate days at varying intensities. This study improved on the study by Hill et al. (6) by including

two more exercises and increasing the length of the exercise bout to 30 min. In contrast to the findings of Hill et al. (6), this study found an increase in BP that occurred 1 min after exercise at 60% of one repetition maximum (RM) and 1 and 15 min after exercise at 80% of one RM. However, this resistive exercise protocol may still not have been representative of the workouts performed by young, healthy adults because it only included six exercises and lasted just 30 min. In addition, in both studies the protocols could have been more individualized by using a 6–12 RM for upper body exercises and 10–15 RM for lower body exercises (9) because a specific RM protocol does not elicit the same number of RM for all exercises or for all people (7,8). Consequently, the shortcomings of these two studies makes it difficult to draw conclusions. To our knowledge no data exist on the effects of an acute session of resistive exercise on ambulatory BP beyond 2 h after resistive exercise in normotensive men and women.

The purpose of this study was to determine whether the elevated BP observed during resistive exercise affects ambulatory BP in the 24 h after the cessation of exercise. We hypothesized that an acute session of resistive exercise would elevate ambulatory BP in the 24 h after the exercise session when compared with a control day without prior resistive exercise. In addition, there is minimal information available on whether training status affects an individual's 24-h BP response after an acute resistive exercise session. It has been shown that both resistive and aerobic training clearly affect an individual's hemodynamic response during resistive exercise (3,13). Fleck and Dean (3) determined that, compared with sedentary untrained individuals,

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strength-trained individuals had a significantly reduced peak systolic and diastolic BP and a smaller increase from rest to peak for systolic and diastolic BP during a resistive exercise. The increased BP response during resistive exercise of sedentary individuals may result in a greater elevation in 24-h ambulatory BP after a resistive exercise session when compared with resistive trained individuals. Furthermore, the plasma norepinephrine levels that are elevated for up to 24 h after resistive exercise (19) may have less of an effect on the sympathetic nervous system of resistance- and endurance-trained individuals due to a desensitized sympathetic nervous system (12). Therefore, it is possible that individuals with different habitual physical activity habits may have different hemodynamic responses during and after a resistive exercise session. To test this, we compared the 24-h ambulatory BP response after acute resistive exercise session of sedentary, and resistance- and endurance-trained individuals. We hypothesized that young sedentary individuals would have greater elevations in ambulatory BP after an acute session of resistive exercise compared with resistance- and endurance-trained individuals. If this is true, then resistive exercise prescription for untrained individuals may need to be revised.

## METHODS

**Subjects.** A total of 36 healthy male and female subjects 18–26 yr of age were recruited from the University of Maryland student body. The study was approved by the University of Maryland Institutional Review Board and all subjects provided written informed consent at the first laboratory visit. Subjects were initially screened using a medical history questionnaire and by personal interviews to exclude those taking any ergogenic aids or medications, or having any chronic medical conditions. The subjects were recruited into three groups: sedentary (six male, six female), resistance-trained (six male, six female), or endurance-trained, (six male, six female) individuals. These groups were based solely on the subjects' self-reported habitual physical activity status. The resistance-trained group had undergone regular resistance training at least three times per week for the past 12 months and did not participate in any endurance training during that time period. The endurance-trained group had undergone endurance training for a minimum of 3 d a week at an intensity of greater than 60% of their  $\dot{V}O_{2max}$  for at least the past 6 months and had not performed any resistance training for the past 6 months. The sedentary group had not participated in regular endurance or resistance training for at least 3 months and had no prior resistance training experience.

Height, weight, and subcutaneous skin-fold thicknesses were measured at the initial laboratory visit. Body composition was determined using the Jackson and Pollock seven-site skin-fold technique (10). BP at rest was recorded after the subject sat quietly for 10 min, with five readings recorded 5 min apart using an ambulatory BP monitor. All subjects then participated in a resistive exercise practice session to familiarize themselves with the Cybex equipment

(Medway, MA) and to determine the weight and seat settings to be used on the experimental day. The Cybex machines that were used and the order they were performed for the acute resistive exercise session were as follows: chest press, leg press, upright row, leg curl, latissimus pull down, leg extension, military press, calf raises, lower back, triceps, abdominals, and biceps curls. After the practice session, subjects performed an 8-repetition maximum (8 RM) test for each upper-body exercise and a 12-repetition maximum (12 RM) for each lower-body exercise to determine the weight to be used during the acute resistive exercise session. The 8- and 12-RM tests represent the maximal resistance that could be moved through the full range of motion for 8 and 12 repetitions, respectively.

**Experimental day.** Subjects arrived at the laboratory at 7:00 a.m. on the day of testing. Subjects were advised to eat a light meal before coming to the laboratory. Female participants were tested during the luteal phase of their menstrual cycle. After 10 min of seated rest, BP was measured and recorded using an ambulatory BP monitor and the auscultatory method. The auscultatory method was used to assure the accuracy of the ambulatory BP monitor. Subjects then completed a 5- to 10-min warm-up on a cycle ergometer followed by stretching of the major muscle groups. After the warm-up, subjects began the resistive exercise session that consisted of two sets of exercise on each of the 12 machines listed above. The sets were 8 or 12 RM for the upper and lower body exercises, respectively. Subjects rested for 60 s between exercises and the entire exercise session lasted 45–60 min. This session was designed to simulate a typical resistive training regimen used by young persons.

The resistive exercise session ended at approximately 8:30 a.m. After this, all subjects showered and returned to the laboratory to begin the ambulatory BP recording, which began at 9 a.m. The time between the end of the resistive exercise session and the initiation of the ambulatory BP recording was 25–35 min. Subjects were instructed to refrain from participating in any aerobic or resistive exercise throughout the remainder of the day.

**Control day.** Subjects arrived in the laboratory between 7:00 and 7:30 a.m. on the same day of the week as their experimental day. After 10 min of seated rest, BP was measured and recorded using an ambulatory BP monitor and the auscultatory method. After the resting BP measurements, subjects remained in the laboratory and rested. At 8:30 a.m., subjects took a shower and then returned to the laboratory to begin the ambulatory BP recording, which began at 9 a.m. The order of the control and experimental days were randomized.

**24-h ambulatory BP measurement.** A Suntech Accutracker II ambulatory BP monitor (Suntech Medical Instruments, Raleigh, NC) measured heart rate and systolic and diastolic BP three times each hour during waking hours (7 a.m.–11 p.m.) and twice each hour during sleep hours (11 p.m.–7 a.m.). All BP measurements were taken at random during each hour. Therefore, neither the subject nor the tester had any knowledge of when the cuff would inflate

during each hour. The ambulatory BP monitor was set to inflate to 30 mm Hg above the previous systolic reading, and the deflate rate was set at 3 mm Hg·s<sup>-1</sup>, as recommended by the American Heart Association. In addition, the display on the monitor was disengaged to prevent subject observation of BP readings. Subjects recorded the time when the cuff inflated and their activity at that time and were asked to repeat the same life style activities on the second ambulatory BP recording day.

Data from the ambulatory monitors were downloaded to laboratory computers using Suntech Accutracker II software, and the analysis software automatically edited values outside of normal physiologic ranges. Spurious readings due to factors such as movement artifact were also automatically edited. All spurious readings were examined for consistent patterns and, when appropriate, the readings were incorporated into the data.

**Statistical analysis.** Descriptive statistics were used to derive mean  $\pm$  standard deviation for all data. Subject characteristics were compared using a one-way analysis of variance (ANOVA). Ambulatory systolic and diastolic BP and heart rates were averaged for each h of the two 24-h recordings. The 24-h ambulatory BP and heart rate data also were subdivided and averaged for: a) awake hours, b) asleep hours, and c) six 4-h intervals (9 a.m.–1 p.m., 1 p.m.–5 p.m., 5 p.m.–9 p.m., 9 p.m.–1 a.m., 1 a.m.–5 a.m., 5 a.m.–9 a.m.). For BP and HR comparisons the control and experimental day were compared within each group (sedentary, resistive-, and endurance-trained) using a two-way repeated measures ANOVA (gender  $\times$  time) to determine whether any gender differences existed. A repeated-measures ANOVA was used to compare total 24-h, awake, and asleep BP and HR recordings within and between the experimental and control days among the groups. A two-way repeated measures ANOVA was used to compare baseline BP and the different time subdivisions recordings within and between the experimental and control days among the groups. A significance level of  $P < 0.05$  was used to indicate statistical significance.

## RESULTS

A total of 36 male and female subjects were recruited for this study. Three subjects (one sedentary female and two endurance-trained male subjects) could not complete the acute resistive exercise session, and their data were not included in the analysis. There were no significant differences between the sedentary and resistance- and endurance-trained groups for age, height, weight, body composition, BMI, or casual BP (Table 1). Casual BP taken during the initial screening did not differ from baseline readings taken on the control or exercise day (Table 1). No gender differences were evident for any of the BP or HR parameters; therefore, the men's and women's data were combined for all subsequent analysis.

The results showed no significant differences within the groups for the average 24-h, the awake or the asleep systolic or diastolic BP or HR when comparing the control and the

TABLE 1. Subject characteristics.

	Sedentary	Resistance-Trained	Endurance-Trained
Age (yr)	20.3 $\pm$ 1.8	23.4 $\pm$ 2.3	23.5 $\pm$ 3.4
Height (cm)	166.1 $\pm$ 9.2	168.1 $\pm$ 5.2	169.4 $\pm$ 11.3
Weight (kg)	61.6 $\pm$ 10.2	66.9 $\pm$ 5.2	65.4 $\pm$ 11.0
BMI	22.1 $\pm$ 2.3	23.4 $\pm$ 4.1	22.6 $\pm$ 2.6
Body fat (%)	17.6 $\pm$ 5.7	13.2 $\pm$ 6.6	15.9 $\pm$ 7.8
Casual BP			
Systolic (mm Hg)	113 $\pm$ 5	109 $\pm$ 10	110 $\pm$ 12
Diastolic (mm Hg)	70 $\pm$ 6	69 $\pm$ 7	69 $\pm$ 5

Data are mean  $\pm$  standard deviation.

resistive exercise day for any of the groups (Table 2). When the 24 h ambulatory BP recording period was divided into six 4-h periods, the systolic and diastolic BP were reduced somewhat at each period after the resistive exercise when compared with the control day for the sedentary subjects (Fig. 1). However, these reductions were not statistically significant. The resistance-trained subjects had somewhat higher systolic and diastolic BP for the first 12 h after exercise, but these increases also were not statistically significant (Fig. 2). The endurance-trained subjects had similar systolic and diastolic BP for the control and exercise day at all time periods. However, during the third time period there was a nonsignificant increase in diastolic BP of 6.5 mm Hg after the resistive exercise compared to the control day (Fig. 3). A comparison of the 24 ambulatory BP for the three groups indicated that the sedentary, resistance-trained, and endurance-trained subjects had similar responses after the resistive exercise session (Fig. 4). Though the differences were not significant, in the first 4 h, and during hours 8–12 after the resistive exercise session, the sedentary group had lower diastolic BP than the other two groups. In addition, during hours 4–8 diastolic BP in the sedentary and endurance-trained groups were slightly, but not significantly, lower than the resistance-trained group.

## DISCUSSION

The major finding of this study is that systolic and diastolic BP were neither increased or decreased in the hours immediately after and for up to 24 h after an acute session of resistive exercise compared with during a nonexercise control day in young, normotensive men and women. In addition, the results showed that sedentary individuals had a similar 24-h ambulatory BP response after an acute resistive exercise session compared with resistance- or endurance-trained individuals.

To our knowledge, this is the first study to examine 24-h ambulatory BP in sedentary, resistance-, and endurance-trained subjects after an acute resistive exercise session. Others have measured BP up to 2 h after a resistive exercise session in resistance-trained individuals (6) and in female subjects with no prior resistance training (16) but had mixed results. Hill et al. (6) examined the BP response after four resistive exercises performed at 70% of 1-RM for as many repetitions as possible in six young normotensive men. The total workout time ranged from 11 to 18 min, and BP was measured before exercise, 1–10 s after, and 1, 2, 15, 30, and

TABLE 2. Twenty-four hour, awake, and asleep ambulatory blood pressure and heart rate for sedentary, resistance-trained, and endurance-trained subjects.

Day	24-hr BP (mm Hg)	24-hr HR (bpm)	Awake BP (mm Hg)	Awake HR (bpm)	Asleep BP (mm Hg)	Asleep HR (bpm)
Sedentary Control	114 ± 10	76 ± 9	118 ± 9	79 ± 12	103 ± 15	64 ± 10
	57 ± 18		67 ± 5		55 ± 8	
Exercise	111 ± 8	76 ± 7	114 ± 8	80 ± 8	103 ± 12	66 ± 10
	61 ± 3		64 ± 4		54 ± 5	
Resistance-trained Control	110 ± 10	64 ± 10	114 ± 10	70 ± 11	105 ± 12	57 ± 11
	62 ± 4		65 ± 5		58 ± 4	
Exercise	112 ± 10	68 ± 7	116 ± 10	74 ± 7	105 ± 13	61 ± 8
	65 ± 4		68 ± 5		58 ± 6	
Endurance-trained Control	112 ± 11	65 ± 9	115 ± 11	71 ± 9	105 ± 12	57 ± 9
	63 ± 3		66 ± 4		56 ± 2	
Exercise	110 ± 11	67 ± 8	114 ± 11	71 ± 9	100 ± 18	58 ± 7
	63 ± 5		66 ± 6		56 ± 6	

Data are mean ± standard deviation. None of the differences between or within the groups were statistically significant.

60 min after resistive exercise. The results indicated a significant decrease in diastolic BP for up to 1 h after resistive exercise but no significant change in systolic BP from baseline.

O'Connor et al. (16) studied ambulatory BP for up to 120 min after a bout of resistive exercise at three different intensities of a 10-RM using six different exercises in normotensive women. They found significantly elevated systolic BP at 1 min after exercise at 60% of one RM and 1 and 15 min after exercise at 80% of one RM. Although the protocol in the O'Connor et al. study was more vigorous than that used by Hill et al., it was still less than a typical resistive training session used by young persons. By contrast, the protocol in the present study included 2 sets of 12 whole-body exercises, thereby simulating a more typical training session for young persons. In addition, both the Hill et al. (6) and O'Connor et al. (16) studies used either 70% of 1-RM or different percentages of a 10-RM. However, the

protocols could have been individualized by using a 6–12 RM for upper body exercises and 10–15 RM for lower body exercises (9), because a specific RM protocol does not elicit the same number of RM for all exercises or for all people (7,8). In the present study, an 8 and 12 RM was used for the upper body exercise and lower body exercises, respectively, to provide a more individualized protocol.

To determine whether long-term resistive training has an effect on BP response, Fleck and Dean (3) measured intra-arterial BP of strength-trained, novice resistance-trained, and sedentary individuals during resistive exercise. The novice resistance-trained individuals elicited less of a pressor response during resistance exercise than the sedentary individuals, and the body builders had a significantly lower systolic and diastolic peak BP during resistive exercise. The results of this study (3) show that resistance training can

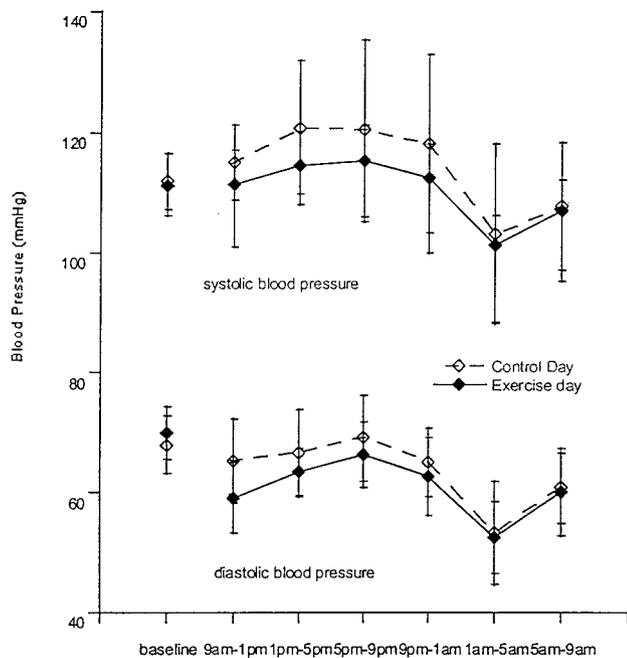


FIGURE 1—Comparison of control and exercise day systolic and diastolic 24-h ambulatory blood pressure for sedentary individuals.

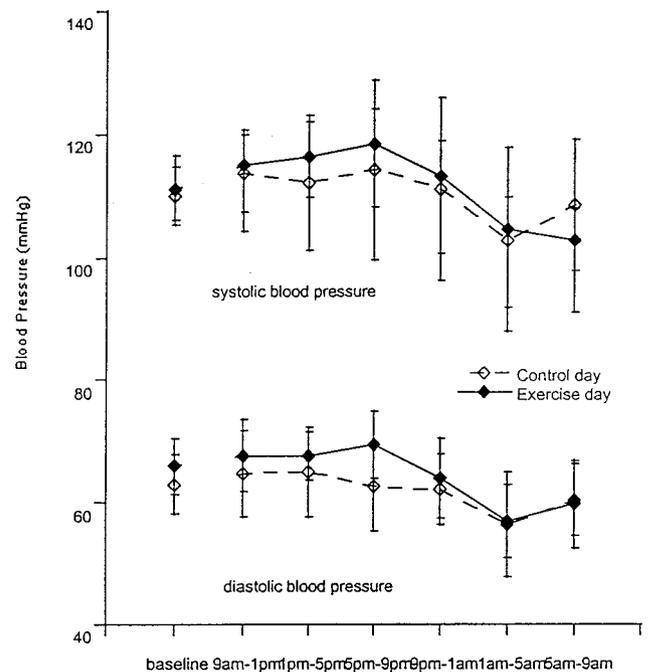


FIGURE 2—Comparison of control and exercise day systolic and diastolic 24-h ambulatory blood pressure for resistance-trained individuals.

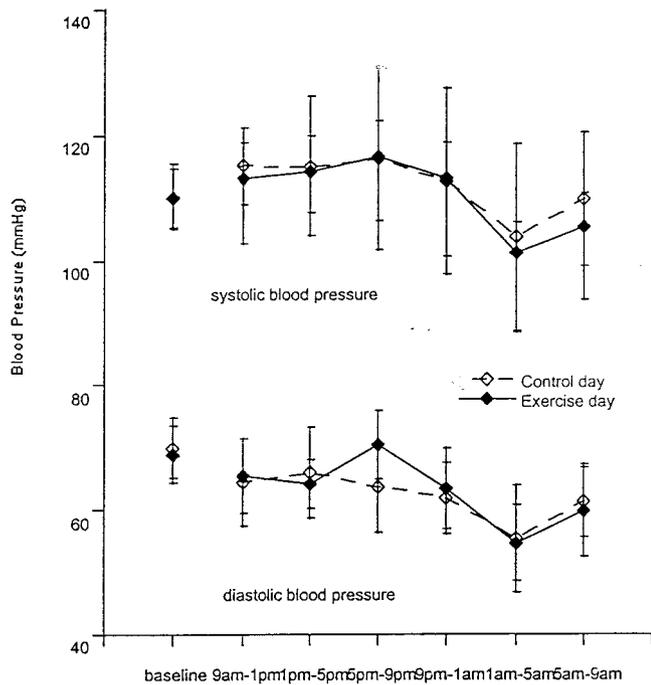


FIGURE 3—Comparison of control and exercise day systolic and diastolic 24-h ambulatory blood pressure for endurance-trained individuals.

reduce the BP response during resistive exercise. This may indicate that an individual's hemodynamic response after resistive exercise is dependent on the amount of prior resistance training. However, the present study found that the ambulatory BP of the sedentary individuals after resistive exercise was similar to that of the resistance- and endurance-trained subjects.

Before this study, the acute affect of resistive exercise on 24-h ambulatory BP in normotensive young persons was unclear. However, BP had been measured only for up to 2 h after resistive exercise. A number of studies had demonstrated significant decreases in systolic and diastolic BP after acute aerobic exercise in hypertensives (1,4,5,11,18,21). In contrast, in normotensives only Kaufman et al. (11) reported a significant reduction in BP after acute aerobic exercise. In that study, systolic BP was significantly reduced by 7 mm Hg for up to 1 h after aerobic exercise. Others (2,18,22) who investigated 24 h ambulatory BP after acute aerobic exercise in normotensives found no difference in 24 h systolic or diastolic BP on the exercise day compared with a nonexercise control day, which is similar to the results of this study after acute resistive exercise.

In the present study, we found no significant change in systolic or diastolic BP after resistive exercise during any of the time periods when compared with the nonexercise day. This study differed from others (6,16) because it compared

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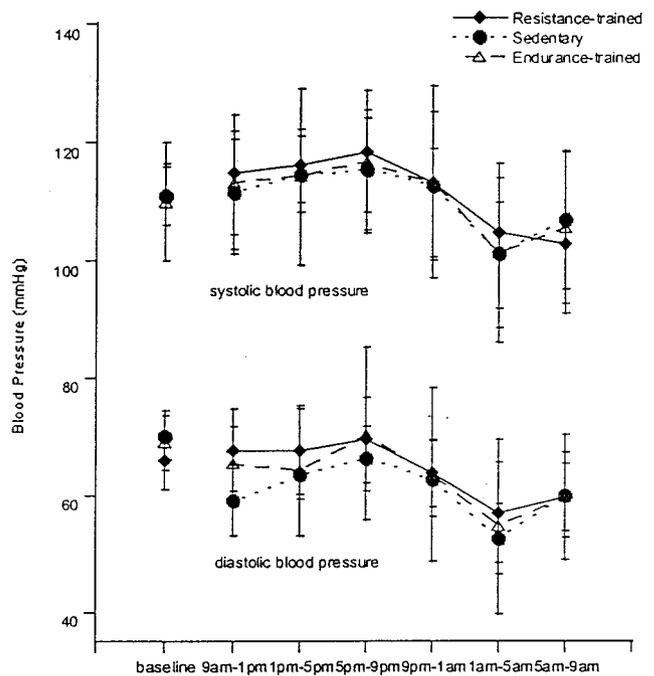


FIGURE 4—Comparison of control and exercise day systolic and diastolic 24-h ambulatory blood pressure for sedentary, resistance-trained, and endurance-trained individuals.

BP and HR during specific time periods between a day with and a day without prior exercise. This protocol also controlled for outside factors that may contribute to changes in BP or HR. Another strength of this study is the practical application of the findings due to the spontaneous and unobtrusive nature of ambulatory BP monitoring. BP measurements on both control and exercise days were obtained on the same day of the week to control for differences in the daily activities between the control and exercise day. Average heart rates between the exercise and control day were similar, providing evidence that activity levels between the two days were similar.

In conclusion, the current investigation found that the elevations in systolic BP, diastolic BP, or heart rate evident during resistive exercise do not persist in the 24 h after the exercise. There also was no difference in BP or HR response based on the training status of the subjects. Thus, it appears that a single session of resistive exercise has no effect on BP during the subsequent 24 h in young normotensive sedentary, or resistance- or endurance-trained men and women.

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