The Effects of Resistance Training on Resting Blood Pressure in Women

HEIDI K. BYRNE1 AND JACK H. WILMORE2

1Department of Physical Education and Sport, State University of New York at Brockport, Brockport, New York 14420; 2Department of Health and Kinesiology, Texas A&M University, College Station, Texas 77843-4243.

ABSTRACT
The purposes of this study were to document the effects of a 20-week resistance training (RT) program or resistance training plus walking (RT/W) program on resting blood pressure in 28 moderately obese women, and to compare resting blood pressures of 42 women of various fitness levels and states of RT. The subjects in the training study were 28 moderately obese women, and the subjects in the cross-sectional study were 42 women of various fitness levels and states of RT. For all subjects, resting blood pressure was measured on 2 consecutive days in a semirecumbent position. Results from the training study showed no significant changes in blood pressure as a result of RT or RT/W. In the cross-sectional study, no significant difference in systolic blood pressure occurred among highly (HRT), moderately (MRT) or untrained (UNT) subjects. Diastolic blood pressure (DBP) was significantly lower in the HRT group when compared with either the MRT or UNT groups, whereas DBP was not different between the MRT and UNT groups. Both the training and cross-sectional studies of this investigation demonstrate that RT is not associated with a chronic increase in resting blood pressure in normotensive women. The cross-sectional study suggests that highly RT individuals might even be at reduced risk for hypertension.

Key Words: weight training, hypertension, women


Introduction
High blood pressure, or hypertension, is a prevalent disease in westernized societies, affecting approximately 50 million adults in the United States (22). The risks associated with hypertension include stroke, heart failure, heart disease, myocardial infarction, renal failure, and kidney disease (19). One of the common forms of nonpharmacologic prescription for hypertension is exercise. Substantial clinical evidence exists that endurance training reduces blood pressure in individuals both with and without hypertension (2, 7, 19). Though the effects are modest (5 mm Hg in patients without hypertension, 5–10 mm Hg in patients with hypertension), any reduction in blood pressure should reduce the risk for stroke and coronary heart disease.

The effects of resistance training (RT) on blood pressure are less clear and need further investigation. Historically, individuals with cardiovascular disease have been discouraged from participating in any form of RT because of the acute increase in blood pressure associated with this type of exercise. Additionally, there have been concerns that intermittent increases in blood pressure during RT could cause vascular wall hypertrophy and, thus, a decreased luminal area, resulting in an increased vascular resistance and increased blood pressure (8). However, limited research has been conducted in this area. The few longitudinal studies that have been conducted have shown decreased (14), increased (12, 13, 16, 20), and unchanged (6, 9, 10) blood pressure with RT. Increases in blood pressure with RT have been shown to occur infrequently; thus, the concern that conventional RT may chronically increase blood pressure may not be warranted, though this area of research needs to be more fully investigated. Additionally, most studies in this area have been conducted on men. Because of its association with obesity, the development of hypertension is especially of concern in overweight or obese men and women. These individuals must weigh the potential benefits of RT for a decrease in fat and an increase in fat-free mass (FFM) versus a potential risk of increased blood pressure or the development of hypertension.

Therefore, the purpose of this study was twofold: to document the effects of a 20-week resistance training program or resistance training plus walking (RT/W) program on resting blood pressure in 28 moderately obese women, and to compare resting blood pressures of 42 women of various fitness levels and states of RT. These data were collected as part of 2 other closely controlled studies investigating the effects of exercise training on resting metabolic rate. It
was hypothesized that the training program would result in a decrease in resting blood pressure in the experimental subjects and that the RT subjects in the cross-sectional study would have a decreased blood pressure when compared with the sedentary subjects.

### Methods

#### Subjects

All subjects recruited from the University of Texas at Austin and the surrounding community volunteered to serve as subjects in this study. None of the subjects had a history of oral contraceptive use for the past year before participation. All subjects were weight-stable (±3 kg) for the past year and had not been clinically diagnosed with an eating disorder. Each subject received an extensive verbal and written description of the study and signed an informed consent form approved by the Institutional Review Board of the University of Texas at Austin.

**Longitudinal Study.** Thirty-six sedentary, normally menstruating women between the ages of 18 and 45 years participated in this study. All subjects were between 30 and 43% body fat. To meet the criterion for “sedentary” status, a subject could not have performed regular exercise for a minimum of the past 2 years. Twenty-five subjects were recruited to participate in the training program, and 11 subjects were recruited to serve as controls. Unfortunately, subjects in the 2 groups had to be recruited separately because of the unwillingness of subjects to participate if assigned to a nonexercising control group. The 25 experimental subjects were then randomly assigned to either a RT-only group or a RT/W group. Six experimental subjects either dropped out of the study or failed to complete the minimum number of workouts (i.e., 75%). Two of the control group subjects were dropped from the study, one because of pregnancy and the other because of the onset of menopause. Their physical characteristics are presented in Table 1. As expected by the experimental design, the subjects were higher than average for their age in relative body fat, as determined by hydrostatic weighing, and lower than average for their age in aerobic fitness, as indicated by their VO₂max. These findings are consistent with the recruitment of a sedentary, overweight population.

**Cross-Sectional Study.** Forty-two women between the ages of 18 and 46 years of age volunteered to serve as subjects in this study. Forty-one of the subjects were normally menstruating, and 1 subject was amenorrheic. All subjects were between 13.5 and 37% body fat and at various levels of cardiovascular fitness and RT. Their physical characteristics are presented in Table 1.

Subjects were then categorized, based on RT status, into one of the following groups: untrained (UNT), moderately resistance trained (MRT), and highly resistance trained (HRT). The UNT group comprised 18 subjects not participating in any current regular exercise and 2 subjects participating in very low levels of activity. The MRT group comprised 12 subjects performing RT 2 to 3 days per week. These subjects also participated in some form of aerobic exercise 2 to 3 times per week. The HRT group comprised 10 subjects participating predominantly in RT a minimum of 4 days per week. Of the 10 subjects, 4 of them also participated in moderate aerobic training (AT) and 1 of them participated in intense RT and AT. Each subject in the study was carefully placed into the appropriate group based on her current training status.

#### Procedures

During the initial screening visit, each subject completed questionnaires to determine health status, exercise history, and menstrual history. A subject was considered normally menstruating if she reported regular menstrual cycles between 25 and 35 days in length for 1 year before participation in the study. The health history questionnaire was completed to ensure that each subject was in good health and did not have a history of cardiovascular or other chronic limiting diseases.

**Longitudinal Study.** Body composition was assessed during the first visit. Subjects were instructed to refrain from eating or ingesting caffeine 4 hours before the test. Hydrostatic weighing to determine body density was conducted as described by Behnke and Wilmore (4), with residual lung volume determined by the oxygen dilution method of Wilmore et al. (25). Relative body fat was estimated from body density by the equation of Lohman (15) for white subjects or Ortiz et al. (17) for the 1 African-American subject. Fat mass (FM) and FFM were obtained by the following equations: FM = (mass × relative fat)/100; and FFM = mass − FM.

Resting blood pressure was then measured on 2 consecutive days for each subject during the follicular phase of the menstrual cycle, which was defined as within the first 10 days from onset of menses. Upon
arrival to the laboratory, subjects were weighed and 3 electrodes were applied to the chest for measurement of heart rate (HR). Subjects were then seated in a recliner chair in a semirecumbent position. Leads were attached to the chest electrodes and interfaced to a Colin Model STBP-780 semiautomated blood pressure monitor (Colin Medical Instruments Corp., San Antonio, TX). A blood pressure cuff was applied to the left arm and attached to the blood pressure monitor. The cuff was considered the proper size if the bladder in the cuff fit around two-thirds (67%) of the circumference of the upper arm. If there was a question as to correct cuff size, guidelines established by The Joint Committee on the Detection, Evaluation, and Treatment of High Blood Pressure (1) were followed using mid-upper-arm circumference measurements. The laboratory used for blood pressure measurement was maintained quiet and dimly lit. Room temperature was maintained between 21 and 24°C. Subjects were provided a light blanket to cover them during the test period, and they were then allowed to rest quietly for 5 minutes. An initial blood pressure reading was taken, and it was followed with blood pressure measurements every 5 minutes for 25 minutes. The blood pressure test was terminated at the end of the 25-minute measurement period.

On the next visit to the laboratory, each subject performed a graded exercise test on a motorized treadmill to assess maximal oxygen consumption (VO2max). Each subject was allowed to become familiar with the treadmill and walk at a comfortable pace until she felt at ease. The test began at 3.0 mph, 0% grade for 2 minutes. The speed was then increased by 0.5 mph every minute until a maximal speed that the subject could maintain was achieved (usually 5 mph). At this time, the speed was kept constant, and the grade increased 2.5% every minute until volitional exhaustion. The O2 volume of expired carbon dioxide (CO2), expired ventilation (E), and respiratory exchange ratio (RER) were measured continuously using a Sensormedics 2900 metabolic cart (Yorba Linda, CA), which was calibrated before and after each exercise test with certified standard gases. HR was measured continuously by telemetry and recorded at 1-minute intervals using a Polar heart rate monitor (Montvale, NJ). VO2max was defined as the point at which oxygen consumption plateaued with an increase in the rate of work, or the peak value, if a plateau was not achieved and the respiratory exchange ratio was greater than 1.10 and the maximal HR was ≥95% of the subject’s age-predicted value.

On the final 2 days of testing, subjects were tested for maximal strength using a 3 repetition maximum lift.

After completing all pretreatment tests, all experimental subjects were randomly assigned to participate in either the RT or RT/W program. Subjects in all 3 groups were instructed not to change either their activity or dietary habits during the 5-month period of the training study other than the additional activity imposed by the experimental treatment to which they were assigned.

Each subject in the RT and RT/W groups participated in a 5-month training program designed to increase FFM and strength. Subjects trained using a combination of Schnell resistance training equipment (Gachenback, Germany) and free-weights 4 days a week (i.e., Monday, Tuesday, Thursday, Friday), with the exercises divided into primarily upper- and lower-body emphasis on alternating days. The Monday and Thursday workouts included the following exercises: standing chest press, pec deck, lying down row, assisted dips, overhead press, side lateral raises, triceps kick back, and abdominal crunches. The Tuesday and Friday workouts included the following exercises: leg press, leg extension, leg curl, lat pull-down, assisted pull-ups, barbell curl, and abdominal crunches. For safety and motivational reasons, subjects trained in pairs. A stretching period preceded and followed each training session.

The resistance-training program was graded in nature to prevent injury and maintain interest and adherence to the training protocol. The phases of the study were as follows.

Phase I: Weeks 1–6. Subjects performed 10–12 repetitions per set, 3 sets per exercise. The resistance was set so that on each exercise the subject fatigued between 10 and 12 repetitions.

Phase II: Weeks 7–20. Subjects performed 3 sets comprising a first set of 10–12 repetitions, a second set of 8–10 repetitions, and a third set of 6–8 repetitions. Resistance was increased for each exercise as the subject gained strength based on the number of repetitions needed to cause fatigue in each subject. Abdominal crunches were performed at each session with subjects performing 1 set until failure initially and working up to 100 crunches per session.

In addition to the RT program described above, the subjects in the RT/W group also walked 3 days of the week. Subjects were trained to monitor their heart rates using palpation of the carotid artery. Subjects were paired to use the “buddy system” for walking workouts. Duration of walk time and average HR during the walk were recorded on a designated form and verified by the walking partner, as the walking sessions were not directly supervised. These forms were turned in to the principal investigator each Monday. Subjects were instructed to wear a good pair of walking shoes to prevent orthopedic problems.

The walking program was graded in nature, with intensity and duration increased as follows:

• Weeks 1–4: Subjects walked for 20 minutes at an HR corresponding to 50% of the predetermined VO2max.
• Weeks 5–8: Subjects walked for 30 minutes at an HR corresponding to 60% of the predetermined \( \text{V}O_2\text{max} \).
• Weeks 9–12: Subjects walked for 30 minutes at an HR corresponding to 65% of the predetermined \( \text{V}O_2\text{max} \).
• Weeks 13–20: Subjects walked for 40 minutes at an HR corresponding to 70% of the predetermined \( \text{V}O_2\text{max} \).

Subjects were tested for strength (3 repetition maximum) during the last week of the training program. At the end of the 20-week training period, subjects were reassessed for blood pressure, body composition, and \( \text{V}O_2\text{max} \). Resting blood pressure measurements were made on 2 consecutive mornings, 36 to 48 and 60 to 72 hours after the last exercise session.

**Cross-Sectional Study.** \( \text{V}O_2\text{max} \) was assessed during the first visit using a graded exercise protocol on a motorized treadmill. The protocol was similar to that used for the subjects in the longitudinal study except that the warm-up speed was 3.5 m·h and the speed of the treadmill was increased by 1.0 m·h every minute until a maximal speed that the subject could maintain was achieved. Body composition and blood pressure measurements were made using procedures identical to the pretraining protocol described for the subjects in the longitudinal study.

**Statistical Analyses**

The analyses were conducted using the SPSS v6.1.1 statistical program (SPSS, Inc., Chicago, IL) for the Macintosh computer. Data are reported as mean ± SE.

**Longitudinal Study.** An intraclass correlation and an analysis of variance (ANOVA) with a repeated measure were performed to determine between-trial reliability between the 2 pretraining repeat trials and between the 2 posttraining repeat trials for systolic blood pressure (SBP) and diastolic blood pressure (DBP). ANOVA with repeated measures was used to analyze the differences among each of the groups for SBP, DBP, mean blood pressure (MBP), and for all other dependent variables (i.e., relative fat, body mass, FFM, FM, \( \text{V}O_2\text{max} \)). When the F ratio was significant at \( p \leq 0.05 \) for a group by time interaction, a simple main effect test was used to compare the change from pretreatment to posttreatment for each group. Significant main effect results were further investigated using single degree-of-freedom contrasts. Data were analyzed with subjects classified by treatment group. Given the power equation of \( N = 2SD^2 (Za + Zb)^2 / \text{expected change}^2 \), it was calculated that 9 subjects were needed for each experimental group (alpha = .05; power = .80).

**Cross-Sectional Study.** An intraclass correlation and ANOVA with a repeated measure were performed to determine between-trial reliability between the repeat trials for SBP and DBP. ANOVA was used to analyze the differences between groups for SBP, DBP, MBP, and for all other dependent variables (i.e., relative fat, body weight, FFM, FM, \( \text{V}O_2\text{max} \)). Data were analyzed with subjects classified by training states, as previously described (HRT, MRT, UNT). Single degree-of-freedom contrasts were used to explore significant main effects. Correlation analyses were used to compare associations between variables.

**Results**

**Reliability of BP Measurements**

Both an intraclass correlation and ANOVA with repeated measures were used to examine the reliability for SBP and DBP in both studies, as shown in Table 2. In the longitudinal study, the ANOVA procedures indicated that no significant differences existed between the 2 pretreatment measurements and between the 2 posttreatment measurements for SBP or DBP. The intraclass correlations for these variables were \( R = 0.63 \) (pre-DBP), \( R = 0.89 \) (post-DBP), \( R = 0.88 \) (pre-SBP), and \( R = 0.88 \) (post-SBP). In the cross-sectional study, no significant differences existed between the 2 SBP and the 2 DBP measurements. The intraclass correlations for these variables were \( R = 0.89 \) (SBP) and \( R = 0.77 \) (DBP).

**Longitudinal Study**

**Training Program Adherence.** The combined attendance for the RT and RT/W groups for the RT program was 90% of the workouts attended. The RT group had an attendance of 92%, whereas the RT/W group had an
88% attendance for the RT workouts and an 85% attendance for the walking workouts.

Subjects in the RT/W group were able to maintain close to the prescribed HR during the 4 phases of the walking protocol; HRs corresponding to 50, 60, 65, and 70% of their VO₂max values were prescribed. Subjects walked at HRs corresponding to 51, 58, 62, and 64% of their VO₂max values for the 4 phases of the training program.

**Alterations with Training.** No statistically significant differences existed in the pretreatment VO₂max values when expressed in liters per minute among the 3 groups, as shown in Table 3. In the posttreatment measures, the RT/W group was the only group to show a significant increase in VO₂max (liters per minute). Changes in body composition are presented in Table 3. FFM in the RT group was shown to be significantly higher than in the control group in the pretreatment measures, which was the only significant difference for pretreatment measurements. Following the 20-week training program, the only change in body composition was an increase in FFM in the RT and RT/W groups.

Blood pressure data are presented in Table 3. No significant group by time interactions were found for SBP, DBP, or MBP. A significant time for main effect for SBP, DBP, and MBP was found. No significant correlations existed between changes in body mass and changes in blood pressure when analyzed by group or when groups were combined.

**Cross-Sectional Study**

**Aerobic Capacity and Body Composition.** Aerobic capacity and body composition data are presented in Table 4. The HRT and MRT groups had significantly higher VO₂max (ml·kg⁻¹·min⁻¹) values than did the UNT group, with no difference between the HRT and MRT groups. The HRT and MRT groups had significantly

---

Table 3. Aerobic capacity, body composition, and blood pressure changes with training.*

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Pre-treatment</th>
<th>Posttreatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RT</td>
<td>RT/W</td>
</tr>
<tr>
<td>VO₂max (ml·kg⁻¹·min⁻¹)</td>
<td>28.2 ± 1.1</td>
<td>30.8 ± 1.6</td>
</tr>
<tr>
<td>VO₂max (L·min⁻¹)</td>
<td>2.37 ± 0.14</td>
<td>2.30 ± 0.16</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>81.1 ± 2.4</td>
<td>74.7 ± 3.3</td>
</tr>
<tr>
<td>Relative (%) body fat</td>
<td>38.9 ± 0.9</td>
<td>38.7 ± 1.8</td>
</tr>
<tr>
<td>FFM (kg)</td>
<td>49.5 ± 1.7‡</td>
<td>45.6 ± 2.0</td>
</tr>
<tr>
<td>FM (kg)</td>
<td>31.5 ± 1.0</td>
<td>29.0 ± 2.1</td>
</tr>
<tr>
<td>SBP</td>
<td>118.9 ± 3.1</td>
<td>114.2 ± 2.4</td>
</tr>
<tr>
<td>DBP</td>
<td>71.8 ± 1.7</td>
<td>70.6 ± 1.2</td>
</tr>
<tr>
<td>MBP</td>
<td>87.5 ± 2.1</td>
<td>85.1 ± 1.5</td>
</tr>
</tbody>
</table>

* RT = resistance training; RT/W = resistance training plus walking; FFM = fat-free mass; FM = fat mass; SBP = systolic blood pressure; DBP = diastolic blood pressure; MBP = mean blood pressure. Data are expressed as mean ±SE.

† Significant difference from pretreatment for the same group (p ≤ 0.05).
‡ Significant difference from control, same time (p ≤ 0.05).

Table 4. Aerobic capacity, body composition, and blood pressure data by level of training.*

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Total (n = 42)</th>
<th>HRT (n = 10)</th>
<th>MRT (n = 12)</th>
<th>UNT (n = 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO₂max (ml·kg⁻¹·min⁻¹)</td>
<td>38.9 ± 1.30</td>
<td>46.8 ± 1.50†</td>
<td>44.8 ± 1.64†</td>
<td>31.4 ± 0.76</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>64.3 ± 1.1</td>
<td>61.3 ± 1.8†</td>
<td>63.1 ± 2.4</td>
<td>66.4 ± 1.6</td>
</tr>
<tr>
<td>Fat-free mass (kg)</td>
<td>47.1 ± 0.8</td>
<td>50.1 ± 1.5†</td>
<td>48.8 ± 1.3†</td>
<td>44.5 ± 0.9</td>
</tr>
<tr>
<td>Fat mass (kg)</td>
<td>17.1 ± 1.0</td>
<td>11.2 ± 0.6†</td>
<td>14.2 ± 1.9†</td>
<td>21.8 ± 1.0</td>
</tr>
<tr>
<td>Hydrostatic relative fat (%)</td>
<td>26.1 ± 1.2</td>
<td>18.2 ± 0.8†</td>
<td>21.9 ± 2.1†</td>
<td>32.6 ± 0.9</td>
</tr>
<tr>
<td>SBP</td>
<td>111.8 ± 1.3</td>
<td>108.3 ± 2.1</td>
<td>112.8 ± 2.1</td>
<td>113.1 ± 2.0</td>
</tr>
<tr>
<td>DBP</td>
<td>66.7 ± 0.8</td>
<td>62.2 ± 1.1†</td>
<td>66.8 ± 1.1‡</td>
<td>69.0 ± 1.2</td>
</tr>
<tr>
<td>MBP</td>
<td>81.8 ± 0.9</td>
<td>77.6 ± 1.2†</td>
<td>82.1 ± 1.2</td>
<td>83.7 ± 1.4</td>
</tr>
</tbody>
</table>

* HRT = highly resistance trained; MRT = moderately resistance trained; UNT = untrained; SBP = systolic blood pressure; DBP = diastolic blood pressure; MBP = mean blood pressure. Values are mean ±SE.
† Significantly different than UNT group (p ≤ .05).
‡ Significantly different than HRT group (p ≤ .05).
higher FFM, lower FM, and lower relative body fat than did the UNT group. Body mass was not significantly different among any of the groups.

**Blood Pressure.** Blood pressure data are presented in Table 4. No significant difference in SBP existed among any of the groups. DBP was significantly lower in the HRT group when compared with either the MRT or UNT groups, whereas DBP was not different between MRT and UNT groups. MBP was significantly lower in the HRT group when compared with the UNT group, but it was not different when compared to the MRT group.

Significant correlations existed among body mass and SBP ($r = 0.32$) and MBP ($r = 0.34$), among FM and DBP ($r = 0.38$) and MBP ($r = 0.35$), among $V_{\text{O}_2\text{max}}$ and DBP ($r = -0.41$), and among percent body fat and DBP ($r = 0.38$) and MBP ($r = 0.32$), with all subjects combined. Therefore, ANCOVA analyses were conducted accounting for each of these variables (body mass, FM, $V_{\text{O}_2\text{max}}$, and percent body fat). However, none of these covariates accounted for a significant amount of the variance for SBP, DBP, or MBP.

**Discussion**

These studies were designed to investigate the effects of resistance exercise training on resting blood pressure using both longitudinal and cross-sectional experimental designs. The 2 studies combined provide us with important information on blood pressure for 70 women without hypertension of various fitness levels and body composition.

There has been a concern that repeated exposure to increases in blood pressure as a result of RT could lead to a chronic increase in resting blood pressure. Hunter and McCarthy (13) demonstrated increased resting SBP in male cyclists as a result of the combination of an 8-week high-intensity cycling and RT program. Subjects in the study were competitive male cyclists who had not been training for 3 months before the study. DBP was not changed posttraining. However, no subjects in their study performed only RT, making it difficult to separate these responses to type of training. Increased resting blood pressure values have also been documented in cross-sectional studies investigating subjects involved in RT. McKeag et al. (16) reported both severe and moderate hypertension in American collegiate football players. Of the 94 athletes screened, 23.4% had persistently increased blood pressure during the preseason period. The incidence of systolic hypertension was doubled by early season from the initial screening. By the end of the season, all but 2 of the players were normotensive. Increases in resting blood pressure have also been reported with high-volume training in swimmers (William P. Morgan, personal communication, June 2000). Blood pressure measurements were made on collegiate swimmers in the preseason and late in the competitive season. Significant increases in blood pressure were seen in the late-season measurements. Blood pressure measurements were made while athletes were sitting on a cycle ergometer before exercise testing. Because the cyclists, football players, and swimmers mentioned above were engaged in other modes of anaerobic training as well as RT, it is impossible to link training mode to the prevalence of hypertension. Spitler et al. (20) demonstrated that male bodybuilders had higher resting SBP and DBP values when compared with population norms for resting blood pressure in sedentary men of the same age. Blood pressures were not adjusted for body mass, and no sedentary control group existed in this study, thus, the need for population norm comparisons. Olympic weightlifters have also been reported to have increased resting blood pressure values associated with overtraining (12). Resting blood pressures before daily practice were monitored in 8 of the national weightlifting team members of Bahrain. Systolic blood pressure rose steadily over the course of a month of very intense training. Once training load was reduced, SBP values were maintained at normal resting levels.

Although increased blood pressure has been shown to be associated with RT, several longitudinal and cross-sectional studies have shown no increase in blood pressure as a result of RT, as found in this study. A 9-week resistive exercise program with 14 normotensive adolescent boys (9) found resting blood pressure unchanged posttraining. The training program used in this study was of the circuit type and was volume rather than intensity oriented. In a study of 7 young, normotensive girls (10), resting blood pressure was unchanged after 20 weeks of high-intensity lower-body RT, despite a significant increase in body mass and FFM. Men and women aged 70–79 years trained for 6 months using either RT or AT in a study by Cononie et al. (6). Resting blood pressure did not change as a result of RT in individuals with normal or slightly increased blood pressure, whereas DBP and MBP dropped with AT when compared with a sedentary control group. The present training study demonstrated a significant “time” main effect of a decrease in resting blood pressure, with no group by time interaction, in the RT, RT/W, and control groups. That is, a decrease in SBP, DBP, and MBP occurred from pretraining to posttraining, with all groups combined, but no statistically significant difference existed among the groups. The addition of more subjects to the present study might have resulted in significant differences between groups, i.e., a significant reduction in resting blood pressure. However, the more potentially useful observation was that no increase in blood pressure occurred in either the RT or RT/W groups, despite overall increases in body mass. Additionally, a significant correlation did not exist between change in body
weight and change in blood pressure for any group of subjects or for all subjects combined.

In agreement with the present training study, the results of the present cross-sectional study also demonstrate that individuals who RT do not exhibit increased resting blood pressure values. This is in agreement with 4 recent studies. Collander and Tesch (5) compared resting blood pressure in young,agematched normotensive male body builders and medical students. Resting blood pressure values were not significantly different between the 2 groups despite a 12 kg greater body mass in the body builders. Ballor and Poehlman (3) examined resting blood pressure in 82 young women separated into 3 groups: sedentary, AT, and RT. Subjects exercised in their respective modes of training at least 3 days per week and had been doing so for a minimum of 2 years. Resting SBP and DBP were not different among the groups. In another study by the same group of investigators (18), blood pressure was compared in AT, RT, and UNT young men. The AT group comprised runners who ran an average of 77 km a week. The RT group comprised body builders who trained 5 to 6 times a week. SBP and MBP were lower in the AT men compared with the RT or UNT groups. DBP was lower in the AT and RT groups when compared with the UNT group. In the most recent study by the same group of investigators (23), 54 healthy middle-aged women were characterized as RT, AT, or UNT. In order to be in a training group, subjects had to participate in their respective modes of training a minimum of 3 days per week. No significant differences in SBP and MBP existed among the groups, whereas DBP was lower in the RT group when compared with either the AT or UNT groups. The present cross-sectional study of 42 normotensive women is in agreement with these cross-sectional studies that suggest that RT is not associated with an increase in resting blood pressure. In the present study, no significant difference in SBP existed among the HRT, MRT, or UNT groups, but DBP was significantly lower in the HRT group when compared with either the MRT or UNT groups. These results suggest that intensity of training may play a role in resting blood pressure response. Body weight, fat mass, percent body fat, and \( V_{O2}\max \) did not explain a significant amount of the variance between groups in this study, suggesting that a mechanism other than these variables was responsible for the lower DBP in the HRT group.

A few longitudinal studies have demonstrated decreases in resting blood pressure as a result of RT. Stone et al. (21) conducted a study to investigate the cardiovascular responses to short-term weight training in young men. Nine sedentary college men trained similarly to Olympic-style weightlifters for 8 weeks. This high-intensity training resulted in a significant drop in resting SBP and no change in resting DBP. In a study investigating the effects of circuit weight training in borderline hypertensive men (11), a 9-week training program resulted in a significant 4 mm Hg decrease in DBP, with no change in SBP. The RT program used was performed 3 days a week and consisted of 3 sets of a 10-station circuit with 20–25 repetitions per set. The exercise/rest ratio was 3:1. In an 8-week program of isometric handgrip exercise training in healthy, young subjects, significant declines in both SBP and DBP were shown posttraining (24). Subjects trained 3 times per week using 4, 2-minute contractions at 30% of their maximum isometric handgrip strength. In a follow-up period of 5 additional weeks in which no isometric training occurred, resting blood pressure values returned to pretraining levels. In a study using healthy, untrained men, 16 weeks of high-intensity RT resulted in significant falls in DBP (5 mm Hg), whereas SBP values were unchanged (14). Subjects trained 3 to 4 times per week. During each session, subjects performed 1 set of 14 exercises and used the greatest weight possible to complete the specified number of repetitions before muscle exhaustion took place. Although the results of this study did not demonstrate a decrease in blood pressure with training, we suspect that replication of this study with a greater number of subjects might result in this finding.

It has been suggested (14) that training must elicit a large increase in aerobic capacity to see decreases in blood pressure. In the present training study, \( V_{O2}\max \) was slightly increased in the RT/W group, but not in the RT group. No differences existed in blood pressure response to training, regardless of changes in aerobic capacity, suggesting that this might not be a necessary ingredient for alterations in blood pressure. No correlations existed among changes in \( V_{O2}\max \) and SBP, DBP, or MBP in the subjects in the training study. However, because the changes in \( V_{O2}\max \) in the RT/W group were small, detectable differences in blood pressure might not be expected. The data from the cross-sectional study also suggest that a high aerobic capacity is not a prerequisite, but it might be associated with low blood pressure values. A significant correlation existed between \( V_{O2}\max \) and DBP (\( r = -0.41 \)) with subjects combined, but not with SBP (\( r = -0.18 \)) or MBP (\( r = -0.29 \)).

**Practical Applications**

Both the training and cross-sectional studies of this investigation demonstrate that RT is not associated with a chronic increase in resting blood pressure in normotensive women. In fact, the cross-sectional study suggests that highly RT individuals might even be at reduced risk for hypertension, although further investigation is warranted. In any event, it does appear that the concern that the acute increases in blood pressure experienced with RT will lead to chronic resting blood
pressure increases is not warranted, at least in this population of normotensive women. Further research will need to be conducted to continue to examine this issue and possible mechanisms involved in alterations in resting blood pressure with resistive exercise training.

References


Acknowledgments

The authors would like to sincerely thank the subjects for participating in this study.