Blackwell Publishing

Journal of the AMERICAN GERIATRICS SOCIETY

 Volume 47(10), October 1999, pp 1215-1221

Strength Training Normalizes Resting Blood Pressure in 65- to 73-Year-Old Men and Women with High Normal Blood Pressure

[Clinical Investigation]

Martel, G. F. PhD[*†]; Hurlbut, D. E. MS[*]; Lott, M. E. PhD[*]; Lemmer, J. T. PhD[*]; Ivey, F. M. PhD[*]; Roth, S. M. MA[*]; Rogers, M. A. PhD[*]; Fleg, J. L. MD[‡]; Hurley, B. F. PhD[*]

From the *Department of Kinesiology, College of Health and Human Performance, University of Maryland, College Park, Maryland; the †Department of Physical Therapy, University of Maryland Eastern Shore, Princess Anne, Maryland; and ‡Baltimore Longitudinal Study of Aging, Laboratory of Cardiovascular Science, Gerontology Research Center, Baltimore, Maryland.

This study was supported by Research Contract 1-AG-4-2148 from the National Institute on Aging.

Address correspondence and reprint requests to Ben Hurley, PhD, Department of Kinesiology, University of Maryland, College Park, MD 20742.

Abstract

OBJECTIVE: To determine the effects of heavy resistance strength training (ST) on resting blood pressure (BP) in older men and women.

DESIGN: Prospective intervention study.

SETTING: University of Maryland Exercise Science Laboratory.

PARTICIPANTS: Twenty-one sedentary, healthy older men (69 ± 1 year, n = 11) and women (68 ± 1 year, n = 10) served as subjects for the study.

INTERVENTION: Six months of progressive whole body ST performed 3 days per week using Keiser K-300 air-powered resistance machines.

MEASUREMENTS: One-repetition maximum (1 RM) strength was measured for seven different exercises before and after the ST program. Resting BP was measured on six separate occasions before and after ST for each subject.

RESULTS: Substantial increases in 1 RM strength were observed for upper body (UB) and lower body (LB) muscle groups for men (UB: 215 vs 265 kg; LB: 694 vs 838 kg; $P < .001$) and women (UB: 128 vs 154 kg; LB: 441 vs 563 kg; $P < .001$). The ST program led to reductions in both systolic (131 ± 2 vs 126 ± 2 mm Hg, $P < .010$) and diastolic (79 ± 2 vs 75 ± 1 mm Hg, $P < .010$) BP. Systolic BP was reduced significantly in men (134 ± 3 vs 127 ± 2 mm Hg, $P < .01$) but not in women (128 ± 3 vs 125 ± 3 mm Hg, $P < .01$), whereas diastolic BP was reduced following training in both men (81 ± 3 vs 77 ± 1, mm Hg, $P = .054$) and women (78 ± 2 vs 74 ± 2 mm Hg, $P = .055$).

CONCLUSIONS: Six months of heavy resistance ST may reduce resting BP in older persons. According to the latest guidelines from the Joint National Committee for the Detection, Evaluation, and Treatment of Hypertension, the changes in resting BP noted in the present study represent a shift from the high normal to the normal category.

Cardiovascular disease is responsible for greater morbidity and mortality than any other medical disorder in people older than age 65.[1] Resting blood pressure (BP) increases with age, and elevated resting BP is a major cardiovascular disease risk factor in older people.[2] Accordingly, the latest guidelines by the Joint National Committee for the Detection, Evaluation and Treatment of Hypertension (JNC VI)[3] recommend that individuals with established high normal BP (130-139 mm Hg systolic and/or 85-89 mm Hg diastolic) seek lifestyle changes, such as regular exercise, as an intervention for reducing resting BP.

Strength training (ST) has been shown to be the most promising intervention for the prevention and treatment of sarcopenia and for improving functional abilities in older people.[4] However, the only study we are aware of that investigated the effects of ST on resting BP in older adults reported no improvements.[5] Consequently, the American College of Sports Medicine Position Stand has come to the conclusion that ST by itself does not consistently result in significant reductions in BP in hypertensive individuals.[6] Because of the very limited information about the effects of ST on resting BP in older men and women, and because ST offers other important health and functional benefits to older people,[7] there is a need for further investigations. Thus, the purpose of this study was to determine the effects of 6 months of whole body ST on resting BP in 65- to 73-year-old men and women with BP in the high normal range.

METHODS

Subjects

Twenty-three previously inactive healthy men (n = 12) and women (n = 11) between 65 and 73 years of age volunteered to participate in the study. Two subjects (one man and one woman) did not complete the study because of health reasons unrelated to the investigation. Thus, 11 men and 10 women completed all aspects of the study. The subjects were all nonsmokers who had not participated in any regular exercise for at least 6 months before the study. A physician performed a medical history and physical examination on all subjects. Subjects were excluded from the study if they had any musculoskeletal problems that would prevent them from successfully completing the ST program or if they were taking any medications known to affect cardiovascular or metabolic function. After the initial screening, all subjects were evaluated using a resting supine and upright 12-lead electrocardiogram (ECG) and a maximal graded exercise treadmill test with simultaneous measurement of maximal oxygen consumption ($V{\cdot}O_2$ max). Only those subjects who showed no signs or symptoms of cardiovascular disease during the maximal treadmill test and had a negative exercise ECG, defined by <2 mm of horizontal or downsloping ST segment depression, were allowed to participate in the study.

After a thorough written and verbal explanation of all methods and procedures, subjects gave their written informed consent according to the guidelines of the Institutional Review Boards at the University of Maryland at College Park, and the Veterans Affairs and Johns Hopkins Bayview Medical Centers in Baltimore, Maryland.

Body Composition

Body composition was assessed before and after ST using a Lunar DPXL dual energy X-ray absorptiometer (Lunar DPXL, 1994) as described previously.[8] Subjects were instructed not to

eat or drink anything after midnight before their morning scan. A calibration standard was scanned daily and measurement accuracy was assured by scanning a water/oil phantom of known proportions (41% fat) monthly. The coefficient of variation of repeated measurements was less than 1.0%.

Graded Exercise Testing and Maximal Oxygen Consumption

To screen for obvious signs of cardiovascular disease and to confirm that the subjects were indeed untrained before their participation in the study, Graded Exercise Testing (GXT) and Maximal Oxygen Consumption ($V{\cdot}O_2$ max) tests were performed simultaneously using a Quinton 3000 ECG system, a Sensor Medics VMAX 229 (Sensor Medics, Inc., 1995) metabolic system, and a Quinton Model 55 treadmill. The metabolic system was calibrated according to manufacturer specifications before all tests were performed. At least two of the three following criteria had to be met in order to determine that a true $V{\cdot}O_2$max test was achieved: (1) a plateau in V·O2 (<150 mL/min^{-1}) despite an increase in work rate, (2) a respiratory exchange ratio (RER) greater than 1.10, and (3) achievement of age-predicted maximal heart rate. The GXT protocol consisted of the subjects walking at a constant speed while the grade was increased by 3.5% every 3 minutes until exhaustion. The treadmill speed was selected during a warm-up period by determining the speed that elicited a heart rate of ~75% of age-predicted maximum. During the GXT, heart rates, blood pressures, ratings of perceived exertion (Borg Scale, 6-20), $V{\cdot}O_2$, and ECG tracings were obtained during the last minute of each stage. The GXT was terminated when subjects indicated they could no longer continue to exercise or when the physician determined that further exercise was contraindicated.[9]

Blood Pressure Measurements

Blood pressure measurements were taken in the seated position with the cuffed arm supported at heart level after 5 minutes of quiet rest using a standard mercury column sphygmomanometer according to JNC VI guidelines.[3] All readings were taken at the same time of day for each person. The fifth Korotkoff sound was used to indicate diastolic BP. Because all of the BP measurements could not be taken by the same investigator, resting blood pressures were recorded once daily and averaged from 6 separate days before training began and 6 separate days after the training period. The six BP measurements taken after the training were averaged to determine the overall effects of the ST program and were also averaged and classified based on whether they were taken 24, 48, or 72 hours after the last exercise bout to provide insight into the relationship between an acute exercise bout and resting BP. Thus, the BPs obtained after the training are presented as a mean of all six end-of-training measurements and as means of two readings taken 24, 48, and 72 hours after the previous exercise session. The investigator taking the posttraining BP was blinded to all previous blood pressures measurements taken during baseline and after training.

Strength Testing

One repetition maximum (1 RM) strength tests were performed before and after the ST program using the same Keiser K-300 air-powered resistance machines and free weight dumbbells that were used for training. The tests consisted of the unilateral leg press, unilateral leg extension, chest press, lat pull down, overhead shoulder press, triceps pushdown, and unilateral biceps curls. These exercises were chosen because they could easily be tested in a standardized way using objective criteria. Five repetition maximum (5 RM) strength testing was conducted separately after completion of the pretraining 1 RM tests in order to determine the

starting resistance for the ST program. For strength testing, the maximum amount of resistance that could be lifted with proper form once and five times were recorded as the 1 RM and 5 RM, respectively. The subjects were allowed 30 seconds of rest between trials, and an average of five trials were completed before achieving their maximum capacity. Before-training strength testing was performed following six familiarization sessions in which the participants completed the training program exercises with little or no resistance and were instructed on proper warm-up, stretching, and lifting techniques. These low-resistance training sessions were conducted to familiarize the subjects with the equipment, to help control for the large 1 RM strength gains that commonly result from skill (motor learning) acquisition during the initial stages of training, and to help prevent injuries and reduce muscle soreness following the strength testing protocol. Strength tests were conducted by the same investigator for each participant, both before and after training, with special attention paid to consistency of seat adjustment, body position, and level of vocal encouragement. Where appropriate, straps and/or belts were used to stabilize the subject so that recruitment of outside muscle groups was minimized.

Strength Training Program

The ST program consisted of the following nine exercises using the Keiser K-300 air-powered machines: unilateral leg press, chest press, unilateral leg curl, lat pulldown, unilateral leg extension, overhead shoulder press, upper back rowing, triceps pushdown, and abdominal crunch. In addition, biceps curls using free weight dumbbells and abdominal exercises on a floor mat were also performed. After all familiarization training sessions were completed, the ST program began. The first four to five repetitions of each exercise were performed at a five repetition maximum (5 RM) resistance. The resistance was then reduced by the subjects just enough to perform one or two additional repetitions. This process was repeated for all subsequent repetitions without altering the cadence of the repetitions until a total of 15 continuous repetitions were completed. This procedure allowed subjects to exert near-maximal effort on all repetitions and was made possible by thumb buttons or foot pads on the Keiser equipment, which allow for immediate changes in resistance during exercise. The concentric phase of each repetition was performed in ~2 seconds and the eccentric in ~3 seconds. Starting and finishing resistances were recorded for each exercise. The training resistance (5 RM) was monitored during each session and was increased as strength improvements took place. All subjects were allowed 2 to 3 minutes of rest between sets throughout the entire ST program.

For the first 3 months of the training program, all subjects performed two sets of 15 repetitions of the leg exercises and one set of 15 repetitions for the upper body and trunk exercises for each exercise session. To maintain high subject compliance, variety was added to the ST routine after 3 months by having subjects gradually increase resistance, after a warm-up performed at 50% of their initial 1 RM, until failure. This resulted in ~15 RM, including the warm-up repetition. The abdominal crunches performed on the mat were done to fatigue after each ST session for the entire 6 months.

All subjects were asked to maintain their current dietary intake and outside exercise habits, and body weight was recorded at least once a week throughout the duration of the study to verify compliance. All training sessions were monitored by at least two exercise physiologists.

Statistical Analysis

Analysis of variance (ANOVA) with repeated measures was used to detect significant

within-group differences, gender group differences, and time-by-group interactions. Repeated measures ANOVA with Bonferroni post hoc procedures were used to detect significant differences between the baseline BP measurements and the measurements taken 24, 48, and 72 hours after the last training session. Unpaired *t* tests were used where appropriate for comparisons between genders. In addition, multiple regression analysis was used to determine the relationship between changes in BP and the initial BP, age, gender, and changes in strength. Statistical significance was accepted at $P < .050$ for all tests. All statistical analyses were performed using SPSS/PC + Studentware software (SPSS, Inc., Chicago, IL, 1995). The data are reported as mean ± standard error.

RESULTS

The physical characteristics of the subjects are shown in Table 1. No significant changes in total body mass following the training program were seen in either the men or the women, but the men weighed more than the women both before and after training (85 ± 3 vs 73 ± 2 kg, $P < .010$). There were small yet significant increases in fat free mass (FFM) with training ($P < .050$) when the men and women were combined. However, these increases were not statistically significant when the men and women were analyzed separately. Although the men had lower body fat than the women at baseline (29 ± 1 vs 43 ± 1%, $P < .010$), there were no significant changes in percent body fat as a result of ST in either sex. The men had significantly higher $\dot{V}O_2$ max values than the women when expressed in absolute terms (L/min^{-1}, $P < .050$), but not when expressed relative to body mass ($mL/kg^{-1}/min^{-1}$).

	Men (n = 11)		Women (n = 10)	
	Before Training	After Training	Before Training	After Training
Age (yr)	69 ± 1		68 ± 1	
Height (cm)	173 ± 2		161 ± 2	
Body mass (kg)	85 ± 3	83 ± 3	73 ± 2	73 ± 2
$\dot{V}O_2$ max ($mL \cdot kg^{-1} \cdot min^{-1}$)	24 ± 2		20 ± 1	
Body fat (%)	29 ± 1	28 ± 2	43 ± 1	42 ± 2
Fat free mass (kg)	59 ± 1	59 ± 1	41 ± 1	42 ± 1

All values are mean ± standard error of the mean (SE).
None of the within group differences were significant.

Table 1. Physical Characteristics for Subjects Before and After Six Months of Strength Training

The men displayed higher absolute 1 RM strength values than the women in all muscle groups tested ($P < .001$). One RM strength values increased significantly in all muscle groups ($P < .001$). When men and women were combined, however, the men improved their strength levels on the overhead shoulder press machine ($P < .001$), whereas the women did not (Table 2). When the various 1 RM strength values were pooled together into lower body (LB) and upper body (UB) values, both increased significantly after training ($P < .001$). The men showed larger increases than women for the UB strength exercises ($P < .050$), whereas there were no time-by-group interactions for LB strength. Resting BP values after training are reported for the men and women combined as an average of all BP measurements (i.e., 24, 48, and 72 hours combined, Figure 1) as well as gender-separated averages taken 24, 48, and 72 hours following the last training session (Figures 2 and 3). Significant training-induced decreases in systolic BP (SBP) (131 ± 2 vs 126 ± 2 mm Hg, $P < .010$) and diastolic BP (DBP) (79 ± 2 vs 75 ± 1 mm Hg, $P < .010$) were observed when men and women were combined (Figure 1). The mean resting SBP and DBP recorded 24 hours after the last training session were also significantly lower after training (SBP: 131 ± 2 vs 121 ± 3 mm Hg, $P < .001$; DBP: 79 ± 2 vs 73 ± 1 mm Hg, $P < .010$, respectively). Similar but smaller declines in SBP and DBP were observed 48 hours after the last

training session (SBP: 131 ± 2 vs 127 ± 2 mm Hg, $P < .050$; DBP 79 ± 2 vs 76 ± 1 mm Hg, $P = .010$, respectively). However, BPs recorded 72 hours after the last training session were not significantly different from those before training (SBP: 131 ± 2 vs 127 ± 3 mm Hg, DBP: 79 ± 2 vs 77 ± 2 mm Hg).

	Men (n = 11)			Women (n = 10)		
	Before Training	After Training	% Change	Before Training	After Training	% Change
Leg Press (kg)	537 ± 23	635 ± 24*	18	350 ± 29	446 ± 26*	27
Leg Extension (kg)	157 ± 7	203 ± 9*	29	92 ± 7	117 ± 8*	27
Chest Press (kg)	46 ± 2	54 ± 2*	17	27 ± 2	31 ± 1*	15
Lat Pulldown (kg)	51 ± 1	63 ± 2*	24	29 ± 1	36 ± 1*	24
Shoulder Press (kg)	38 ± 2	45 ± 2*	18	26 ± 1	28 ± 1	8
Triceps Extension (kg)	52 ± 2	68 ± 3*	31	31 ± 2	39 ± 1*	26
Biceps Curls (kg)	27 ± 1	35 ± 1*	30	15 ± 1	20 ± 1*	33

All values are mean ± SE.
*Significantly higher than before training ($P < .001$).
Strength values for leg press, leg extension, and biceps curls are the sum of unilateral tests from both legs and arms.

Table 2. 1 RM Results for Subjects Before and After Six Months of Strength Training

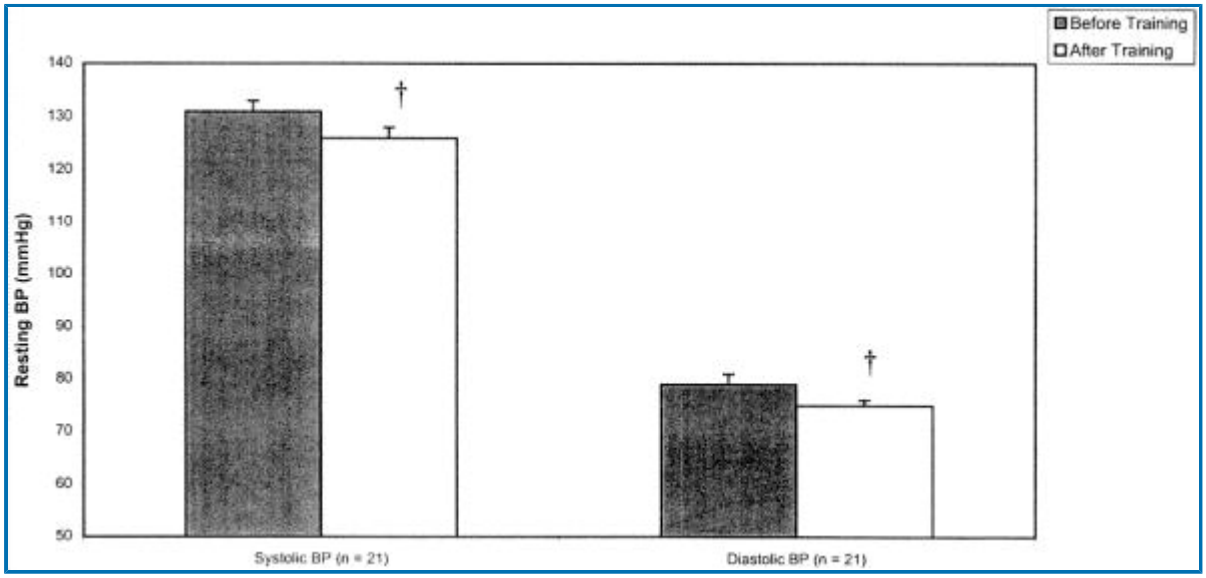

Figure 1. Resting SBP and DBP before and after ST in men and women (n = 21). There was a significant reduction in both SBP and DBP with ST (†$P < .010$).

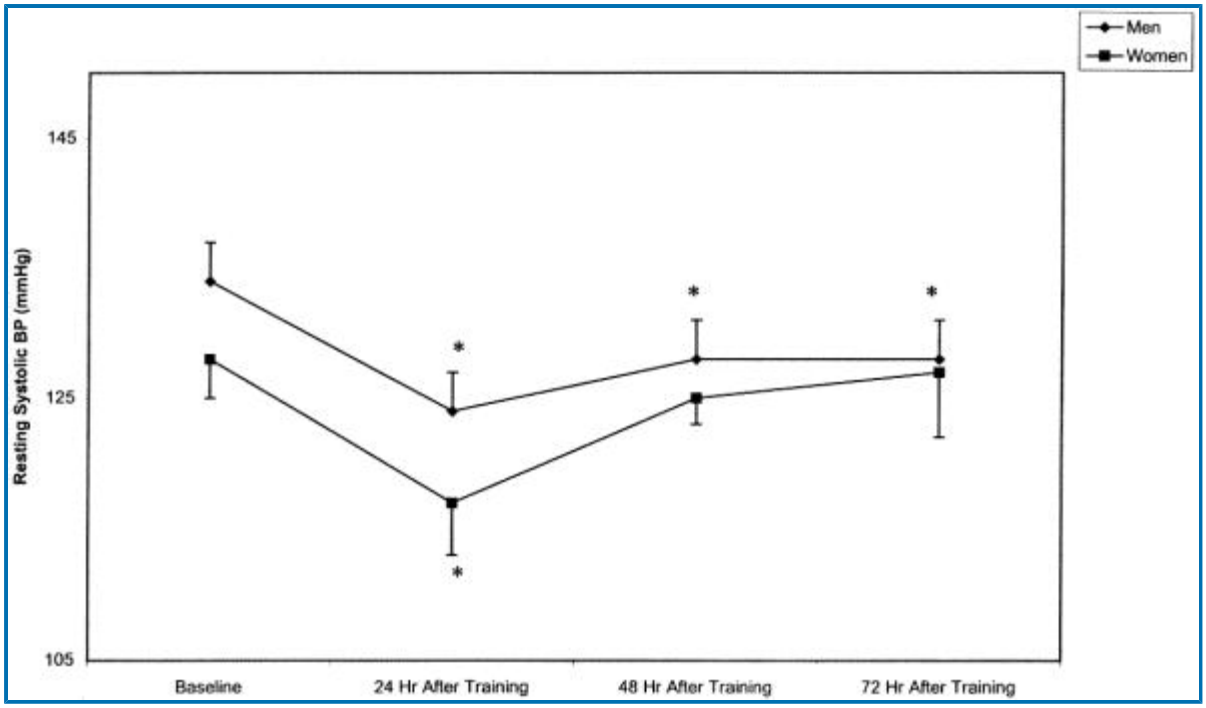

Figure 2. Resting SBP after training at 24, 48, and 72 hours after the last ST session in men versus women. Men and women both showed significantly lower SBP at 24 hours after the last exercise bout when compared with baseline values, whereas only the men showed significant reductions 48 and 72 hours after the last ST session (*P < .050).

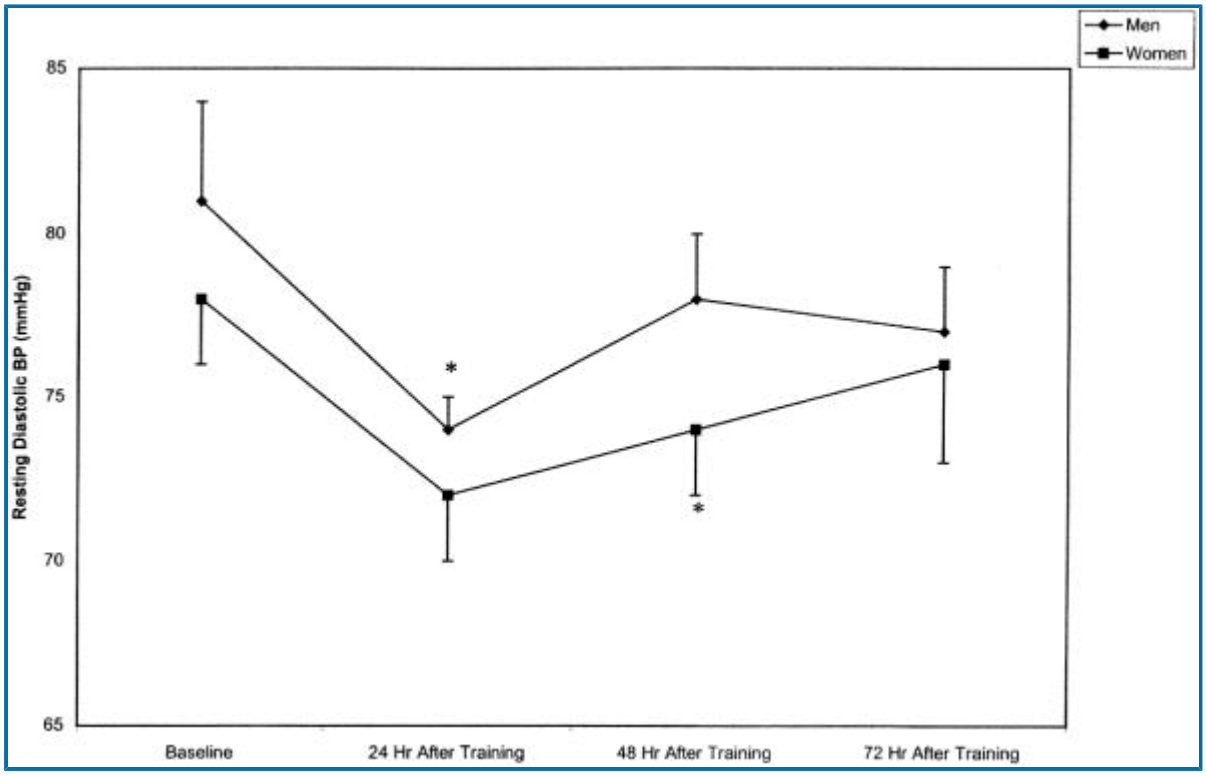

Figure 3. Resting DBP after training at 24, 48, and 72 hours after the last ST session in men versus women. Men showed significantly lower DBP at 24 hours after the last exercise bout when compared with baseline values, whereas women showed significant reductions 48 hours after the last ST session (*P < .050).

Gender-based data analysis indicates that the average SBP from all readings taken 24, 48, and 72 hours after training was reduced significantly in men (134 ± 3 vs 127 ± 2 mm Hg, P < .010) but not in women (128 ± 3 vs 125 ± 3 mm Hg, P = .104). The average DBP was lower after training in both men (81 ± 3 vs 77 ± 1 mm Hg, P = .054) and women (78 ± 2 vs 74 ± 2

mm Hg, $P = .055$). When analyzed separately, the men demonstrated significantly lower resting SBP 24, 48, and 72 hours after the last exercise session and significantly lower DBP only at 24 hours after the last exercise session ($P < .050$). The women demonstrated significantly lower SBP 24 hours after the last exercise bout and significantly lower DBP 48 hours after the last exercise session (both $P < .050$) (See Figures 2 and 3).

Multiple regression analysis showed that changes in SBP or DBP were not significantly related to changes in upper or lower body strength, gender, or age. There was, however, a strong relationship between changes in DBP and initial values for DBP ($P < .001$). This relationship approached significance when using initial values for SBP ($P < .059$).

DISCUSSION

The results of the present study show that whole body ST can reduce resting BP in 65- to 73-year-old men and women with high normal resting BP. The reductions were maintained for up to 48 hours after the last ST session and were sufficient to shift subjects from the high normal to the normal category as defined by the Joint National Committee on the Detection, Evaluation and Treatment of Hypertension.[3] Because a large proportion of cardiovascular disease occurs in people with high normal BP,[10] it is important to improve the recognition of the role of high normal BP in the development of hypertension and target organ damage.[3] Therefore, the new JNC VI guidelines recommended that individuals with high normal BP undertake some form of lifestyle modification to lower their resting BP to normal levels. The category shift found in the present study has important implications, especially if corroborated by others, because overall cardiovascular morbidity and mortality is reduced in individuals who shift from the high normal to the normal BP category as much or more than those with established hypertension.[11] When the BP responses to ST in the present study were analyzed by gender, men showed reductions in BP that were not observed for the women (i.e., 48 and 72 hours after the last exercise bout for SBP and 24 hours after the last exercise bout for DBP). Before training, the men as a group had resting BP measurements that were 6 mm Hg higher for SBP (134 vs 128 mm Hg) and 3 mm Hg higher for DBP (81 vs 78 mm Hg) than those of the women. Nevertheless, gender did not seem to explain changes in either systolic or diastolic pressures.

The BP lowering effects of aerobic exercise training in older and younger men and women have been well documented.[5,12-14] However, little information exists on the effects of conventional ST programs on resting BP among older men and women. The magnitude of reduction in resting BP found in the present study is similar to that of aerobic exercise and other nonpharmacological treatments for hypertension.[6] Furthermore, the present study provides further evidence that heavy ST does not chronically elevate resting BP, as has been feared in the past.

The limited information that is available on the effects of ST on resting BP is conflicting. For example, Hagberg et al.[15] examined the effects of 5 months of ST on BP in hypertensive adolescents immediately after 5 months of aerobic exercise training. SBP was found to be 17 mm Hg lower following ST compared with baseline values, whereas DBP values were maintained at the reduced levels elicited by the endurance training. This study provides evidence that ST may have a lowering effect on BP, but it is difficult to separate the combined effects of both aerobic and ST on BP following the training. Hurley et al.[16] also examined the effects of 16 weeks of heavy resistance ST on resting BP in 11 normotensive middle-aged men. Supine DBP

was found to be significantly reduced (84 vs 79 mmHg) following the training with no significant changes in supine SBP. There were similar reductions in DBP after training in the present study (79 vs 75 mm Hg); however, significant reductions were also seen for SBP (131 vs 126 mm Hg). Although the present study and prior studies by Hagberg et al.[15] and Hurley et al.[16] show evidence of a possible lowering effect of ST on BP, not all studies have supported these findings. In the only previous study we could find addressing the effects of ST on BP in older men and women, Cononie et al.[5] investigated the effects of 6 months of ST on resting BP in a group of 70- to 79-year-old men and women. No changes were seen following ST in either SBP or DBP in individuals characterized as having normal or elevated BP. A similar group of individuals performing 6 months of aerobic training in the same study showed significant BP reductions, but no significant differences in SBP when compared to the ST or control groups after training.

Although most studies show significant reductions in resting BP as a result of aerobic exercise training, other studies comparing the effects of ST and aerobic training on resting BP have also shown no differences between aerobic and ST for the effectiveness in reducing resting BP.[17,18] Smutok et al.,[17] compared the results of 20 weeks of ST with that of aerobic training and no exercise for the same period of time in 37 previously sedentary middle-aged men. No significant changes in resting BP were detected after training in any of the groups. Blumenthal et al.[18] studied 99 men and women with untreated mild hypertension (systolic BP 140-180 mm Hg, diastolic BP 90-105 mm Hg) randomly assigned to 4 months of either aerobic exercise training, strength and flexibility training, or a control group. Despite significant within group reductions of 7 to 9 mm Hg in resting SBP and 5 to 6 mm Hg in resting DBP after ST, there were no significant differences between any of the groups. There were also no significant group differences when comparing ambulatory BP readings before and after the training period.

All of the studies described attempted to control for normal variation in BP by taking multiple measurements over a number of different days, in three instances using a random-zero sphygmomanometer,[5,15,18] and by including a nonexercising control group for comparison purposes. The present study attempted to control for the normal variation in BP by recording measurements over multiple days, six occasions before and after training, and by following the recommendations of JNC VI for proper BP measurement, whereas the number of resting BP recordings in previous studies were suboptimal.[19-21] Conflicting results may also be attributable to differences in the ST programs. The ST program in the present study used a level of resistance and repetitions similar to some studies [5,16,17] but more intense than others.[18,20] For example, Norris et al.[20] reported using a strength training protocol that was designed for beginning weight lifters, whereas subjects in the study by Blumenthal et al.[18] utilized circuit training, a method normally characterized by lower levels of resistance and a higher number of repetitions. The present study required the subjects to begin each ST exercise with a 5 RM resistance, then to slightly reduce the resistance just enough to complete one or two more repetitions and to continue this process until a total of 15 repetitions were completed. This allowed for near maximal contractions for a majority of each set of ST exercises.

The effectiveness of ST for reducing BP, particularly DBP, may depend on initial BP levels. The results of this study suggest that as a group, those with the highest initial BP values tend to respond to ST with the greatest BP reductions. Part of this tendency may be explained by regression toward the mean. However, we cannot say for sure that a similar reduction in resting BP would not occur in individuals with lower BP levels after this type of ST.

Data from the Framingham Heart Study [22] have indicated that the risk of coronary heart

disease (CHD) events increases continuously as a function of SBP, starting as low as 120 mm Hg or less. Because of the higher absolute risk of CHD events with age, the attributable risk of such modest SBP elevations in older people is substantial. These data have led to the current JNC VI guidelines suggestion that individuals with high normal blood pressure take nonpharmacological measures to lower their blood pressure. The present findings suggest that a lifestyle modification such as ST may reduce BP in older individuals while also serving as an ideal intervention for the prevention of sarcopenia and falls.

In summary, heavy resistance ST seems to have a beneficial effect on resting BP in 65- to 73-year-old subjects with high normal BP. Reductions of 5 mm Hg and 4 mm Hg were observed for SBP and DBP, respectively. The magnitude of these reductions was sufficient to shift these individuals as a group from the high normal to the normal BP category, thus reducing this CHD risk factor. Furthermore, these reductions were maintained for up to 48 hours, which is the typical interval used between training sessions.

ACKNOWLEDGMENTS

The authors thank Dr. Barbara Albert for screening our subjects, Dorothy O'Donnell for her help with subject recruitment, and Kevin Cross, Dan Barlow, Brennan Harmon, Bob Harper, Tanya Limpakan, Cari Litton, Autumn Powell, Brian Tracy, and Ken Wilund for their help in training the subjects throughout the study. We also thank the staff at the University of Maryland Wellness Research Laboratory for their assistance with the conduct of this study and all the subjects who volunteered.

REFERENCES

1. Frishman W, Bauman J, Soberman J et al. Treatment of ischemic heart disease in the elderly: Beta-adrenergic blockade and coronary artery bypass surgery. In: Wenger NK, Furberg CD, Pitt E, eds. Coronary Heart Disease in the Elderly. New York: Elsevier, 1986, pp 153-197. [Context Link]

2. Kaplan N. Clinical Hypertension, 5th ed. Baltimore: Williams and Wilkins, 1990. [Context Link]

3. The Sixth Report of The Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (JNC VI). Arch Intern Med 1997;157:2413-2446. [Context Link]

4. Fiatarone MA, O'Neill EF, Ryan ND et al. Exercise training and nutritional supplementation for physical frailty in very elderly people. N Engl J Med 1994;330:1769-1775. **Ovid Full Text** | **Bibliographic Links** | [Context Link]

5. Cononie CC, Graves JE, Pollock ML. Effect of exercise training on blood pressure in 70- to 79-yr-old men and women. Med Sci Sports Exerc 1991;23:505-511. [Context Link]

6. Hagberg JM, Blair S, Ehsani AA et al. Position stand: Physical activity, physical fitness, and hypertension. Med Sci Sports Exerc 1993;25: i-x. [Context Link]

7. Hurley BF, Hagberg JM. Optimizing health in older persons: Aerobic or strength training? Exerc Sport Sci Rev 1998;26:61-89. **Bibliographic Links** | [Context Link]

8. Treuth MS, Ryan AS, Pratley RE et al. Effects of strength training on total and regional body composition in older men. J Appl Physiol 1994;77:614-620. [Context Link]

9. American College of Sports Medicine. Guidelines for Exercise Testing and Prescription, 5th Ed. Philadelphia, PA: Lea & Feibiger, 1995. [Context Link]

10. Kannel WB. Blood pressure as a cardiovascular risk factor: Prevention and treatment. JAMA 1996;275:1571-1576. **Ovid Full Text** | **Bibliographic Links** | [Context Link]

11. National High Blood Pressure Education Program. National High Blood Pressure Education Program Working Group Report on Primary Prevention of Hypertension. Bethesda, MD: US Department of Health and Human Services. National Heart, Lung, and Blood Institute. NIH publication No. 1993:93-2669.

[Context Link]

12. Hagberg JM, Montain SJ, Martin WH, Ehsani AA. Effect of exercise training in 60- to 69-year-old persons with essential hypertension. Am J Cardiol 1989;64:348-353. **Bibliographic Links** | [Context Link]

13. Kokkinos PF, Narayan P, Colleran JA et al. Effects of regular exercise on blood pressure and left ventricular hypertrophy in African-American men with severe hypertension. N Engl J Med 1995;333:1462-1467. **Ovid Full Text** | **Bibliographic Links** | [Context Link]

14. Gordon NF, Scott CB, Levine BD. Comparison of single versus multiple life-style interventions: Are the antihypertensive effects of exercise training and diet-induced weight loss additive? Am J Cardiol 1997;79:763-767. **Bibliographic Links** | [Context Link]

15. Hagberg JM, Ehsani AA, Goldring D et al. Effect of weight training on blood pressure and hemodynamics in hypertensive adolescents. J Pediatr 1984;104:147-151. **Bibliographic Links** | [Context Link]

16. Hurley BF, Hagberg JM, Goldberg AP et al. Resistive training can reduce coronary risk factors without altering VO_2 max or percent body fat. Med Sci Sports Exerc 1988;20:150-154. **Bibliographic Links** | [Context Link]

17. Smutok MA, Reece C, Kokkinos PF et al. Aerobic versus strength training for risk factor intervention in middle-aged men at high risk for coronary heart disease. Metabolism 1993;42:177-184. **Bibliographic Links** | [Context Link]

18. Blumenthal JA, Siegel WC, Appelbaum M. Failure of exercise to reduce blood pressure in patients with mild hypertension. JAMA 1991;266:2098-2104. **Bibliographic Links** | [Context Link]

19. Stone MH, Wilson GD, Rozenek R. Cardiovascular responses to short-term Olympic style weight-training in young men. Can J Appl Sport Sci 1983;8:134-139. **Bibliographic Links** | [Context Link]

20. Norris R, Carroll D, Cochrane R. The effects of aerobic and anaerobic training on fitness, blood pressure, and psychological stress and well-being. J Psychosom Res 1990;34:367-375. **Bibliographic Links** | [Context Link]

21. Van Hoof R, Macor F, Lijnen P et al. Effect of strength training on blood pressure measured in various conditions in sedentary men. Int J Sports Med 1996;17:415-422. **Bibliographic Links** | [Context Link]

22. Vokonas PS, Kannel WB. Epidemiology of coronary heart disease in the elderly. In: Tresch DD, Aronow WS, eds. Cardiovascular Disease in the Elderly Patient. Monticello, NY: Marcel Dekker, 1994, pp 91-123. [Context Link]

Key words: resistance training; hypertension; aging; cardiovascular disease; exercise

---

Accession Number: 00004495-199910000-00008
