Progressive strength training in sedentary, older African American women

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ABSTRACT
ADAMS, K. J., A. M. SWANK, J. M. BERNING, P. G. SEVENE-ADAMS, K. L. BARNARD, and J. SHIMP-BOWERMAN. Progressive strength training in sedentary, older African American women. Med. Sci. Sports Exerc. Vol. 33, No. 9, 2001, pp. 1567–1576. Purpose: This study investigated effects of an 8-wk, low-frequency and low-volume, supervised, progressive strength training program emphasizing free weight, multijoint movements on the muscular power, strength, endurance, and flexibility of African American women 44 to 68 yr of age. Methods: Nineteen sedentary African American women were randomly assigned to a strength training (ST) only group (N = 12; mean age, 51 yr) or a nonexercise control (C) group (N = 7; mean age, 52 yr). Maximal power, strength, absolute endurance, and flexibility were assessed before and after training. Subjects trained 2 d wk⁻¹ using free weight (barbells and dumbbells) and machine (plate loaded) exercises for two to three sets of 8 to 10 repetitions on both primary and assistance exercises. Results: Upper body power (medicine ball put distance) significantly increased statistically (P < 0.002), but gains possibly lacked practical significance because of measurement variation. Lower body power (peak watts on bicycle) experienced a small, nonsignificant increase in the ST group. Significant increases (P < 0.000) in 1RM muscle strength occurred in the ST group (leg press, +99.8%; bench press, +34.4%). Absolute endurance significantly increased (P < 0.000) in the ST group (leg press repetitions to failure at 70% pretest 1RM, +221%; bench press repetitions to failure at 50% pretest 1RM, +112%). Significant flexibility gains occurred in the ST group (sit-and-reach test, +8.2%; P = 0.017). No significant changes occurred in power, strength, absolute endurance, or flexibility in the C group. Conclusion: This study demonstrates that 8 wk of low-frequency, supervised, progressive strength training emphasizing free weight, multijoint movements can safely cause significant gains in muscle strength, absolute endurance, and flexibility in older African American women. Key Words: STRENGTH, POWER, ENDURANCE, FLEXIBILITY, AGING

The 1992 Health and Retirement Study (15) surveyed 957 African American women self-respondents age 51 to 61 yr; slightly over one half of respondents reported difficulty in performing activities of daily living such as walking and climbing stairs. African American women have a higher risk of many chronic diseases (e.g., cardiovascular disease, diabetes), a lower level of physical activity, and a higher rate of obesity than white women (5,15,23,28,29,46). African American women still suffer significant social and economic costs because of falls and fractures despite having a lower rate of bone fractures related to osteoporosis than white women (48). Unfortunately, the 1991 National Health Interview Survey reports that African American women participate in fewer “strengthening activities” than any racial/ethnic group (5). Strength training, which targets the development of muscular power, strength, endurance, and flexibility, has the potential to significantly impact many problems associated with aging identified in African American women.

For example, Bassey et al. (11) found strong correlations (0.83 to 0.93) in women between leg extensor power and functional abilities such as chair-rising speed, stair-climbing speed, walking speed, and stair climbing power. Development and maintenance of adequate lower body muscle power/body weight ratios in women may offer a larger reserve of power for retention of functional independence in old age (11,49). Maintenance of muscular strength and endurance in aging significantly impacts a woman’s ability to perform activities of daily living and to participate in activities designed to maintain aerobic fitness (6,13,17,35,40,45,46,49). In support, strength training has increased spontaneous activity (16,37), and increased lean body mass (14,16,18,21,22,37,39,41) and decreased fat (39) in postmenopausal women. Additionally, strength training has simultaneously impacted many factors that relate to the risk for falls and fractures, including muscle power,
strength, mass, and dynamic balance (36,37). Strength training in older women has demonstrated a reduction in cardiovascular stress (e.g., heart rate, systolic blood pressure, and rate pressure product) while carrying the same absolute weight before and after training (40). Furthermore, during repetitive daily activities, increased strength leads to a lower number of motor units recruited to accomplish a given submaximal task (e.g., walking), increasing absolute endurance and delaying onset of fatigue during work or play (6,40,45). Flexibility may also be increased by full range of motion strength training (3,19,45), possibly contributing to the ability to meet the functional demands of life, participate in leisure activities, and reduce injury (3,8,20,26,45).

Despite the positive health benefits of strength training demonstrated in other populations, to our knowledge, no studies have examined the effects of progressive strength training on African American women, a population underrepresented in participation in strength training activities (28,46) and fitness-related research studies (28,29,46). No studies in older women have simultaneously assessed changes in muscle power, strength, endurance, and flexibility, important to overall daily physical function (8,13,35). No studies have assessed changes in upper body power in older women. Similar to lower body power, upper body power may significantly contribute to performance of activities of daily living, such as lifting boxes, opening jars, enjoying recreational activities (e.g., bowling and tennis), or catching oneself in a fall. No studies have assessed absolute muscular endurance of both the upper and lower body in older women, limiting application to repetitive daily tasks. This study also assesses changes in flexibility from strength training alone, adding to the limited information available on strength training’s effects on flexibility in the older adult (8,20,26).

Furthermore, available studies on women have primarily focused on machine-based, single-joint, controlled movement speed (i.e., 3 s eccentric, 3 s concentric) training (14,16,18,27,36,37,41). Many functional activities, such as walking, climbing stairs, or playing with grandchildren, are dynamic activities that require the coordinated, quick contraction of several muscle groups (27,34,42), making it likely that improving or maintaining functional status may require strength training with multiple joint movements (3,25,27,34,42,45). Older women have traditionally avoided free weight, multijoint, progressive strength training because of misconceptions of injury, becoming too muscular, losing femininity, and perceived difficulties in learning proper technique (19).

Therefore, the purpose of the present study was to investigate the effects of an 8-wk, low-frequency and low-volume, supervised, progressive strength training program on the muscular power, strength, absolute endurance, and flexibility of African American women 44 to 68 yr of age. Free weight (barbells and dumbbells) and machine (plate loaded) exercises were performed, with emphasis on free weight, multijoint movements.

TABLE 1. Subject characteristics at baseline.

<table>
<thead>
<tr>
<th></th>
<th>Strength Trained (N = 12)</th>
<th>Control (N = 7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>50.7 ± 7.0</td>
<td>52.0 ± 8.0</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>162.2 ± 5.4</td>
<td>160.8 ± 7.2</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>82.8 ± 13.1</td>
<td>90.0 ± 4.8</td>
</tr>
<tr>
<td>Percent body fat</td>
<td>41.7 ± 5.4</td>
<td>44.9 ± 3.6</td>
</tr>
<tr>
<td>Moderate activity</td>
<td>2.9 ± 0.7</td>
<td>2.4 ± 1.4</td>
</tr>
<tr>
<td>Vigorous activity</td>
<td>0.4 ± 0.7</td>
<td>0.0 ± 0.0</td>
</tr>
</tbody>
</table>

*0 = no activity, 5 = high level of moderate activity.
*2 = no activity, 5 = high level of vigorous activity.
All numbers mean ± SD.

**METHODS**

**Experimental Design**

A pretest/posttest experimental design with random assignment (control and treatment) was used in this study. African American women were recruited from the local community for participation. Testing (identical at pretest and posttest) was selected to include assessment of complete muscular fitness parameters (power, strength, endurance, and flexibility), which are also potentially related to functional performance of daily, job-related, and recreational activities. The treatment group performed 8 wk of low-frequency, progressive (volume and load) strength training emphasizing free weight, multijoint movements. Training program design represented a beginning program for previously sedentary individuals and contained planned progression for simple to complex movement. All sessions were supervised. Design of this study allowed investigation of the effects of progressive strength training on muscular power, strength, endurance, and flexibility in previously sedentary African American women.

**Subjects**

Twenty-six sedentary African American women age 44 to 68 yr from the Louisville, KY, area, volunteered to participate in the study and agreed to be randomly assigned to either a control group or a strength training group. The study was approved by the University of Louisville Human Studies Committee and subjects signed an informed consent to participate. Each subject received a medical examination before initiating any testing procedures. Seven women were excluded from the study because of preexisting medical problems, consisting of uncontrolled high blood pressure (N = 5), blood clots (N = 1), and orthopedic problems (N = 1). The remaining 19 women completed the study. Table 1 lists the descriptive characteristics of these 19 subjects (controls (C), N = 7; strength trained (ST), N = 12). There were no significant differences in age, height, weight, percent body fat, or activity level between subjects. Four of the 19 subjects (two in each group) were taking medications to control blood pressure. Subjects had no prior strength training experience and were not currently participating in any structured exercise program. Subjects classified themselves as “sedentary,” and this was confirmed using the Stanford Activity Scale (44). Resting blood pressure was normal, averaging 128/84 mm Hg. Percent body fat determined by...
bioelectrical impedance using the Segal modified equation for African American women (7) averaged 43.3.

**Testing Protocol**

**Orientation.** Individual testing to familiarize subjects with maximal muscular power, strength, endurance, and flexibility tests took place on day 1. On arrival to the lab, resting blood pressure was assessed. The subject then walked for 5 min on the treadmill at 2.7 mph. Each test technique, purpose, and procedure was explained in detail to the subject, with practice trials allowed until the subject felt comfortable. Practice trials were conducted in the same order of the actual testing and were as follows: 1) medicine ball put, 2) modified Wingate bicycle test, 3) one repetition maximum (1RM) bench press, 4) endurance bench press, 5) 1RM leg press, 6) endurance leg press, and 7) sit-and-reach test. Testing bench press before leg press allowed the subject’s legs to recover from the bicycle test before requiring a maximal effort on the 1RM leg press test.

On the bench press and leg press, familiarization included both repetitions with no weight and near maximal (85 to 95% of 1RM) weighted trials to ensure the learning of proper technique and the “feel” of pushing against a load. Subjects required the greatest amount of time learning the bench press technique because of the coordination involved with learning a free weight, multijoint movement. Each subject’s orientation session lasted approximately 1 h. At the end of the orientation session, the maximal testing session was scheduled. During maximal testing, each individual assessment and all maximal efforts within each assessment were separated by at least a 3-min rest to ensure full recovery. The same technician conducted all tests. On completion of each test except the medicine ball put and the sit-and-reach, the rating of perceived exertion (RPE) was assessed. RPE, using the category RPE scale (6 to 20), helped quantify subjective effort (12). As recommended by Borg (12), standardized instructions relating to the subject’s total perception of exertion and fatigue were stated to each subject before maximal tests.

**Power tests.** A 1-kg, two-handed medicine ball put for maximum distance was used to assess upper body muscular power (32). The medicine ball put test is used in athletics and, similar to the use of vertical jump for lower body power, serves as a representation of upper body power (32). The subject was secured to a chair to eliminate use of momentum and a 1-kg medicine ball was placed in her hands. The subject was asked to “put” the ball (similar to a two-handed basketball chest pass) for maximum distance. Arc of the ball was controlled by a 0.75-m ring positioned 2 m in front of the subject at a height that controlled angle of release at approximately 45 degrees. The subject had two practice trials to coordinate her aim through the ring, followed by three maximal efforts. The best distance was recorded.

Peak lower body power was assessed with a modified Wingate bicycle test (10). Vertical jump was not assessed because of subjects’ lack of confidence in safely performing maximal jump efforts. The Wingate bicycle test is a valid measurement of lower body power (10). A Monark bicycle ergometer with a computer interface (Sports Medicine Industries, St. Paul, MN) was used to determine peak wattage. Resistance was set at 3.5% body weight, since in pilot testing this resistance was determined to be one subjects could pedal for the 10-s test duration. Higher percentages of maximum were found to be too high to maintain pedaling on load initiation. Seat height was set so the subject’s leg was near full extension at bottom pedal position. The subject pedaled the bike at light resistance for 3 min to ensure adequate warm-up. The subject was then asked to pedal as hard and fast as possible against no resistance for 5 s. Using an Instaload flywheel strap (Sports Medicine Industries), resistance was loaded to 3.5% within 1 s and the subject continued to pedal as hard and fast as possible for 10 s. Reproducibility of the power tests in these women was high, with a significant correlation between repeat tests taken 1 wk apart (medicine ball put: \( r = 0.92, P < 0.01 \); modified Wingate bicycle test: \( r = 0.91, P < 0.01 \)).

**Strength (1RM) and absolute endurance (repetitions to failure) tests.**

**Bench press 1RM.** A 1RM bench press was measured according to the methods of Kraemer and Fry (31) using a standard bench and free weights. A 1RM is defined as the weight that can be lifted no more than one time with acceptable form (31). Despite the training protocol’s focus on an 8RM to 10RM training intensity, it was important to evaluate changes in base strength resulting from this beginning training program. The 1RM is the “gold standard” for evaluating strength and is a fundamental crux by which the optimal intensity of training can be established to maximize response (31). A special Olympic size solid aluminum bar weighing 6.8 kg (BFS, Salt Lake City, UT) was used to accommodate low levels of upper body strength. The bench press targets the large muscle groups of the upper body, while distributing forces among the shoulder, elbow, and wrist joints. The subject received the bar from the spotter with arms extended, then in a controlled fashion lowered the bar until touching her chest, then pressed the bar back to the fully extended position. The spotter then helped rack the bar. Feet remained flat on the floor at all times during the press, with buttocks and head in contact with the bench. The 1RM was determined between three to five maximal attempts (31).

**Bench press absolute endurance.** On completion of the bench press 1RM, weight on the bar was lowered to 50% of the subject’s pretest 1RM. A 5-min rest was allowed, then the subject performed repetitions until muscular exhaustion on the bench press, using the same technique as in 1RM testing. Repetitions had to be completed to full arm extension to be counted. Exhaustion was defined as inability to extend the arms. Resting (pausing for \( > 1 \) s) at arm extension was not allowed. Absolute muscular endurance (testing at a percent of subject’s pretest 1RM at pretest and posttest) was chosen instead of relative muscular endurance (testing at a percent of base strength).
percent of subject’s most recent 1RM) to better simulate activities of daily living and employment, where weight of routine tasks remains fairly stable over time. A load of 50% of 1RM (post hoc mean, ~14 kg) was chosen by the principal investigator (K.J.A.), after observation of the orientation session, as an adequate representation of sub-maximal loads requiring repetitive lifting by the upper body in daily life (e.g., grocery bags, young grandchildren, job-related items).

**Leg press 1RM.** A 1RM leg press was measured on all subjects according to the methods of Kraemer and Fry (31) using a plate-loaded Cybex leg press (Cybex International, Owatonna, MN), which supplied resistance both eccentrically and concentrically in a closed kinematic chain movement. The leg press design allows a natural arc movement to be performed by the combined knee and hip motions while maintaining correct ankle position throughout the range of motion. The subject started the movement seated in the leg press at a 45-degree angle with legs fully extended, then lowered the weight in a controlled fashion until a 90-degree angle was achieved at the knee joint. The 90-degree angle between the femur and tibia was established with a goniometer, and a verbal cue (“press”) was given to the subject to extend the legs when appropriate bottom position was reached. The subject then pressed the weight back to the fully extended position. The 1RM was determined between three to five maximal attempts (31). Reproducibility of the 1RM tests in these women was high, with a significant correlation between repeat tests taken 1 wk apart (bench press: r = 0.93, P < 0.01; leg press: r = 0.89, P < 0.01).

**Leg press endurance.** On completion of the leg press 1RM, weight on the leg press was lowered to 70% of the subject’s pretest 1RM. A 5-min rest was allowed, then the subject performed repetitions until muscular exhaustion on the leg press, using the same technique as in 1RM testing. Assessment of absolute muscular endurance was chosen for reasons previously stated. A load of 70% of 1RM (post hoc mean, ~78 kg) was chosen by the principal investigator (K.J.A.) after observation of the orientation session as an adequate representation of the subject’s body weight.

**Flexibility.** Low back and hip flexibility were assessed using the sit-and-reach test according to standard procedures (9).

**Strength Training Prescription**

Subjects performed strength training 2 d·wk⁻¹ for 8 wk for a total of 16 sessions. All sessions were performed in the same private facility (only subjects and personal trainers were in attendance) on the same equipment used in testing. The same two certified personal trainers conducted all training sessions, with no more than two subjects at a time assigned to one personal trainer. Both trainers were certified as National Strength and Conditioning Association (NSCA) Certified Strength and Conditioning Specialists and each possessed > 10 yr of experience training adults. Trainers provided spotting, verbal motivation, and technique tips, and maintained training logs for each training session. Communication between trainers and subjects was emphasized at all times. Training progressed from simple to complex movement (e.g., progressing from body weight lunge with support to free standing dumbbell lunge). Free weight (barbells and dumbbells) and machine (plate loaded) exercises were performed. Exercises included two “primary” exercises (leg press and bench press) and seven “assistance” exercises (dumbbell lunge, hamstring curl, dumbbell incline press, dumbbell row, lat pull-down, triceps press-down, and dumbbell biceps curl).

Training loads were chosen using percentages of pretest 1RM (e.g., 70% and 80% of 1RM) and the RM continuum (e.g., 8RM to 10RM). As the women were able to properly perform the prescribed number of repetitions with a given weight, loads were progressively increased by the trainer in increments relative to the specific exercise (i.e., biceps curl would have smaller absolute increase than leg press), subject strength level, and quality of technique (33). Both trainers used previous personal training experience with sedentary subjects, visual feedback from performance of the exercise, and verbal feedback concerning perceived ability from the subject to determine increments (33). Comfortable, controlled, training speed through the eccentric/concentric exercise motion was subject-determined as in traditional bodybuilding style training (19).

During weeks 1 and 2, subjects used 70% of 1RM for one to two sets of 10 repetitions (1 to 2 × 10) for primary exercises, and 1 to 2 × 10 at a weight perceived as moderate by the subject for assistance exercises. Progression in volume (sets) while staying at 70% of 1RM allowed for positive adaptation to the new stresses of strength training in these previously sedentary, older subjects without undue muscle soreness or emotional stress. Furthermore, 70% of 1RM represented a load these women could manage comfortably while optimizing technique in the initial weeks of training. Past experience of the investigators with untrained subjects has shown that attempting to handle loads that are too high initially in an exercise such as the incline dumbbell press would likely cause setbacks because of fears of injury (dumbbells over head) and poor technique. During week 3, subjects used 80% of 1RM for 3 × 8 for primary exercises, and 2 × 10 at a weight perceived as moderate to heavy by the subject for assistance exercises. During weeks 4 through 8, weight was increased on an individual basis by the trainer to ensure that eight repetitions were the maximum number that could be performed by the subject for three sets (3 × 8) on primary exercises and 10 repetitions were the maximum number that could be performed by the subject for two sets (2 × 10) on assistance exercises. Relative training intensity (percent of initial 1RM) determined by post hoc averaging of training loads over 16 sessions was 89% of pretest 1RM squat press and 85% of pretest 1RM bench press. Simple, supervised progression in volume, load, and technique helped ensure consistent adaptation to overload and formation of a positive opinion toward the training program and modalities.
Strength training sessions lasted approximately 1 h, and were separated by at least 1 day of rest. Before each session, each subject’s resting blood pressure was assessed, followed by 5 min of walking on the treadmill. After each session, subjects cooled down with a 5-min treadmill walk and a seated blood pressure assessment. No flexibility exercises were performed.

**Control Group**

Women in the control group were asked to maintain their current activity patterns during the study. The women were specifically asked not to start any strength training program.

**Statistical Analysis**

Means and standard deviations were calculated. Student’s $t$-tests for independent samples were used for comparisons between groups. Repeated measures ANOVA with time as a within-subject factor and treatment as a between-subject factor was used to compare the two groups over time. When a statistically significant group by time interaction was encountered, further comparisons were made by using Student’s $t$-test for paired or independent samples as appropriate. All tests were two-tailed, with a significance criterion at $P < 0.05$. To control for family-wise error when making multiple comparisons, alpha level was modified using a Bonferroni adjustment (47). Statistical power was $> 0.80$ at a significance value equal to 0.05 for all tests (47).

**RESULTS**

All 19 subjects completed the study (C group, $N = 7$; ST group, $N = 12$). Attendance at the 16 sessions was 92.2%. No injuries or muscle soreness that required missing a training session occurred in any subject. There were no significant differences at baseline between the ST and C groups on any performance variable. Percent body fat did not change in either group over the course of the study (overall average: pretest, 43.3; posttest, 43.2).

### Power

The ST group significantly increased (Bonferroni correction, $P < 0.008$) medicine ball put distance over the training period by 4.6 ± 3.9% (0.2 m, $P = 0.002$). This percentage increase in put distance was significantly greater than the C group’s percent change ($P = 0.003$). However, the C group did experience a nonsignificant 4.3 ± 7.7% (0.2 m, $P = 0.193$) decrease in put distance from pretest to posttest. Despite the changes in opposite directions, posttest means were not significantly different between groups ($P = 0.442$). There were no significant changes in lower body power output (watts) for the ST and C groups. Similar to the medicine ball put, the ST and C groups had comparable percent changes in opposite directions, with the ST group increasing peak watts by 6.1 ± 7.7% (18 W, $P = 0.026$) and the C group decreasing peak watts by 6.4 ± 0.1% (16 W, $P = 0.138$) from pretest to posttest. Again, posttest means were not significantly different between groups ($P = 0.378$). Despite the high reproducibility of medicine ball put distance ($r = 0.91$, $P < 0.01$) and peak watts ($r = 0.92$, $P < 0.01$) with these subjects, the comparable increases and decreases between the ST and C groups raises concerns regarding simple variation during power data collection.

### 1RM strength

The ST group significantly increased (Bonferroni correction, $P < 0.008$) bench press and leg press 1RM strength over the training period by 34.4 ± 17.1% (10.1 kg, $P = 0.000$) and 99.8 ± 36.6% (107.2 kg, $P = 0.000$) (Figs. 1 and 2). The C group did not significantly change bench press (8.2 ± 7.7%, $P = 0.038$) or leg press (17.7 ± 12.0%, $P = 0.023$) 1RM strength from pretest to posttest (Figs. 1 and 2). The ST group’s percentage increases in bench press and leg press were significantly greater than for the C group ($P = 0.000$). At posttest, the ST group’s 1RM strength scores were significantly greater than the C group’s scores (bench
press, $P = 0.049$; leg press, $P = 0.004$). RPE averaged 13 for bench press and 14 for leg press 1RM assessments for all subjects. It is important to note that RPE did not change from pretest to posttest in the ST group, despite handling significantly greater weights for 1RM at posttest.

**Endurance.** Results of the absolute endurance tests are presented in Figures 3 and 4. The ST group significantly increased (Bonferroni correction, $P < 0.008$) bench press and leg press absolute endurance over the training period by $112.3 \pm 43.2\%$ (22.8 repetitions, $P = 0.000$) and $221.1 \pm 104.4\%$ (24.8 repetitions, $P = 0.000$). The C group did not significantly (Bonferroni correction, $P > 0.008$) change bench press ($18.8 \pm 15.3\%$, $P = 0.036$) or leg press ($-1.2\%$, $P = 0.542$) absolute endurance from pretest to posttest. Both the mean posttest bench press and leg press muscular absolute endurance scores and percentage increases of the ST group were significantly greater than the C group’s scores ($P = 0.000$). RPE in the ST group did not change from pretest to posttest despite significant increases in absolute endurance performance. Overall, RPE averaged 16 for bench press and 17 for leg press endurance assessments.

**Flexibility.** The ST group experienced a significant $8.2 \pm 0.1\%$ (3.1 cm, $P = 0.017$) increase in their sit-and-reach score over the training period. A nonsignificant $2.1 \pm 6.0\%$ (0.7 cm, $P = 0.410$) increase occurred in the C group’s flexibility score from pretest to posttest. No significant group interactions occurred.

**DISCUSSION**

The primary findings of this study were that 8 wk of low-frequency and low-volume, supervised, progressive strength training emphasizing free weight, multijoint movements caused significant improvements in muscular strength, absolute endurance, and flexibility in previously sedentary African American women 44 to 68 yr of age. Strength training also caused significant increases in upper body power, but lower body power did not significantly increase. In contrast to past reports of difficulties in involving African American women in a structured exercise programme.
program (5,15,28,29), this study’s compliance was extremely high (92.2%), and subjects indicated training was a safe and enjoyable experience. No compensation was offered subjects; however, women in the study did have a “personal trainer” to help motivate and support them during the training experience. During the study, a tremendous change in self-confidence in their ability to meet physical challenges was observed in subjects.

Muscular power. Strength-trained subjects in the present study significantly increased 1-kg medicine ball put distance by 0.2 m. However, as stated in the Results section, practical significance of this small increase in upper body power may be lacking. Strength training alone did not result in significant increases in lower body power generated on a bicycle ergometer. Training program design of this study represented a nonperiodized, beginning program for previously sedentary individuals. Sometimes, this type of strength-based program in untrained subjects may increase power by increasing force (i.e., power = force × velocity) (4,19,38). However, the present program’s lack of specificity for power development (moderate intensity (8RM to 10RM), low frequency (2 d·wk⁻¹), low volume (two to three sets per exercise), and repetition velocity (comfortable, controlled)) may not have required adequate increased recruitment and firing frequency of high-threshold, high-force, Type II motor units to significantly increase power in these subjects (19,38,43). Additionally, lack of specificity between power testing and training modalities may have limited results (43).

Recently, studies in healthy older adults have used a nonlinear periodization plan to improve power, which over the course of the training week combined high-intensity strength training with explosive exercise (light loads of approximately 50 to 60% of 1RM moved as explosively as possible through the range of motion) (21,22). This mixed program design holds true to the specificity concept in that high-intensity strength training targets the maximal force component of the power equation, while lighter load, higher velocity training improves the ability to generate force rapidly (4,21,22,38). Results of the present study, combined with results of Hakkinen et al. (21,22), suggest that the optimal program for development of power in healthy, older adults includes velocity specific, explosive work.

Ideally, the present study would have continued, incorporating linearly periodized, power specific training in the next phase that capitalized on the subject’s newly developed strength base and comfort with multijoint free weight movements (19,38,45). Organization of training phases linearly is in agreement with many athletic-based, periodized programs, which first lay a strength and technique foundation, then follow with power specific training (19,38,45). Through continued investigation of training design to optimize upper and lower body power in the older adult, we may improve their performance in many important functional and recreational activities such as preventing falls, playing with grandchildren, or hitting a round of golf.

Muscular strength. Women in the present study significantly increased their 1RM bench press by 34.4% (Fig. 1). To our knowledge, this is the first study in older women to train and assess 1RM bench press strength with free weights (e.g., barbell, dumbbells) which, in contrast to machines, requires balance and stabilization during the movement. Results compare favorably with machine-based studies in which women used similar training intensities (80 to 90% 1RM), frequencies (2 d·wk⁻¹), and volumes (2 to 3 × 8 to 10), during which bench press strength improved from 22% at 15 wk (41) to 25 to 43% at 6 months (25,39). Changes in 1RM incline dumbbell press were not assessed; however, training logs reveal increases in 10RM (workout weight) from week zero (range, ~2.5- to 5-kg dumbbells) to week 8 (range, ~7.5- to 15-kg dumbbells). Despite initial expression of fear to the trainers/spotters regarding weight being overhead in both the bench press (barbell) and incline press (dumbbells), subjects rapidly expressed confidence in their ability to perform the movements safely with proper

![FIGURE 4—Comparison of absolute muscular endurance (repetitions) (A) and percent change in absolute muscular endurance (B) in leg press performance before and after 8 wk of progressive strength training. C, control; ST, strength trained. *P < 0.001 vs corresponding pretest value (A) and vs C value (B). #P < 0.001 vs C posttest value. Values are mean ± SD.](image-url)
The present study’s dramatic 99.8% increase in leg press strength (Fig. 2) was higher than that observed in several other studies in older women (6,14,36,39,41), which ranged from 18% at 3 months (6) to 50% at 1 yr (14). Results of Mazzetti et al. (33) suggest the close supervision and motivation offered by personal trainers in the present study may have contributed to the significant improvement in leg press strength. Also, it must be noted that it is difficult to compare percent gain among the various strength training studies using older adults. IRM testing modes and methodologies; muscle group tested; subject’s initial strength levels; the volume, intensity, and frequency of training protocols; equipment used (machines vs free weights); and personalized attention to subjects all affect outcomes.

Balance was not measured in this study. However, an interesting observation was that even with an average pretest leg press of 115.9 kg, not one of the strength training group could perform a body weight lunge without holding a support for balance. At the end of the study, the free-standing lunges were being performed by all of the strength trained group with dumbbells ranging from approximately 5 to 15 kg for two sets of 10 repetitions. Dumbbell lunges are a free weight, multijoint movement that require balance, stabilization, and coordination to perform. Neuromuscular coordination is especially critical in the elderly, where coordination and balance problems together with mechanical efficiency can affect basic functional tasks critical to independent living (11,27,37,49). One subject stated that before the study she was about to sell her sports car because of physical problems getting in and out of the car. As the study progressed, she found that transfer in and out of the car was “no problem” and she was enjoying the car again. Improvements in upper and lower body strength of the magnitude seen in the present study may contribute to the ability to maintain functional independence and a high quality of life throughout the lifespan (8,13,17,35).

An important observation in this study is that gains in strength were significant and no injuries were observed. Training intensity was progressive, and a significant portion of the exercises involved multijoint, free weight movements that require balance, stabilization, and motor control to perform. Furthermore, in contrast to the majority of machine-based studies (14,18,27,36,37,41), training speed was not controlled (i.e., 3 s eccentric, 3 s concentric) but, similar to traditional bodybuilding training, a comfortable, controlled speed was self-selected by the subject. The present study, along with others (1,25), provides supporting evidence for the safe and effective use of progressive, free weight, multijoint strength training in older women. Future studies in the older adult comparing free weight to machine-based strength training are needed to address optimal transfer of training to functional activities.

Muscular endurance. Strength training significantly improved absolute muscular endurance by 112.3% in bench press (Fig. 3) and 221.1% in leg press (Fig. 4) in women of this study. Despite the lack of specific endurance-based, low-intensity, high-repetition and high-volume strength training (8,19), these dramatic gains in absolute muscular endurance are expected when IRM strength significantly increases (8,33,45), as seen in the present subjects (bench press.+34.4%; leg press.+99.8%). Maximal strength and absolute muscular endurance are related in that the stronger the individual, the lower percent of maximum a given submaximal load will be (40,45). By requiring a lower percent of maximal strength to perform a given submaximal task, cardiovascular stress may be reduced (2,6,8,40,45), decreasing the probability of heart attacks and stroke in older women (40,45). This potential is especially pertinent to African American women, who have a mortality rate from cardiovascular disease approximately 1.5 times greater than white women (29). Dramatic improvements in absolute muscular endurance as observed in this study may have significant impact on the ability to safely perform recreational activities such as walking, hiking, cross-country skiing, and biking (2,3,6,8,40,45). Furthermore, increases in muscular endurance improve the functional reserve necessary to conquer the stresses of the day’s repetitive submaximal muscular activities (13,35,40,45).

This is the first study to assess the effects of strength training on absolute muscular endurance of the upper and lower body in older women. The majority of longitudinal studies investigating strength training and older women have failed to assess either absolute or relative muscular endurance (14,21,22,24,25,27,36,37,39,41). Furthermore, upper body absolute endurance was assessed with a free weight, multijoint movement (e.g., barbell bench press), requiring balance and stabilization to perform. Future studies are needed to address optimal development of muscular endurance in the older adult and the relationship to functional outcomes.

Muscular flexibility. Adequate flexibility may help a person meet the functional demands of life, as well as enhance participation in leisure activities (3,8,20,45). Lack of flexibility may increase injury rate and may cause functional problems, particularly in the sedentary, middle-aged, and elderly (8,20,30,45). Kligman and Pepin (30) state that older adults with high levels of muscular strength and flexibility rarely require long-term health care. Many researchers believe that strength training performed through a full range of motion will improve flexibility (2,3,19,45). However, Hurley and Hagberg (26) point out that published results fail to support this assumption. In fact, results of flexibility studies vary, as do the subjects and methodologies used to study this question. Furthermore, effects of strength training on flexibility in the older adult have received limited attention (3,8,20,26,45). The present study performed only progressive strength training through the full range of motion. No flexibility work was conducted. This allowed us to investigate the effects of the strength training program alone on flexibility as recommended by other researchers (20,26).

Flexibility, as measured by the sit-and-reach test, significantly improved by 8.2% in the strength trained group. These results are in contrast to results of Girouard and
Hurley (20), who demonstrated a reduction in shoulder abduction with combined strength and flexibility training in 14 men averaging 61 yr old. Women in the present study performed no flexibility work, but did train three movements with resistance through the full range of motion that targeted muscles of the low back and hips used in the sit-and-reach test (leg press, dumbbell lunge, and hamstring curl). Because of the lack of comprehensive flexibility measures, it is difficult to make conclusions about the effects of strength training on flexibility from this study. However, these limited findings do support the viewpoint that full range of motion, multijoint, progressive strength training enhances flexibility.

In conclusion, this study demonstrated significant, simultaneous gains in muscle strength, absolute endurance, and flexibility in older African American women after 8 wk of low-frequency and low-volume, supervised, progressive strength training emphasizing free weight, multijoint movements. Changes in upper and lower body muscular power were positive, but lacked practical and statistical significance. Despite limitations of this study relating to the short length of the training intervention and the lack of functional measures as outcomes, results are important as evidence to further promote the safety and efficacy of progressive strength training in older adults, specifically African American women. African American women are a population that typically has low participation in muscular fitness activities; has significant functional limitations related to muscular power, strength, endurance, and flexibility; and is underrepresented in the exercise science research. On the basis of these facts, and in view of our results, strength training is important for improving and maintaining older African American women’s strength and endurance necessary for performing daily activities.

The authors wish to express their sincere gratitude for the effort and dedication of the subjects.

This work was supported by a Research on Women grant from the University of Louisville.

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