Effect of resistance and aerobic training on regional body composition in previously recreationally trained middle-aged women

Steven J. Fleck, Cora Mattie, and Henry C. Martensen III

Abstract: Twelve middle-aged women (mean age 41.9 ± 1.6 y) performed variable-cam resistance training and aerobic training 3 times/week for 14 weeks. One repetition maximum (1 RM) significantly increased between pre-training and training week 7 (13.1%–17.8%), between training week 7 and post-training (10.8%–14.1%), and between pre-training and post-training (25.5%–30.9%). Total-body lean soft tissue and total % body fat determined by duel-energy X-ray absorptiometry (DEXA) significantly increased (2.2%) and decreased (1.4%), respectively. Arm, trunk, and total upper-body (arm + trunk) lean soft tissue significantly increased (0.7%–4.6%). Total body fat tissue and all regional measures of fat tissue and % fat showed no significant changes. Significant correlations were shown between pre-testing and post-testing 1 RM in the bench press, lat pull down, and overhead press in all instances, except for post-training bench press and total upper-body lean soft tissue (r = 0.58–0.90). In contrast, non-significant correlations were shown between pre- and post-testing 1 RM of the leg press, with the exception of pre-training and total lean soft tissue and pre-training and leg lean soft tissue. In conclusion, resistance training resulted in consistent strength gains in middle-aged women, which were accompanied by regional changes in upper-body composition, whereas lower-body composition moved in the hypothesized direction, but did not achieve significance.

Key words: body composition, dual-energy X-ray absorptiometry, strength training, variable cam.

Résumé : Douze femmes d’âge moyen (41.9 ± 1.6 ans) participent à un programme d’entraînement à la force sur un appareil à came variable et à un programme d’entraînement aérobie à raison de trois fois par semaine pendant 14 semaines. Le maximum sans répétition (1 RM) augmente significativement du début à la 7e semaine (13.1 % – 17.8 %), de la 7e semaine à la fin du programme (10.8 % – 14.1 %) et du début à la fin (25.5 % – 30.9 %). La masse maigre totale et le pourcentage de gras corporel, déterminés par absorptionimétrie à rayons X en double énergie (DEXA), de façon significative augmentent (2,2 %) et diminuent (1,4 %), respectivement. La masse maigre des membres supérieurs, du tronc et du haut du corps (tronc + membres supérieurs) augmente significativement (0,7 % – 4,6 %). On n’observe aucune modification de la masse adipeuse, de ses mesures régionales et du pourcentage de gras. On observe en tout moment des corrélation significatives entre les valeurs de 1 RM du début et de la fin de l’entraînement au développé couché, au tirage à la poulie haute et au développé assis (r = 0,58–0,90); ce n’est cependant pas le cas pour les valeurs de développé couché et de la masse maigre totale du haut du corps observées après l’entraînement. Par contre, on n’observe pas de corrélations significatives entre les valeurs de 1 RM du début et de la fin de l’entraînement au développé des jambes sauf pour la masse maigre des jambes et de la masse maigre totale du début et de la fin de l’entraînement. En conclusion, la force des femmes d’âge moyen augmente par l’entraînement à la force; on observe également des modifications régionales de la composition corporelle du haut du corps. Quoique non significative, on observe tel qu’il a été prévu une modification de la composition corporelle du bas du corps.

Mots clés : composition corporelle, absorptionimétrie à rayons X en double énergie, entraînement à la force, came variable.

Introduction

Total-body resistance training has become a popular and important exercise component in a total conditioning program for women. Recently, regional body compositional changes as a result of resistance training in women have been examined using magnetic resonance imaging (MRI) and duel-energy X-ray absorptiometry (DEXA). Regional body compositional changes are important considerations for health, as abdominal fat has been linked to cardiovascular risk. Additionally, changes in regional lean soft tissue are important for the maintenance and development of strength in specific regions of the body.

There are relatively few studies examining regional body compositional changes as a result of resistance training in women and the majority of these studies have used younger women (aged 20–28 y) as subjects. Several studies looking...
at a variety of age groups have used resistance training only to examine regional body compositional changes. Abe et al. (2000) demonstrated significant changes in measures of upper body muscle thickness, whereas nonsignificant changes in lower body muscle thickness were demonstrated in 4 of 5 measurement sites. In another study, leg lean soft tissue increased significantly during the second half of a 5-month resistance-training program in younger women (mean age 20 y), whereas arm and trunk lean soft tissue significantly increased only during the first half of the training program (Chillibeck et al. 1998). These studies clearly show that lean soft tissue can be increased as a result of resistance training. However, inconsistency is shown concerning whether or not resistance training only causes significant body composition changes in various regions of the body and whether or not different regions of the body show greater or lesser body composition changes than other regions of body.

Many women interested in general fitness do not perform resistance training only, but perform a combination of resistance and aerobic training. Three studies have examined regional body compositional changes as a result of performing a combination of both resistance and aerobic training. After 6 months of training, young women (mean age 28 y) showed a significant increase in leg lean soft tissue with no change in leg fat tissue, whereas trunk and arm lean soft tissue showed nonsignificant changes, but significant reductions in fat tissue (Nindl et al. 2000). Kraemer and colleagues (2004) training younger women (mean age 23 y) for 6 months demonstrated greater changes in upper arm muscle cross-sectional area than was shown in upper leg muscle cross-sectional area. Older post-menopausal women (mean age 55 y) showed small but significant changes in leg and arm lean soft tissue, but not in trunk lean soft tissue, and small but significant changes in leg and arm fat tissue, but not trunk fat tissue, after a year of training compared with a control group (Teixeira et al. 2003). Similar to the resistance training only studies, these 3 studies show inconsistency concerning whether or not significant body composition changes occur in various regions of the body and whether various regions of the body show greater or lesser body composition changes than other regions of body.

It is possible that the inconsistencies concerning regional body compositional changes in the above studies are due to differences in the populations studied or training programs used. All of the above-cited studies appear to have used untrained or untrained but physically active subjects. Thus, training status does not appear to be a factor concerning whether or not regional body compositional changes occur. Whether or not regional body compositional changes occur could also be dependent upon subject age. However, this does not appear to be the case. The youngest group studied (mean age 20 y, Teixeira et al. 2003) showed significant changes in measures of upper-body muscle thickness, but nonsignificant changes in lower-body muscle thickness were demonstrated. The oldest population studied (mean age 55 y, Chillibeck et al. 1998) showed small but significant changes in both leg and arm lean soft tissue. Both of these groups showed significant changes in a measure of upper-body regional muscle mass. However, the older population was the only group to show significant changes in a measure of lower-body muscle mass. It might have been expected that the younger group would show the most consistent changes in both upper- and lower-body muscle mass. All of the other studies cited above (Kraemer et al. 2004; Nindl et al. 2000; Chillibeck et al. 1998) studied younger populations (mean age 20–28 to 23 years), therefore differences in regional body composition changes attributable to the age group studied cannot be clearly examined. The above studies all used total-body resistance-training programs consisting of 6–11 exercises/ session, 2–5 sessions/week, 1–5 sets/exercise, and 6–8 or 10–12 repetitions/set and demonstrated significant changes in some measures of regional body composition. However, no consistent pattern is apparent between the various parameters of resistance-training program design and whether or not changes to regional body composition occur in specific body regions and not in others.

There is relatively little and inconsistent information concerning regional body compositional changes in untrained or sedentary women and no study has examined regional body composition changes in women aged approximately 40 y who are already performing a recreational resistance and aerobic-training program. Therefore the major purpose of this study was to examine regional and total-body compositional changes in middle-aged women (39–44 y) with a history of performing both resistance and aerobic training. The design of the resistance-training program (3 sets of 10 repetition maximums (RM)) and aerobic-training program (20 min at 60%–70% of age predicted maximal heart rate) are similar in training volume and intensity to common health and fitness-training programs and within the guidelines recommended for general health fitness (American College of Sports Medicine 1998, 2002). It was hypothesized that all regional measures of lean soft tissue will increase significantly, whereas all regional measures of body fat will change nonsignificantly.

**Materials and methods**

**General study design**

Women between the ages of 39 and 44 y volunteered to be subjects in a 16 week training study that included both resistance and aerobic training. Although the focus of this study was strength and body composition changes caused by resistance training, aerobic training was included in the training program so that the training program resembled what women in this age group generally perform to bring about health and fitness benefits. The total duration of the study was 16 weeks. However, this included a 2 week introduction period to the testing and the resistance- and aerobic-training protocols. Neural adaptations cause large increases in maximum strength independent of muscle mass changes during the first several weeks of training (Moritani 1992; Sale 1992). The purpose of the introductory period was to minimize any neural learning effect on the 1 RM testing using the equipment used for training and testing in the study and to insure that both the resistance and aerobic training were performed at the desired intensities during the 14 weeks of actual training. One repetition maximum testing and a field test of aerobic fitness (20 m shuttle run) were performed on 4 occasions: before the 2 week introductory period, pretraining (after the 2 week introductory period), after 7 weeks of training, and after conclusion of 14 weeks of training or
post-training. Body composition was determined using dual-energy X-ray absorptiometry (DEXA) on 2 occasions: pre-training and after completion of 14 weeks of training.

**Subjects**

Twelve subjects (pre-training mean ± SD and range: age, 41.9 ± 1.6 y, 40–44 y; height, 165.4 ± 7.3 cm, 156.3–178.3 cm; body mass, 68.1 ± 12.3 kg, 51.9–93.3 kg; BMI, 41.2 ± 7.3 kg·m⁻², 33.2–58.2 kg·m⁻²) began and completed all aspects of the study. Compliance with all training and testing sessions was 100%. After an informal briefing describing all aspects of the study methodology and time requirements, subjects read and signed an informed consent form approved by an institutional review board before participating in any aspect of the study. Inclusion criteria for participation included performing recreational resistance and aerobic training 2–3 times/week for a minimum of 6 months, but no formal, organized training program; normal menstruation (cycle approximately 28–30 d in length), not currently being on or planning to initiate a diet weight-reduction program during the 16 weeks of the study; and not having any other medical reasons, such as orthopedic problems or taking of medication, that would prohibit performance of rigorous physical activity. The recreational-training programs performed by the subjects varied widely. Although all subjects performed 8–12 repetitions/set in their weight-training program, the number of sets varied between 1 and 3 per exercise per training session. Eight of the 12 subjects performed a variety of free-weight and machine-based resistance-type exercises, whereas 4 subjects performed only machine-based exercises. None of the subjects had previously used the variable-cam resistance-training equipment used in the study. Aerobic training performed as part of the subjects recreational-training program varied widely in session duration (15–40 min/session). Only one of the subjects used heart rate to monitor aerobic-training intensity before participation in the study. Subjects with a history of performing both resistance and aerobic training were recruited for several reasons: (i) past-training history indicated that subjects would be compliant and complete the prescribed training program, (ii) past-training history indicates the subjects would tolerate the intensity and volume of the training program without excessive soreness interfering with performing the prescribed training, and (iii) past resistance-training history would help minimize neural adaptation that could help stabilize the initial pre-training 1 RM strength testing.

**Training protocols**

During the actual 14 weeks of training, sessions consisting of both resistance and aerobic training were performed 3 d/week with at least 1 d of rest between sessions. Resistance training was always performed first in all training sessions. The resistance exercises were performed in the following order: leg press, bench press, seated row, overhead press, leg curl, leg extension, chest fly, lat pull down, arm curl, tricep extension, and resistive-ball abdominal crunches. All exercises except resistive-ball abdominal crunches were performed using variable-cam resistance-training machines (Strive Fitness Inc., Canonsburg, Penn.). This equipment allows the resistance curve of an exercise to be easily adjusted before beginning the exercise. There are 3 major resistance curve settings. Settings 1, 2, and 3 result in a bell shaped, ascending, and descending resistance curve, respectively. During the first 2 training sessions of the 2 week introductory period, 1 set of exercises at the adjustable cam setting of 1 was performed at the perceived 10 RM resistance at cam setting 1. The next 2 training sessions of the introductory period consisted of 2 sets: 1 set performed at cam setting 1 and 1 set performed at cam setting 2. Both sets were performed using the perceived 10 RM resistance at cam setting 1. During the last 2 training sessions of the introductory period and for the remainder of the study 3 sets of each exercise were performed with 1 set being performed using cam setting 1, 2, and 3 and all were performed using the 10 RM at cam setting 1. The resistive-ball abdominal crunch exercise followed an identical pattern of increasing the number of sets to 3 during the introductory period. Resistance for individual exercises was increased by 1.1 kg whenever a subject could perform all 3 sets of an exercise for 10 repetitions. Rest periods between sets of individual exercises and between exercises were 1 min in length.

In all training sessions, aerobic training was initiated 5–10 min after completion of the resistance training exercises. Initial aerobic training consisted of 20 min of either treadmill running or stationary cycling at 60% of each subject’s age-predicted maximum heart rate (ACSM 1998). During the 2 week introductory period, workload was gradually increased so that subjects trained at 70% of their age-predicted maximum heart rate and subjects trained at 70% of age-predicted maximum heart rate for the remainder of the study. Heart rate was monitored during all aerobic training sessions using heart rate watches. Heart rate was checked at 5 and 10 min into each training session and during the last minute of the 20 min training session.

**Strength testing**

One repetition maximum strength was determined for 4 exercises included in the total-body resistance-training program. One repetition maximum strength was determined for the bench press, leg press, lat pull down, and overhead press in the order listed. A composite strength score defined as the sum of the 1 RM of the 4 exercises tested was also calculated. All strength testing was performed using the same resistance training equipment used in the training program (Strive Fitness Inc.). All 1 RM testing was performed using an adjustable cam setting of 1 (bell shaped resistance curve) and all 1 RM testing sessions for each subject were performed at the approximate same time of the day (within 1 h) to minimize any diurnal effects on strength.

The 1 RM testing protocol used here has been used in previous studies examining strength changes in women (Kraemer et al. 2000, 2003, 2004; Marx et al. 2001) and has been described previously (Kraemer and Fry 1995). Briefly, this protocol consists of a warm-up set of 5–10 repetitions at 40%–60% of the perceived 1 RM, a second warm-up set of 3–5 repetitions at 60%–80% of the perceived 1 RM, followed by no more than 4 attempts to determine the 1 RM for each exercise. Rest periods of 3–5 min were allowed between warm-up sets and 1 RM attempts. Five minute rest periods were allowed between exercises. These relatively long rest periods insure recovery between 1 RM attempts. Perceived 1 RM is an estimate of the 1 RM based on training resistance.
and number of repetitions performed per set in training if possible and in consultation with the subject being tested. Successive 1 RM tests use the previous 1 RM as the perceived 1 RM for the first 1 RM attempt. Interclass correlation coefficients between the tests occurring before the 2 week introductory period and pre-training for the 4 exercises for which 1 RM was tested ranged between 0.92 and 0.94.

Body composition

DEXA has been shown to have good reproducibility determination of for total body mass, total body fat mass, total body lean soft tissue, arm lean soft tissue, and leg lean soft tissue (Economos et al. 1997; Figueroa-Colan et al. 1998; Fuller et al. 1992) and is a sensitive method for assessing small changes in body composition (Houtkooper et al. 2000). Therefore, it was chosen to evaluate body composition in the present study. Body composition variables were determined using a DEXA fan beam scanner (Hologic Inc., Bedford, Mass.). The DEXA scanner was calibrated daily using a phantom (serial No. 71202) before performing body composition determination. The scanner calibrated on the first attempt on all occasions and no repairs were performed on the scanner between the pre-testing and post-testing body composition determinations. The same experienced technician performed all DEXA scanning procedures on all subjects. Body composition of individual subjects was determined at the approximate (within 1 h) same time of the day and 24–48 h after the last training session preceding the DEXA scanning procedure. The body composition variables determined were total body, arm (left + right), leg (left + right), and trunk % fat; lean soft tissue (g); and fat tissue (g). Standardized landmarks were used to separate the different regions of the body. Briefly, a line bisecting the glenoid fossa was used to separate the arms from the trunk and a line across the top of the iliac crests was used to separate the legs from the trunk. Total upper body composition variables defined as arm (left + right) plus trunk % fat, lean soft tissue, and fat tissue were also calculated to better represent the tissue used in the upper-body resistance exercises for which 1 RM’s were determined.

Predicted peak oxygen consumption

Peak oxygen consumption ($V_{O2 \text{peak}}$) was predicted using the 20 m shuttle run test (Leger and Lambert 1982). All tests were performed indoors on the same surface after completion of the 1 RM strength testing. Velocity of each 20 m shuttle during the test was paced by a CD (Australian Sports Commission, Belconnen, Australia). Tests were terminated when the subject could not maintain the pace for 3 successive 20 m shuttles. The number of shuttles completed was used to estimate predicted peak oxygen consumption (mL·(kg·min)$^{-1}$). The Interclass correlation coefficient between the tests occurring before the 2 week introductory period and pre-training for the prediction of $V_{O2 \text{peak}}$ was 0.96.

Statistical analysis

Subjects were allowed to choose whether to perform stationary cycling or treadmill running as their aerobic training on a session-by-session basis. This is a potential confounding variable for the body composition variables because the caloric expenditure between these 2 modes of training may be different. Nine of the 12 subjects chose to do cycle training during all training sessions. Two of the subjects chose to do treadmill running during all training sessions and 1 subject chose to cycle for 45% and to treadmill run for 55% of the training sessions. Statistical analysis of the body composition data of the 9 subjects choosing to cycle during all training sessions resulted in the same variables showing statistical significance as presented in Table 4 for the entire group, with the exception of total % body fat, where no significant difference ($p = 0.7$) was shown between pre- and post-training for the subjects that only cycled. Statistical analysis demonstrated that addition of 1 more subject with the same mean % fat pre- and post-training as the group of 9 subjects choosing to cycle during all training sessions would result in a significant difference ($p = 0.47$) between pre- and post-training % fat. Additionally, no significant differences were shown between the changes in body composition of the subjects choosing to cycle or treadmill run. Therefore, the data from the subjects choosing to cycle and run were pooled for statistical analysis.

Repeated-measures analyses of variance (ANOVA’s) were used in the analysis of predicted $V_{O2 \text{peak}}$. 1 RM strength, and training-weight percent of 1 RM (calculated using training weights for the last training session immediately before 1 RM testing sessions) with Tukey’s honestly significant difference (HSD) test used as a post hoc test where indicated. Dependent t tests were used in the analysis of total and regional body-composition changes. Correlation coefficients between pre-training strength measures and pre-training body-composition variables and between post-training strength measures and post-training body-composition variables were determined using Pearson’s product–moment correlations. The level of significance for all statistical analyses was $p \leq 0.05$. All statistical procedures were performed using Statistica Software (StatSoft, Tulsa, Okla.). Using the nQuery Advisor software (Statistical Solutions, Saugus, Mass.), the statistical power for the n size of this investigation ranged from 0.82 to 0.94 for the variables examined.

Results

General subject characteristics

No significant change in the subjects total body mass (mean ± SD, range: pre-training, 68.1 ± 12.3 kg, 51.9–93.3 kg; post-training, 67.7 ± 11.3 kg, 52.6–86.8 kg) or BMI (pre-training 41.2 ± 7.3 kg·m$^{-2}$, 33.2–58.2 kg·m$^{-2}$; post-training, 40.9 ± 6.5 kg·m$^{-2}$, 33.6–54.1 kg·m$^{-2}$) was found between pre- and post-training.

Strength

Significant strength gains in all 4 exercises tested and in the composite strength score were seen between pre-training and week 7 of the program, between pre- and post-training, and between week 7 and post-training (Table 1). Strength gains from pre-training to week 7 ranged from 13.1% in the overhead press to 17.8% in the lat pull down (Table 2). Strength gains from pre-training to post-training ranged from 25.5% in the overhead press to 30.3% in the lat pull down. Strength gains from week 7 to post-training ranged from 10.8% in the lat pull down to 14.1% in the leg press.
The only significant change in training weight percent of 1RM demonstrated for an individual exercise during the training program was an increase from pre-training to week 7 in the leg press value (Table 3). At pre-training, the training weight percent of 1 RM values demonstrated significant differences between exercises with the bench press being less than the lat pull down and greater than the overhead press; the leg press being less than the lat pull down and greater than the overhead press; and the lat pull down being greater than the overhead press. After 7 and 14 weeks of training the training weight percent of 1 RM values demonstrated significant differences between exercises with the bench press being less than the leg press and lat pull down; the leg press being greater than the overhead press; and the lat pull down being greater than the overhead press.

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Pre-training (kg)</th>
<th>Week 7 value (kg)</th>
<th>Week 14 value (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench press</td>
<td>40.9±8.0</td>
<td>46.9±8.2*</td>
<td>51.9±7.4†</td>
</tr>
<tr>
<td>Leg press</td>
<td>124.0±25.8</td>
<td>141.7±27.0*</td>
<td>160.2±25.2†</td>
</tr>
<tr>
<td>Lat pull down</td>
<td>43.5±6.8</td>
<td>51.1±8.4*</td>
<td>56.6±9.4†</td>
</tr>
<tr>
<td>Overhead press</td>
<td>25.6±5.0</td>
<td>29.0±6.4*</td>
<td>32.0±6.2†</td>
</tr>
<tr>
<td>Composite</td>
<td>233.9±41.6</td>
<td>268.5±43.0*</td>
<td>300.8±37.0†</td>
</tr>
</tbody>
</table>

*Significantly greater than pre-training value.
†Significantly greater than week 7 value.

### Table 2. One repetition maximum percent changes with training.

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Pre-training to week 7 (%)</th>
<th>Pre-training to week 14 (%)</th>
<th>Weeks 7 to 14 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench press</td>
<td>15.5</td>
<td>28.3</td>
<td>11.1</td>
</tr>
<tr>
<td>Leg press</td>
<td>14.7</td>
<td>30.9</td>
<td>14.1</td>
</tr>
<tr>
<td>Lat pull down</td>
<td>17.8</td>
<td>30.3</td>
<td>10.8</td>
</tr>
<tr>
<td>Overhead press</td>
<td>13.1</td>
<td>25.5</td>
<td>11.4</td>
</tr>
<tr>
<td>Composite</td>
<td>15.2</td>
<td>29.8</td>
<td>12.7</td>
</tr>
</tbody>
</table>

### Table 3. Training weight percent of 1 repetition maximum (RM).

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Pre-training value (%)</th>
<th>Week 7 value (%)</th>
<th>Week 14 value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bench press</td>
<td>61±11*</td>
<td>58±5*</td>
<td>58±4*</td>
</tr>
<tr>
<td>Leg press</td>
<td>63±6†‡</td>
<td>70±6*‡</td>
<td>67±4*‡</td>
</tr>
<tr>
<td>Lat pull down</td>
<td>71±7*§</td>
<td>73±7*§</td>
<td>72±6*§</td>
</tr>
<tr>
<td>Overhead press</td>
<td>51±6*‡§</td>
<td>55±7 ‡</td>
<td>55±6  ‡</td>
</tr>
</tbody>
</table>

*Significant difference between the bench press and exercises marked with the same symbol at that time point.
†Significant difference pre-training vs. week 7 value for leg press.
‡Significant difference between the leg press and exercises marked with the same symbol at that time point.
§Significant difference between the lat pull down and exercises marked with the same symbol at that time point.

The only significant change in training weight percent of 1RM demonstrated for an individual exercise during the training program was an increase from pre-training to week 7 in the leg press value (Table 3). At pre-training, the training weight percent of 1 RM values demonstrated significant differences between exercises with the bench press being less than the lat pull down and greater than the overhead press; the leg press being less than the lat pull down and greater than the overhead press; and the lat pull down being greater than the overhead press.

### Body composition

Total body mass and total body fat mass did not change significantly from pre-training to post-training (Table 4). While total % body fat decreased significantly (1.4%) and total body lean soft tissue mass increased (2.2%) significantly. Arm, trunk, and total upper body lean soft tissue mass all significantly increased pre-training to post-training. All regional measures of % fat and fat tissue mass showed no significant changes.

### Correlations between strength and lean soft tissue

Thirty-four of the 40 correlations between lean soft tissue measures showed positive significant correlations (pre-training and post-training) to strength (Table 5). Bench press 1 RM showed positive significant correlations to all pre-training and post-training measures of lean soft tissue except in one case (pre-training vs. total upper body lean soft tissue). Pre-training and post-training lat pull down, overhead press, and composite 1 RM all showed significant positive correlations to all pre-training and post-training measures of lean soft tissue. However, pre-training leg press 1 RM only showed significant positive correlations to pre-training lean soft tissue in 2 instances, total-body and leg lean soft tissue. Post-training leg press 1 RM did not demonstrate any significant correlations to any post-training measures of lean soft tissue.

### Estimated peak oxygen consumption

Estimated VO$_2$ (mL/(kg-min)$^{-1}$) demonstrated significant improvement from pre-training (26.0 ± 5.9 mL/(kg-min)$^{-1}$ to week 7 (28.0 ± 5.0 mL/(kg-min)$^{-1}$) and 14 (29.3 ± 4.9 mL/(kg-min)$^{-1}$) values. No significant difference was demonstrated between the week 7 and 14 values.

### Discussion

The major findings of the present study relate to strength and body compositional changes in middle-aged women performing a training program consisting of both resistance and aerobic training when diet is not controlled. One repetition maximum strength in all exercises tested significantly and consistently increased throughout the duration of the study.
Total body mass did not change significantly. Regional lean soft tissue changes in all regions except the legs supported the hypothesis that all regional measures of lean soft tissue would increase. The study's results also supported the hypothesis that regional fat tissue measures would not change significantly. Total % fat tissue also demonstrated a nonsignificant change. However, total % fat did significantly decrease. The body compositional changes indicate that the training program performed results in small but significant changes in total body fat, total lean soft tissue, and regional lean soft tissue in all regions but the legs. Collectively, the changes in body composition result in no significant change in total body mass. Regional and total lean soft tissue significantly correlated to 1 RM strength of upper-body pre- and post-training in all but 1 of 24 correlations; however, leg press 1 RM pre- and post-training did not correlate to regional or total-body lean soft tissue in 6 of 8 correlations. The training program also resulted in significant increases of predicted VO₂ peak.

The adjustable-cam training protocol used in the present study did produce significant and consistent 1 RM strength gains. Strength gains ranged from 13.1% for the overhead press to 17.8% for the lat pull down from pre-training to week 7 of the program; week 7 to post-training strength gains ranged from 10.8% in the lat pull down to 14.1% in the leg press. Thus, strength gains showed a pattern of less improvement as training progressed. A pattern of decreasing yet significant strength gains as training progresses has been noted in previous studies on women undergoing physical training (Kraemer et al. 2000, 2003; Marx et al. 2001) and has been concluded to be the normal pattern of strength loss of total body fat tissue due to the performance of a conditioning program consisting of both resistance and aerobic training (Nindl et al. 2000) and slightly greater than that noted (1.4%) in a group of 117 postmenopausal women (mean age 55 y) during 1 year of resistance training (Teixeira et al. 2003). This indicates these middle-aged women still had the capability of physiological adaptations resulting in total lean soft tissue gains similar in magnitude (% change) to those seen in younger women. The nonsignificant change (14.1%) in total fat tissue was smaller than that shown (10%) by the group of 33 younger women (Nindl et al. 2000) and slightly greater than that shown (1.5%) by the older group of 117 women (Teixeira et al. 2003). Collectively, these results indicate that as women age loss of total body fat tissue due to the performance of a conditioning program consisting of both resistance and aerobic training becomes more difficult. This conclusion is supported by a study training both young (n = 9, mean age 26 y) and older (n = 10, mean age 68 y) women with the same resistance training program for 6 months in which the young and older women showed fat mass decreases of 4.4% and 2.2%, respectively (Lemmer et al. 2001).

Studies examining regional body compositional changes as a result of resistance training in younger women (mean age 20–28 y) have shown conflicting results. After 6 months of resistance and aerobic training, 33 young women (mean age 28 y) showed a significant increase in leg (5.5%) lean soft tissue, but no significant change in leg fat tissue (Nindl et al. 2000). Nonsignificant changes in trunk and arm lean soft tissue were shown, but significant decreases in arm (31%) and trunk (12%) fat tissue occurred. The results of this study indicate that the lower body musculature of women hypertrophies more than the trunk and arm, while fat tissue losses in the trunk and arm are more apparent than in the leg. In a second study examining regional muscle

### Table 4. Body composition changes.

<table>
<thead>
<tr>
<th>Region</th>
<th>Mass (kg)</th>
<th>LST (g)</th>
<th>FT (g)</th>
<th>% fat</th>
<th>Pre-training</th>
<th>LST (g)</th>
<th>FT (g)</th>
<th>% fat</th>
<th>Post-training</th>
<th>LST (g)</th>
<th>FT (g)</th>
<th>% fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total body</td>
<td>68.1±12.3</td>
<td>41572.3±5086.7</td>
<td>22805.9±7764.8</td>
<td>33.5±5.6</td>
<td>4235.4±598.1</td>
<td>2497.3±723.5</td>
<td>35.1±5.7</td>
<td>20447.1±2786.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm</td>
<td>2.2</td>
<td>–4.1</td>
<td>–1.4</td>
<td>0.003</td>
<td>2497.3±723.5</td>
<td>35.1±5.7</td>
<td>20447.1±2786.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trunk</td>
<td>0.047</td>
<td>0.047</td>
<td>0.047</td>
<td>0.637</td>
<td>2497.3±723.5</td>
<td>35.1±5.7</td>
<td>20447.1±2786.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** LST, lean soft tissue; FT, fat tissue.

*Significant change pre-training to post-training.
hypertrophy in a group of 39 young women (mean age 23 y), MRI techniques were used to examine arm and leg hypertrophy changes as a result of 6 months of resistance and aerobic training (Kraemer et al. 2004). In this study, significant upper-arm muscle cross-sectional area increases (15%–19%) and significant upper-leg muscle cross-sectional area increases (5%–9%) were shown. These results indicate that the upper body musculature of women undergoes greater hypertrophy than the lower body musculature. A third study examining regional body-compositional changes using DEXA technology in 19 young women (mean age 20 y) performing only resistance training indicated significant increases in trunk, arm, and leg lean soft tissue (Chillibeck et al. 1998). However the greatest increases in lean soft tissue occurred in the arms, which showed a significant 7.5% increase in the first 10 weeks of training and a non-significant 2.3% increase from weeks 10 to 20, followed by the legs, which showed a non-significant 1.4% increase in the first 10 weeks of training and a significant 2.0% increase from weeks 10 to 20, followed by the trunk, which showed a non-significant 0.5% increase in the first 10 weeks of training and a significant 2.7% increase from weeks 10 to 20. These studies on younger women show no clear pattern of whether or not there is greater hypertrophy of specific muscle groups or body regions or whether or not fat tissue losses occur to a greater extent in specific body regions as a result of the performance of resistance training.

The present study’s results on middle-aged women indicate that the arm (4.6%) and trunk (0.7%) undergo significant increases in lean soft tissue, while leg (1.2%) lean soft tissue is not significantly altered as a result of combined resistance and aerobic training. However, no significant changes in any regional measure of fat tissue or % fat were shown in the present study. Even though some regional body composition measures did not show significant changes all measures of lean soft tissue, fat tissue and % fat changed in the present study. Even though some regional body composition measures did not show significant changes all measures of lean soft tissue, fat tissue and % fat changed in the direction desirable for increases in strength and fitness. A study (Abe et al. 2000) in which 20 women of a similar age (mean age 41 y) to those in the present study performed only weight training 3 d/week for 12 weeks showed significant increases in all upper-body muscle thickness measures determined (10%–31%), but only a significant difference in 1 of 5 lower-body muscle thicknesses determined (7%–8%). The present and previous study both indicate that the upper body hypertrophies to a greater extent than the lower body in middle-aged women. A study comparing groups of older postmenopausal women (mean age 55 y) who resistance trained for 1 year (n = 117) to a control group (n = 116) who did not train showed small but significant changes in leg and arm lean soft tissue (0.3 and 0.1 kg), but not in trunk lean soft tissue, and small but significant changes in leg and arm fat tissue (0.5 to 0.1 kg), but not trunk fat tissue (Teixeira et al. 2003). This difference between studies may indicate that longer training periods (>14 weeks as in the present and previous studies on middle-aged women; Abe et al. 2000) are necessary to produce significant changes in leg regional lean soft tissue and in all regional fat tissue in middle-aged and older women. Conversely, it may represent a difference in study design: in the present and previous studies on middle-aged women (Abe et al. 2000), pre- to post-training differences were examined within the training group, whereas in the study on postmenopausal women, differences were examined between the training group and a control group.

Positive correlations between muscle cross-sectional area or size and strength have been shown for a single joint or single muscle group (i.e., knee extension, arm curl) type exercises (Miller et al. 1992; Neder et al. 1999) and for multi-joint or multi muscle group (i.e., bench press, leg press) type exercises (Brechue and Abe 2002; Chillibeck et al. 1998; Horvat et al. 2003). Therefore, it is accepted that muscle size influences maximal strength. Pre- and post-training correlation coefficients between 1 RM strength and lean soft tissue measurements in the present study show significant positive correlations in 31 of 32 cases (Table 5) and little change pre-training to post-training in the upper-body exercises tested (bench press, lat pull down, overhead press) and for composite strength. However, pre- and post-training correlation coefficients between leg press 1 RM and lean soft tissue measurements were not significant in 6 of 8 cases. These results indicate that, for the upper-body exercises, the use of women with at least 6 months resistance training experience and a 2 week introductory period to the training and testing protocols resulted in a consistent relationship between lean soft tissue and strength. This suggests that the study design minimized the effect of neural adaptations on strength in upper body exercises because the correlation coefficients between lean soft tissue and 1 RM strength remained relatively constant, but did not minimize the effect of neural adaptations on the performance of the leg press exercise because in 6 of 8 cases correlation coefficients between leg lean soft tissue and leg press 1 RM were not significant.

Rutherford and Jones (1986) suggested that with more complex exercises neural adaptations play a dominant role early in training and hypothesized reliance upon neural adaptations for strength increases may delay hypertrophy of the muscles used in these exercises. They further state that with more complex exercises that involve movement at more than 1 joint (multi-joint exercises), fixator muscles used in support of the prime movers may have to increase in strength or improve their ability to activate and coordinate contractions before hypertrophy of the prime movers occurs. This results in strength gains before significant hypertrophy of the prime movers occurs (Rutherford and Jones 1986). In the present study, subjects with at least 6 months resistance...
training experience were used to minimize neural adaptations so that hypertrophy would begin to take place as soon as possible in the training program. The lack of a significant increase in leg lean soft tissue, but significant increases in arm and trunk lean soft tissue, suggests that it may take longer for the leg musculature of women to hypertrophy, indicating a greater reliance on neural adaptations and (or) longer duration for “fixator” muscles of the leg musculature to become strong enough to support the resistance necessary for the prime movers involved in the leg press to hypertrophy. The dependence on muscle groups not typically thought of as involved in an exercise for successful performance of the exercise was shown by a trend \((p = 0.09)\) for an increase in 1 RM squat ability in young women who perform only upper body exercises (Kraemer et al. 2004). Although we are aware of no direct data demonstrating the need for a longer training duration for hypertrophy to occur when performing multi-joint exercises, this possible need was considered in the training program design of the present study. The training program included both single- and multi-joint exercises for both the arm (i.e., bench press, arm curl, tricep extension) and leg (i.e., leg press, leg extension, leg curl). Despite this consideration, no significant change in leg lean soft tissue occurred during the duration of the study.

Chilibeck and colleagues (1998) demonstrated significant increases in lean soft tissue of the arms from pre-training to week 10 of training in a 20 week program in young women \((n = 19, \text{mean age 20 years})\), with no further significant change from weeks 10 to 20. Trunk and leg lean soft tissue did not change significantly from pre-training to week 10 of training, but did significantly increase from weeks 10 to 20. Abe and colleagues (2000) also demonstrated that the upper-body musculature hypertrophies earlier and to a greater extent than the lower-body musculature during 12 weeks of weight training in 20 middle-aged women \((\text{mean age 41 years})\). Both of these studies indicate the need for a longer training duration for hypertrophy of the leg musculature to occur in comparison to hypertrophy of the arm musculature in women. Results of the present study indirectly support the conclusion from these 2 previous studies that it takes longer for hypertrophy of the leg musculature \((\text{i.e., no significant change in lean soft tissue in the present study})\) to occur in comparison with the upper-body musculature \((\text{i.e., significant increase of lean soft tissue in the present study})\) of women.

In the present study, it is possible that a difference in training intensity may have resulted in a significant increase in upper-body lean soft tissue and no change in lower-body lean soft tissue. At pre-training, week 7, and week 14, the leg press exercise was performed at a greater intensity than 2 (bench press, overhead press) and at a lower intensity than 1 (lat pull down) of the upper-body exercises for which 1 RM was tested. This gives no clear indication as to whether or not a difference in training intensity between the upper- and lower-body exercises may account for the different lean soft tissue response between the upper and lower body. The training intensities do indicate a difference between exercises at all time points for which this variable was calculated. This supports previous data demonstrating significant differences between exercises in the maximal number of repetitions women can perform at different percentages of 1 RM (Hoeger et al. 1990). The present study’s training intensities in all but one comparison \(\text{(leg press pre-training vs. the week 7 value)}\) showed no significant changes as training progressed. This is in disagreement with previous data demonstrating trained women perform significantly greater maximal numbers of repetitions to failure in various exercises than untrained women (Hoeger et al. 1990). This would indicate that trained women use a greater percent of 1 RM when performing a certain number of repetitions to failure. This difference between the present study and this previous study may be due in part to the definition of trained. The subjects in the present study were performing resistance training recreationally for at least 6 months before the start of the study. The trained subjects in the previous study were performing weight training up to 4 years. Collectively, these 2 study’s results indicate that if training results in the ability to use a greater percentage of 1 RM to perform a certain number of repetitions, it takes longer than 14 weeks of training for this to occur.

Performance of aerobic activity by the lower-body musculature may have caused the lack of the significant increase in leg lean soft tissue. Some studies do demonstrate that performance of concurrent resistance and aerobic training does compromise maximal strength increases \(\text{(see review by Dudley and Fleck 1987)}\), which might indicate compromised muscle hypertrophy in the lower-body musculature. However, not all studies demonstrate compromised strength levels when concurrent resistance and aerobic training are performed \(\text{(see review by Dudley and Fleck 1987)}\). Both the resistance- and aerobic-training programs used in studies demonstrating compromised strength levels are of a higher intensity and volume than programs that would be performed for recreation or general fitness \(\text{(Dudley and Fleck 1987)}\). Studies using training programs similar to the program used in the present study and representative of programs

### Table 5. Correlation coefficients between 1 RM strength and lean tissue.

<table>
<thead>
<tr>
<th></th>
<th>Bench press</th>
<th>Leg press</th>
<th>Lat pull down</th>
<th>Overhead press</th>
<th>Composite</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-training</td>
<td>Post-training</td>
<td>Pre-training</td>
<td>Post-training</td>
<td>Pre-training</td>
</tr>
<tr>
<td>Total LST</td>
<td>0.58*</td>
<td>0.65*</td>
<td>0.61*</td>
<td>0.35</td>
<td>0.81*</td>
</tr>
<tr>
<td>Arm LST</td>
<td>0.67*</td>
<td>0.74*</td>
<td>0.47</td>
<td>0.19</td>
<td>0.79*</td>
</tr>
<tr>
<td>Leg LST</td>
<td>0.68*</td>
<td>0.64*</td>
<td>0.61*</td>
<td>0.26</td>
<td>0.78*</td>
</tr>
<tr>
<td>Total upper-body LST</td>
<td>0.48</td>
<td>0.61*</td>
<td>0.54</td>
<td>0.35</td>
<td>0.75*</td>
</tr>
</tbody>
</table>

**Note:** LST, lean soft tissue.

*Significant correlation between variables.
used for general fitness do not show compromised strength levels or total-body fat-free mass in either adult men (mean age 27 y, McCarthy et al. 1995) or women (mean age 20 y, Volpe et al. 1993). Both of these studies trained subjects for both strength and endurance 3 d/week with a total-body resistance-training program and endurance training consisting of running for 25 min at 75% of age-predicted maximal heart rate (Volpe et al. 1993) or running for 45 min at 70% of heart rate reserve (McCarthy et al. 1995). These studies did not determine regional body composition; however, they did demonstrate no significant compromised strength increases, which could indicate lack of compromised increases in lower-body lean soft tissue. Studies on women undergoing both aerobic and resistance training have shown significant increases in measures of leg lean soft tissue in younger women (mean age 28 and 23 y, respectively; Nindl et al. 2000; Kraemer et al. 2004) and in postmenopausal women (mean age 55 y; Teixeira et al. 2003). These 3 studies indicate that concurrent performance of aerobic and resistance training does not necessarily result in nonsignificant increases in leg lean soft tissue. Thus, it is unlikely that performance of aerobic activity with the lower body and not the upper body resulted in the lack of a significant increase in lean soft tissue of the lower body.

In summary, our subjects demonstrated significant and consistent strength increases over the 14 weeks of training. Significant increases in arm and trunk regional lean soft tissue and a small but nonsignificant increase in leg lean soft tissue resulted in a significant increase in total lean soft tissue. Non-significant decreases in arm, trunk, and leg fat tissue resulted in a significant decrease in total % body fat. Additionally, in middle-aged women, it may be more difficult or take longer training durations to bring about significant changes in lean soft tissue of the leg compared with the arm and trunk.

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References


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