SHORT-TERM EFFECTS OF RESISTANCE TRAINING FREQUENCY ON BODY COMPOSITION AND STRENGTH IN MIDDLE-AGED WOMEN

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ABSTRACT

Benton, MJ, Kasper, MJ, Raab, SA, Waggener, GT, and Swan, PD. Short-term effects of resistance training frequency on body composition and strength in middle-aged women. J Strength Cond Res 25(11): 3142–3149, 2011—Although a dose–response relationship between resistance training frequency and strength has been identified, there is limited research regarding the association between frequency and body composition. This study evaluated the effects of 3 vs. 4 d wk−1 of resistance training on body composition and strength in middle-aged women. Twenty-one untrained women (age 47.6 ± 1.2 years) completed 8 weeks of resistance training either 3 nonconsecutive days of the week using a traditional total-body protocol (RT3) or 4 consecutive days of the week using an alternating split-training protocol (RT4). The RT3 completed 3 sets of 8 exercises, whereas RT4 completed 3 sets of 6 upper body exercises or 6 sets of 3 lower body exercises. Both groups completed 72 sets per week of 8–12 repetitions at 50–80% 1 repetition maximum. Weekly training volume load was calculated as the total number of repetitions × load (kg) completed per week. Body composition was measured using air displacement plethysmography. At baseline and after 8 weeks of resistance training, there were no significant between-group differences. Both protocols resulted in significant increases in absolute lean mass (1.1 ± 0.3 kg; p = 0.001), body weight (1.0 ± 0.3 kg; p = 0.005), body mass index (0.3 ± 0.1 kg m−2; p = 0.006), strength (p < 0.001), and weekly training volume load (p < 0.001). Correlation analysis revealed that weekly training volume load was strongly and positively related to gains in lean mass (r = 0.56, p = 0.05) and strength (r = 0.60, p = 0.006). In these untrained, middle-aged women, initial short-term gains in lean mass and strength were not influenced by training frequency when the number of training sets per week was equated.

KEY WORDS: lean mass, split training, total-body training, volume load

INTRODUCTION

The ability of regular resistance exercise to elicit increases in lean mass and strength has been well documented (2,3,14,17). Its benefits are undeniable, especially for middle-aged women who are at high risk for sarcopenia (26,32) and weight gain leading to overweight and obesity (9). Current physical activity guidelines for health recommend at least 2 d wk−1 of resistance training (15). However, these may be considered “minimal” recommendations for maintenance of musculoskeletal health. Indeed, ample evidence exists to confirm the feasibility and utility of higher doses of resistance exercise for progressive adaptation (23,24). Increasing the frequency of resistance exercise may provide further advantages, especially gains in lean mass (1). Previous studies have confirmed that resistance exercise frequency may influence body composition in untrained, young (4,6) and old (21,29) women. To date, the effect of resistance exercise frequency has not been well studied in women during middle age when they are known to experience an exaggerated loss of muscle as a result of hormonal changes associated with menopause (31). Because it is likely that middle-aged women may benefit greatly from the preventative effect of resistance exercise, additional research pertaining to the dose–response in this population is warranted.

One of the barriers to increasing the frequency of resistance exercise is the need for adequate recovery time. In untrained middle-aged women, there is an acute effect of heavy resistance exercise that results in diminished force production of the trained muscle for up to 48 hours after exercise (13). It is therefore of importance when designing an optimal resistance exercise program to allow adequate time to recover from neuromuscular fatigue. For this reason, when individual resistance exercise bouts are designed to
stress the major muscle groups of the entire body, a 2- to 3-d-wk⁻¹ regimen is often recommended (1). However, this type of training may not be ideal for optimizing gains. For higher frequency resistance training, individual muscle groups are isolated and trained during a single exercise bout. To ensure recovery with a training frequency of 3–4 d-wk⁻¹, each major muscle group is trained only 1–2 times per week (1). This allows the total weekly volume load of the training program to be distributed over more sessions than the traditional 3-d-wk⁻¹ protocol.

Current evidence regarding the effect of resistance training frequency on body composition and accretion of lean mass is limited and inconclusive (28,33). Although resistance exercise frequency exerts a strong influence on training outcomes, factors such as volume load (number of repetitions × load) are also influential and interrelated (18,30). It is therefore of importance to control for variables such as volume when evaluating the effect of frequency. This has previously been done by modifying the number of exercises and sets completed on individual days so that different groups complete the same total number of sets per week (4,6,19).

When the total number of sets per week is equated, previous research has demonstrated that in young women 3 d-wk⁻¹ of 1-set training results in superior gains in strength and lean mass compared to 1 d-wk⁻¹ of 3-set training (19). However, in combined groups of men and women, 2 d-wk⁻¹ of 3-set training provides similar results to 3 d-wk⁻¹ of 2-set training when the total number of sets per week remains equal (6). Finally, when 2 d-wk⁻¹ of total-body training is compared to 4 days of split training, no effect of frequency is observed in young women as long as the total number of exercises and sets performed each week is equated (4). To date, the influence of 3 d-wk⁻¹ of total-body training has not been compared to 4 d-wk⁻¹ of split training with equated sets. Furthermore, although middle-aged women are at greater risk for loss of muscle than young women, they have not yet been studied separately from men or younger women. Given their greater vulnerability, it would be desirable to evaluate their response to different training frequencies and their ability to adapt to a split-training protocol to identify the most effective exercise prescription for maintenance of lean mass and strength.

The purpose of this study was to evaluate the short-term effects of 3 vs. 4 d-wk⁻¹ of resistance training with equated sets on body composition and strength in untrained, middle-aged women. Our hypothesis was that greater training frequency would result in superior gains in lean mass and strength because of the greater number of discrete bouts of muscle stimulus throughout the week and longer periods of recovery for each muscle group. A secondary purpose was to evaluate the association between training characteristics such as volume load and subsequent changes in body composition and strength so as to identify those factors with the greatest influence on adaptation.

**Methods**

**Experimental Approach to the Problem**

This study was undertaken to evaluate the effect of different resistance training frequencies with equated training sets on body composition and strength in untrained, middle-aged women. A nonrandomized design was adopted to enhance adherence and allow for the natural inclinations of women who choose to exercise. To replicate “real-world” conditions and promote adherence (11), subjects self-selected training groups of either 3 nonconsecutive or 4 consecutive d-wk⁻¹. Both training protocols included an equal number of sets per week. An 8-week training period was chosen for efficiency, based on prior research by Candow and Burke (6) demonstrating that increases in lean mass can be observed in as little as 6 weeks in untrained adults. To control for dietary influences on lean mass, data were excluded for any subject who exhibited a loss of 2.0 kg or more during the 8-week study period. To control for potential influences of outside exercise or physical activity on body composition, subjects were untrained before enrollment and were prohibited from engaging in any other form of vigorous physical activity during the course of the study. Changes from baseline to week 8 in absolute and relative lean and fat mass and upper and lower body strength were compared between 3- and 4-day training groups. Furthermore, to evaluate the influence of volume on changes in body composition and strength, weekly training volume load (calculated as the total number of exercises × the number of sets × the number of repetitions × load [kg] per week) was assessed for each subject.

**Subjects**

Twenty-three untrained women, aged 40–55 years, were recruited from the community for an 8-week resistance training program. For purposes of the study, “untrained” was defined as having no formal resistance training experience or having not participated in resistance exercise for at least 6 months. After completion of informed consent, subjects self-selected 1 of 2 groups: (a) resistance training 3 d-wk⁻¹ (RT3) or (b) resistance training 4 d-wk⁻¹ (RT4). Exclusion criteria included self-reported smoking, diagnosis by a physician of cardiovascular disease or diabetes, any orthopedic condition that would prevent them from safely engaging in resistance exercise, or regular participation in any type of vigorous physical activity. The study was approved by the Institutional Review Boards of Valdosta State University and Arizona State University.

**Measurements**

To ensure consistency in measurement, all testing was conducted by the same researcher. Anthropometric assessments including height, weight, waist circumference, and body composition were recorded before and after the study period. Poststudy measurements were obtained 24–36 hours after the last training bout. All measurements were conducted
in the morning between 6:00 AM and 10:00 AM with subjects well hydrated and having consumed no food for 8–12 hours. “Height” was measured in centimeters using a standard wall-mounted stadiometer. Subjects were measured without shoes, with backs aligned against a wall. “Weight” was measured in kilograms using a calibrated computerized scale (Life Measurement Instruments, Concord, CA, USA) during assessment of body composition. “Waist circumference” was measured at the level of the umbilicus in centimeters with a Gulick tape to ensure constant tension and using standardized procedures (5). “Air displacement plethysmography” (Bod Pod®, Life Measurement Instruments) was used to determine body composition, including lean and fat mass. Subjects wore minimal clothing (bathing suit or exercise bra and shorts) and were asked to void before the procedure. Lung volumes were predicted using the manufacturer’s equation.

Strength Testing
To design a training protocol of appropriate intensity, all subjects completed 3 sessions of maximal strength testing scheduled at least 24 hours apart during the 2-week period before commencement of resistance training. The maximum weight they could lift one time with good form (1 repetition maximum [1RM]) was determined for chest press, shoulder press, latissimus pulldown, seated row (RT4 only), biceps curl, triceps pushdown, leg press, leg extension, and leg curl using the procedure described by Kraemer and Fry (16). The greatest weight lifted for each exercise during the 3 sessions was identified as the 1RM for purposes of training. All strength testing was conducted using the same Cybex® (Medway, MA, USA) machines used for the resistance training program and served to familiarize subjects with the exercises before beginning the 8-week resistance training program. Calculated intraclass correlations for the chest and leg press were $r = 0.97$ (95% confidence interval [CI]: 0.94–0.99) and $r = 0.98$ (95% CI: 0.96–0.99), respectively ($p < 0.0001$).

Resistance Training
“Group RT3” completed 3 bouts of resistance exercise weekly (a total of 24 sessions). To provide at least 24 hours of rest between each exercise session, training was scheduled on nonconsecutive days throughout the week. Each session consisted of 3 sets of 8–12 repetitions of 8 exercises (chest press, leg press, latissimus pulldown, leg extension, shoulder press, leg curl, biceps curl, triceps pushdown) designed to stimulate all of the major muscle groups of the body. Exercises were counterbalanced to avoid excessive fatigue of small muscle groups and, for efficiency, paired into supersets (chest press–leg press, latissimus pulldown–leg extension, shoulder press–leg curl, biceps curl–triceps pushdown). Both training protocols included a total of 72 sets per week.

“Group RT4” completed 4 bouts of resistance exercise weekly (a total of 32 sessions) on consecutive days. Each session consisted of either 3 sets of 8–12 repetitions of 6 exercises (upper body training) or 6 sets of 8–12 repetitions of 3 exercises (lower body training). To provide adequate rest (at least 48 hours) for individual muscle groups, training sessions were alternated between upper body (chest press, latissimus pulldown, shoulder press, seated row, biceps curl, triceps pushdown) and lower body (leg press, leg extension, leg curl) exercises. Exercises were paired into supersets (chest press–latissimus pulldown, shoulder press–seated row, biceps curl–triceps pushdown, leg extension–leg curl) for efficiency with the exception of the leg press that was trained alone (Figure 1).

Research staff directly supervised and maintained logs of all training sessions. Initially, intensity was set at 10 repetitions at 50% 1RM for the first set of each exercise and 8–12 repetitions at 80% 1RM for the remaining sets of each exercise. Load was increased 5–10% when participants were able to consistently complete 10–12 repetitions with good form for all sets of each exercise. Weekly training volume load was calculated as follows: the total number of exercises × the total number of sets × the total number of repetitions × the load (kg) per week.

<table>
<thead>
<tr>
<th>RT3 – Non-Consecutive Days</th>
<th>Day 1 – Total Body</th>
<th>Day 2 – Total Body</th>
<th>Day 3 – Total Body</th>
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</thead>
<tbody>
<tr>
<td>3 sets of 8-12 repetitions of:</td>
<td>3 sets of 8-12 repetitions of:</td>
<td>3 sets of 8-12 repetitions of:</td>
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<tr>
<td>Lat Pulldown – Leg Extension</td>
<td>Lat Pulldown – Leg Extension</td>
<td>Lat Pulldown – Leg Extension</td>
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<tr>
<td>Shoulder Press – Leg Curl</td>
<td>Shoulder Press – Leg Curl</td>
<td>Shoulder Press – Leg Curl</td>
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<td>3 sets of 8-12 repetitions of:</td>
<td>6 sets of 8-12 repetitions:</td>
<td>3 sets of 8-12 repetitions of:</td>
<td>6 sets of 8-12 repetitions:</td>
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<tr>
<td>Shoulder Press – Seated Row</td>
<td>Leg Extension – Leg Curl</td>
<td>Shoulder Press – Seated Row</td>
<td>Leg Extension – Leg Curl</td>
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</tr>
<tr>
<td>Biceps Curl – Triceps Pushdown</td>
<td></td>
<td>Biceps Curl – Triceps Pushdown</td>
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</table>

Figure 1. Resistance training model.
Weekly training time was calculated as the sum of the training time (minutes) for all individual sessions each week.

**Diet**

To control for potential dietary influences, subjects were instructed not to change their diet or restrict calories during the course of the study to promote gains in lean mass (muscle). Because deliberate caloric restriction (dieting) would inhibit muscle growth and therefore impact internal validity, an a priori decision was made before data analysis to exclude data from subjects exhibiting a weight loss of 2.0 kg or more during the study. In addition, subjects were instructed not to exercise on an empty stomach. If they had not eaten a regular meal within 2 hours, they were asked to eat a light snack of approximately 150 cal 30–60 minutes before the training sessions.

**Physical Activity**

To control for potential confounding effects, all subjects were instructed not to change their physical activity level during the study. Particularly, they were not to participate in any type of vigorous physical activity or sports.

### Table 1. Subject characteristics at baseline and after 8 weeks of resistance training.*†

<table>
<thead>
<tr>
<th></th>
<th>RT3 (n = 11)</th>
<th></th>
<th>RT4 (n = 10)</th>
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<th>Combined groups (N = 21)</th>
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<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Post-RT</td>
<td>Baseline</td>
<td>Post-RT</td>
<td>Baseline</td>
</tr>
<tr>
<td><strong>Age (y)</strong></td>
<td>49.5 ± 1.4</td>
<td>45.5 ± 1.8</td>
<td>45.5 ± 1.8</td>
<td>47.6 ± 1.2</td>
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<tr>
<td><strong>Weight (kg)</strong></td>
<td>76.8 ± 5.0</td>
<td>78.2 ± 5.1</td>
<td>77.5 ± 4.8</td>
<td>78.9 ± 4.9</td>
<td>77.1 ± 3.4</td>
</tr>
<tr>
<td><strong>BMI (kg·m⁻²)</strong></td>
<td>29.1 ± 1.7</td>
<td>29.6 ± 1.8</td>
<td>28.7 ± 1.5</td>
<td>28.9 ± 1.5</td>
<td>29.0 ± 1.1</td>
</tr>
<tr>
<td><strong>WC (cm)</strong></td>
<td>89.4 ± 3.9</td>
<td>89.9 ± 3.7</td>
<td>92.2 ± 4.1</td>
<td>91.4 ± 3.9</td>
<td>90.8 ± 2.8</td>
</tr>
<tr>
<td><strong>HC (cm)</strong></td>
<td>109.4 ± 3.4</td>
<td>109.9 ± 3.3</td>
<td>107.2 ± 3.3</td>
<td>106.7 ± 3.3</td>
<td>108.3 ± 2.3</td>
</tr>
<tr>
<td><strong>Lean mass (kg)</strong></td>
<td>42.0 ± 1.9</td>
<td>43.3 ± 2.1</td>
<td>46.3 ± 2.1</td>
<td>47.0 ± 2.2</td>
<td>43.9 ± 1.5</td>
</tr>
<tr>
<td><strong>Lean mass (%)</strong></td>
<td>55.5 ± 2.4</td>
<td>56.1 ± 2.3</td>
<td>59.1 ± 2.5</td>
<td>59.3 ± 2.4</td>
<td>57.2 ± 1.7</td>
</tr>
<tr>
<td><strong>Fat mass (kg)</strong></td>
<td>34.9 ± 3.6</td>
<td>35.1 ± 3.5</td>
<td>32.6 ± 3.8</td>
<td>32.7 ± 3.7</td>
<td>33.9 ± 2.5</td>
</tr>
<tr>
<td><strong>Fat mass (%)</strong></td>
<td>44.5 ± 2.4</td>
<td>43.9 ± 2.3</td>
<td>40.9 ± 2.5</td>
<td>40.7 ± 2.4</td>
<td>42.8 ± 1.7</td>
</tr>
</tbody>
</table>

*RT3 = resistance training 3 d·wk⁻¹; RT4 = resistance training 4 d·wk⁻¹; BMI = body mass index; WC = waist circumference; HC = hip circumference.
†Data presented as mean ± SE.
‡Significantly different from baseline (p = 0.005, η² = 0.343, power = 0.848).
§Significantly different from baseline (p = 0.006, η² = 0.326, power = 0.819).
|                      |               |                      |               |                      |                          |

### Table 2. Comparison of 3- and 4-d·wk⁻¹ training protocols.*†

<table>
<thead>
<tr>
<th></th>
<th>RT3</th>
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<th>RT4</th>
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<tbody>
<tr>
<td></td>
<td>Week 1</td>
<td>Week 8</td>
<td>Week 1</td>
<td>Week 8</td>
</tr>
<tr>
<td><strong>Weekly training time (min·wk⁻¹)</strong></td>
<td>82.4 ± 3.2</td>
<td>78.9 ± 3.2</td>
<td>87.8 ± 3.4</td>
<td>93.9 ± 3.3</td>
</tr>
<tr>
<td><strong>Weekly training volume load (kg·wk⁻¹)</strong></td>
<td>16,671.7 ± 1,371.0</td>
<td>23,745.7 ± 1,368.6‡</td>
<td>22,432.1 ± 1,437.9</td>
<td>28,586.6 ± 1,435.4‡</td>
</tr>
<tr>
<td><strong>Chest press volume load (kg·wk⁻¹)</strong></td>
<td>1,689.9 ± 107.3</td>
<td>2,589.1 ± 114.0§</td>
<td>1,395.5 ± 112.5</td>
<td>1,804.7 ± 119.5§</td>
</tr>
<tr>
<td><strong>Leg press volume load (kg·wk⁻¹)</strong></td>
<td>6,906.6 ± 785.0</td>
<td>9,285.5 ± 807.7§</td>
<td>11,328.9 ± 823.3</td>
<td>14,033.2 ± 847.1‡</td>
</tr>
</tbody>
</table>

*RT3 = resistance training 3 d·wk⁻¹; RT4 = resistance training 4 d·wk⁻¹.
†Data presented as mean ± SE.
‡Significantly different from baseline (p < 0.001).
§Significantly different from baseline and RT4 (p < 0.01).
Table 3. Changes in maximal (1RM) upper and lower body strength.*†

<table>
<thead>
<tr>
<th></th>
<th>RT3</th>
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<th>RT4</th>
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<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Post-RT</td>
<td>Baseline</td>
<td>Post-RT</td>
</tr>
<tr>
<td>Chest press (kg)</td>
<td>37.4 ± 2.5</td>
<td>50.0 ± 5.5‡</td>
<td>44.5 ± 3.0</td>
<td>59.7 ± 4.1‡</td>
</tr>
<tr>
<td>Leg press (kg)</td>
<td>105.1 ± 9.8</td>
<td>135.7 ± 16.7§</td>
<td>119.7 ± 11.5</td>
<td>178.6 ± 19.6§</td>
</tr>
</tbody>
</table>

*1RM = maximum weight lifted at 1 time; RT3 = resistance training 3 d wk⁻¹; RT4 = resistance training 4 d wk⁻¹.
†Data presented as mean ± SE.
‡Significantly different from baseline (p < 0.001, η² = 0.854, power = 1.0).
§Significantly different from baseline (p < 0.001, η² = 0.548, power = 0.99).

Statistical Analyses
Data were analyzed using SPSS version 14.0, with mean and SE reported for all measurements. Significance was set at p ≤ 0.05. Descriptive statistics were used to assess subject characteristics. Pre–post changes in anthropometrics, strength, weekly training volume load, and weekly training time were evaluated using repeated measures analysis of variance with a Bonferroni adjustment. Effect size was expressed as eta-squared (η²). An eta-squared value of <0.2 was determined to be a small effect, a value of 0.2–0.8 was considered a medium effect, and a value of >0.8 was considered a large effect (12). Pearson correlations were used to identify relationships between weekly training volume load, training time, absolute and relative measures of lean and fat mass, and upper and lower body strength. A linear regression analysis was conducted based on the results of the coefficient analysis using gains in lean mass and strength as dependent variables and weekly training volume load at weeks 1 and 8 as independent variables.

Results
All 23 subjects completed the 8-week resistance training program. However, 2 participants (1 in each group) were excluded from the analysis because of a loss of >2.0 kg body weight during the course of the study. Both training protocols were well tolerated with no reported injuries, and subjects consistently denied muscle soreness when queried before each training session. Adherence to scheduled training sessions was 98% in both groups.

No significant differences (p > 0.05) between RT3 (n = 11) and RT4 (n = 10) were observed for age, body weight, body mass index (BMI), circumferences, or body composition either at baseline or after 8 weeks of resistance training (Table 1). Overall, at baseline, subjects were middle aged (47.6 ± 12 years) and overweight (BMI 29.0 ± 1.1 kg·m⁻²), with centralized body fat (waist circumference 90.8 ± 2.8 cm). After 8 weeks of progressive resistance training, there was a significant increase in absolute lean mass (1.1 ± 0.3 kg; p = 0.001, η² = 0.45, power = 0.962) that was accompanied by increases in body weight (1.02 ± 0.3 kg; p = 0.005, η² = 0.343, power = 0.848) and BMI (0.3 ± 0.1 kg·m⁻²; p = 0.006, η² = 0.326, power = 0.819).

There was no significant difference (p > 0.05) between groups in weekly training volume load at weeks 1 and 8. Both training groups completed a total of 72 sets per week requiring similar weekly training times throughout the course of the study (Table 2). Although no change in weekly training time was observed, weekly training volume load increased significantly in both groups, with RT3 increasing 42% and RT4 increasing 27% (p < 0.001). Increases in upper and lower body strength (p < 0.001) were also observed. Chest press 1RM increased 34% in both groups, whereas leg press 1RM increased 29% in group RT3 and 49% in group RT4 (Table 3). Weekly training volume load specifically for chest and leg press exercises reflected increases in strength. Chest press volume load increased 53% for RT3 and 29% for RT4 (p < 0.001), whereas leg press volume load increased 34% for RT3 and 24% for RT4 (p < 0.001) (Table 2).

Weekly training volume load at both week 1 and week 8 had a significant association with increases in lean mass (r = 0.60, p = 0.03 and r = 0.56, p = 0.05, respectively) and lower body strength (r = 0.56, p = 0.01 and r = 0.60, p = 0.006, respectively) and was found to be a significant predictor at both time points for gains in lean mass (ρ = 0.03, ρ = 0.5, respectively) and lower body strength (ρ = 0.01, ρ = 0.006, respectively). Weekly training time was not significantly related to increases in lean mass or strength at either time point.

Discussion
Limited research findings are currently available regarding the effect of resistance training frequency on body composition and gains in lean mass in untrained populations (4,6,29). To our knowledge, this was the first study to evaluate the effect of resistance training frequency on body composition in a single group of middle-aged women. Our principal finding was that 8 weeks of progressive resistance training resulted in significant increases in lean mass, and this was unaffected by training frequency when weekly training sets
were equated. Our secondary finding was that total weekly training volume load was a significant predictor of gains in lean mass and strength at week 1 and remained so at week 8. In other words, women who were able to lift more initially and throughout the study achieved greater benefits.

Although meta-analysis has identified a dose–response relationship between resistance training frequency and strength (24), this effect may be dependent on training volume rather than actual frequency, as would be suggested by the consistent relationship we found between weekly training volume and gains in lean mass and strength. It is not possible, given individual strength characteristics, to completely control for training volume. For example, at a given intensity (% 1RM), interindividual differences will result in different repetitions per set. In this study, to isolate frequency, the total number of sets per week was the same for each group. This design was successful, and as a result, weekly training volume load was found to be similar for each protocol, despite the number of days trained.

Our findings are in agreement with those of Candow and Burke (6), who previously compared the effect of resistance training either 2 or 3 d·wk$^{-1}$ on strength and muscle mass in untrained adults. Their training protocol consisted of 2–3 sets of 10 repetitions at 60–90% 1RM for 9 exercises and was controlled so that training volume was equal between groups. After 6 weeks, equivalent increases in lean mass and strength were observed in both groups despite training frequency. However, because age ranged from 27 to 58 years, and both men and women were combined within groups, it is difficult to exclude the potential effects of age and gender on their findings. Our study, which was specifically restricted to middle-aged women, clearly demonstrates the influence of training volume load on short-term gains in lean mass and strength regardless of training frequency.

In contrast, Taaffe et al. (29) evaluated the effects of a resistance training program in older adults, who completed 3 sets of 10 repetitions at 80% 1RM for 8 exercises either once, twice, or thrice a week. After 24 weeks, muscle and strength gains occurred similarly in all 3 groups, despite differences in training volume. However, subjects ranged in age from 65 to 79 years. It is possible that given their advanced age and probable level of deconditioning, a threshold training stimulus of sufficient volume provided only 1 d·wk$^{-1}$ would be sufficient to increase strength and lean mass over a 6-month period, with no additive effects from greater frequency or volume.

This threshold concept is supported by the findings of Galvao et al. (10), who evaluated the effect of 1 vs. 3 sets of resistance training on strength in elderly men and women aged 65–78 years. Subjects completed either 1 or 3 sets of 7 exercises twice a week for 20 weeks. Gains in strength were observed as a result of single-set training, but they were significantly less than multiple-set training achieved. This is consistent with the proposed influence of training volume, yet inconsistent with the findings of Taaffe et al. (29).

However, the 1-set group reported by Galvao et al. (10) achieved a lower weekly training volume than the 1 d·wk$^{-1}$ training group reported by Taaffe et al. (29) and so may not have achieved the threshold-training stimulus needed for maximum effectiveness. Based on these findings, it appears that for initial training adaptations among elderly individuals, when a threshold-training stimulus is met, further increases in volume load or frequency may not result in greater gains.

Our data indicate that gains in lean mass and strength are not influenced by training frequency when the number of training sets per week is equated. This is supported by the findings of Calder et al. (4), who used a split vs. whole-body training protocol similar to ours to evaluate the effect of resistance training either 2 or 4 d·wk$^{-1}$ on strength and body composition in college-aged women. Although training frequency differed, weekly training volume was equalized between groups by splitting the whole-body exercises trained 2 d·wk$^{-1}$ into upper and lower body exercises that were each trained twice separately for a total of 4 d·wk$^{-1}$. Weekly training volume was similar between groups that each completed 80 sets per week (5 sets of 6–12 repetitions at 75–90% 1RM for 8 exercises), broken up into 2 or 4 training sessions. After 20 weeks, significant increases in both strength and lean mass were observed that were not affected by training frequency.

Overall, evidence supports our findings that given a sufficient training stimulus, weekly training volume load may have a greater influence on gains in lean mass and strength than frequency. Untrained, middle-aged and overweight women safely tolerated a training volume that stimulated significant gains in lean mass in only 8 weeks. However, given that muscle hypertrophy is unlikely during the first 4 weeks of a resistance training program (20,27), the gains in lean mass we observed were most likely to have occurred during the second half of the 8-week period. By comparison, Nichols et al. (22) reported gains in lean mass of only 1.5 kg in older women after 6 months of heavy resistance training 3 times per week. Although these gains may have been somewhat limited by age (67.1 ± 1.5 years), the comparable increase of 1.2 kg observed in our study speaks of the level of stimulus it provided in a much shorter period of time. It is possible that over a longer period of time, not only would greater gains have been exhibited but also an influence of training frequency may have been observed.

Potential limitations to this study include the nonrandomized design. However, unless women are able to adhere to an exercise protocol, they will not achieve its full benefits. It was therefore felt to be advantageous and reflective of real-world conditions to allow women to self-select their training frequency. Self-selection has previously been found to promote exercise adherence without impairing the effectiveness of the exercise modality (11). Use of this design is supported by the meta-analysis conducted by Conca et al. (7) in which well-designed, nonrandomized observational studies were found to provide results consistent with those of randomized controlled trials and the findings of Witt et al. (34) that treatment outcomes for nonrandomized subjects
were comparable to those of randomized subjects. We believe that the success of the nonrandomized design is reflected by our 98% adherence rate. By comparison, Sigal et al. (25) reported adherence of only 80–85% for middle-aged women and men randomized to 3 d wk⁻¹ of either aerobic or resistance training, whereas an 8-week supervised resistance training program for overweight diabetic women and men resulted in only 87% adherence (8).

The principal finding of this study was that in middle-aged women, an 8-week progressive resistance training program resulted in significant increases in lean mass that were unaffected by training frequency when weekly training sets were equated. Furthermore, our secondary finding was that weekly training volume load exerted the strongest influence on training adaptations. These results support the benefit of progression in volume load during the initial phases of a resistance training program to promote gains in strength and lean mass.

**Practical Applications**

Current physical activity guidelines for health recommend at least 2 d wk⁻¹ of resistance training (15). However, these are “minimal” recommendations, and increased frequency can provide additional benefits, including the ability to increase weekly training volume load and as a result gains in lean mass and strength. Consecutive-day split training is a viable option for increasing weekly training volume load that also promotes convenience by increasing flexibility in scheduling training sessions. Although often considered too difficult for nonathletes, we have shown that split training is well tolerated, even by novices. For convenience and to promote adherence, women beginning a resistance training program should be taught both training protocols so that they may schedule training sessions to fit their normal, weekly routine as closely as possible. Further, for prescriptive purposes, efforts should be made to prioritize increases in weekly training volume load as a predictor for muscular adaptation.

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**References**


