Effects of Different Resistance Training Frequencies on the Muscle Strength and Functional Performance of Active Women Older Than 60 Years

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Abstract

Farinatti, PTV, Geraldes, AAR, Bottaro, MF, Lima, MVIC, Albuquerque, RB, and Fleck, SJ. Effects of different resistance training frequencies on the muscle strength and functional performance of active women older than 60 years. J Strength Cond Res 27(8): 2225–2234, 2013—Training frequency is an important resistance training variable, but its relative contribution to strength and functional performance (FP) gains in senior populations is not yet well defined. The present study investigated the effect of different resistance training frequencies on the strength and FP in active women aged 60 years and older. A total of 48 women (60–78 years) underwent a 16-week training program for 1 set of 10 repetition maximums (10RM) of each exercise, being assigned in groups that performed training frequencies of 1, 2, or 3 days per week (EG1, EG2, and EG3) and a control group. Strength and FP tests were applied before and after the training protocol. All EGs, but not the control group, exhibited 10RM increases (bench press, seated dumbbell curl, knee extension, standing calf raise, p < 0.01). The 10RM increase for seated dumbbell curl and knee extension was always greater in the higher frequencies (p < 0.05). Timed up and go test improved equally in all EGs (p < 0.01). Chair sit-and-stand improvements in EG3 (−15.7%) and EG2 (−9.8%) were greater than in EG1 (−4.6%) (p < 0.01). Gait-speed improvement in EG3 (−11.6%) was greater than in EG2 (−5.1%) and EG1 (−3.9%) (p < 0.01). In conclusion, a higher weekly training frequency increased FP and strength to a greater extent than lower frequencies in active senior women.

Key Words: aging, exercise, physical training, fitness, health

Introduction

Functional fitness can be defined as the physiological capacity to safely perform daily physical activities without extreme fatigue (39). The aging process results in significant decline in both muscle mass and strength (18), which is related to overall body frailty, increased risk of falls, and decreased physical and functional fitness (2,7,9). Because of the close relationship between functional capacity and strength, it is important to maintain or increase strength levels while aging (18). This is especially true for women, whose muscle and strength losses can reach the threshold needed to maintain functional independence at an earlier age than in men (7).

Strength or resistance training seems to be effective to slow the effects of sarcopenia (2,15,34). However, many training variables, such as resistance, number of repetitions and sets, recovery intervals, exercises performed, speed of movement, exercise order, duration of training sessions, and training frequency can affect training outcomes. Despite the existing recommendations for young (1,39) and aged individuals (2,34) concerning these variables, the ideal combination of frequency, volume, and intensity of training to produce the greatest increases in strength or functional ability is yet to be defined (15,17).

Training frequency is one of the most important aspects of training volume and adherence to an exercise program (17,19,38). Although most studies with previously sedentary senior subjects used a resistance training frequency of 3 times per week (10,11,32,34), some studies (12,15,38) suggested that lower frequencies would be sufficient to promote strength...
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gets in sedentary older subjects. For instance, it has been demonstrated that resistance training performed 2 times per week results in significant increases in maximal strength, muscle cross-sectional area, and functional performance in senior women with no previous resistance training experience (13,14). However, to date, we are aware of only 2 studies that have specifically investigated the influence of weekly frequency on strength gains in older subjects (8,38). One study reported no significant differences among groups that trained 1-, 2-, or 3-times per week (38), whereas the other showed that 1 set of exercises performed once weekly improved strength and training twice a week (8). Although there is a lack of evidence supporting that resistance training performed 3 days per week produces better results, compared with programs performed once or twice a week, a systematic review concluded that most studies investigating the response of senior subjects to strength training used a frequency of 3 times per week (33).

Although resistance training frequency is a major component of training volume (1), there is little information regarding the impact of training frequency on functional ability, especially, in active senior subjects (25). As young individuals become more highly trained, increases in resistance training volume may be necessary to bring about further increase in strength (1). So an increase in resistance training frequency may also be important in physically active compared with older sedentary subjects, to improve strength and functional ability. However, the results of a recent meta-analysis were unclear with regard to the role of training frequency in producing strength and functional gains in older subjects of different training levels (36).

Therefore, the purpose of the present study was to compare the effects of 16 weeks of low volume (1 set of each exercise) resistance training with either 1, 2, or 3 sessions per week on strength and functional performance of physically active senior women. It was hypothesized that greater resistance training frequency would result in increased strength and functional ability gains.

METHODS
Experimental Approach to the Problem
The present study tested the hypothesis that different resistance training frequencies would influence the gains in strength and functional performance in community-dwelling physically active individuals aged 60 years and older. After meeting the exclusion and inclusion criteria, subjects were randomly assigned to experimental groups using different training frequencies and a control (CG) group. Subjects included in the experimental groups participated in a 16-week resistance training program with frequencies of 1 time per week (EG1, 16 sessions in total), 2 times per week (EG2, 32 sessions in total), and 3 times per week (EG3, 48 sessions in total). The CG did not engage in strength training but performed light stretching exercises once a week.

All participants were instructed not to engage in any other additional physical activity program while participating in the study, but continued their regular activity levels and dietary habits. Data were included in the analysis only if a subject completed all sessions for a specific experimental group.

The timeline of all phases of the study is outlined in Table 1. The study consisted of several major parts: adaptation period, pretesting, 16-week training program, and posttesting. Before pretesting, all groups performed a 2-week training adaptation period (1 set of 10 repetitions using a comfortable resistance) of the 4 exercises performed to test strength, to assure that subjects learned proper exercise technique before pretesting. No adaptation period was allowed for the functional tests because they were similar to usual daily tasks.

After the end of the adaptation period, the subjects performed 10 repetitions maximum (10RM) tests of 4 exercises (dumbbell bench press [DBP], seated dumbbell curl [SDC], knee extension [KE], and standing calf raise [SCR]) and a battery of functional tests (timed up and go [TUG], chair sit-and-stand [CSS], and gait speed tests [GS]). The 10RM testing began 48–72 hours after the last adaptation session. The 10RM tests were performed on 4 nonconsecutive days to avoid fatigue bias. The DBP and KE were tested on one day and the SDC and SCR on another day. The order of 10RM testing was determined in a counterbalanced design. To determine the test-retest reliability of the load corresponding to the 10RMs, 48–72 hours after the first tests (DBP and KE or SDC and SCR) the 10RMs were retested. Functional testing began 48–72 hours after the last 10RM testing session (days 11–17 in Table 1). Performance of only one functional test was determined on each day, also in a counterbalanced order. The functional tests were repeated 48–72 hours later to determine test-retest reliability.

The 16-week training program began 48–72 hours after the last day of pretesting. The choice of the load corresponding to 10RM was based on the last ACSM (2) stand position for improvements in strength and hypertrophy in older adults [60–80% of 1 RM for 8–12 repetitions]. The 10RM load falls within the 8–12 repetitions range proposed by the ACSM, being compatible with the strength increase.

Posttesting started 48–72 hours after the last training session. The ordering and procedures of posttesting assessments were exactly the same as used in the pretesting. However, no sessions were dedicated to test-retest reliability verification. All pre- and posttesting was performed in a single blind fashion; the evaluators did not know to what group subjects were assigned. Similarly, training sessions were monitored by personnel not directly involved with the study.

Subjects
The study was approved by institutional ethical committee and written informed consent was obtained from all

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participants in accordance with the Declaration of Helsinki. Subjects were recruited from 5 public and private institutions for senior citizens, which offered physical activity programs (dance, walking, etc), through meetings and advertising. The following inclusion criteria to allow study participation were used: (a) be 60 years or older, (b) be functionally independent for daily activities, (c) be physically active, and (d) not performing a resistance training program in the prior 6 months.

The National Health Foundation Prevalence Risk Study Questionnaire (26) was used to obtain general information (e.g., age and address) and data concerning physical activity level. The Multidimensional Functional Assessment Questionnaire (24) was used to assess functional ability level. The following exclusion criteria were applied: (a) illness or physical handicap that could limit functional performance or increase health risk during exercise (for instance, uncontrolled hypertension, blindness, or amputations), (b) inability to understand the explanations concerning the purposes, characteristics, and possible risks and benefits of the exercise program.

A total of 48 volunteers satisfied all inclusion and exclusion criteria. All subjects were classified as functionally independent, obtaining the maximum score on the Multidimensional Functional Assessment Questionnaire (24). Additionally, before the study, subjects claimed they performed about 50 minutes of activity on 4 days per week and were classified as physically very active (26). The optimal

<table>
<thead>
<tr>
<th>Phase</th>
<th>Week-day interval</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptation</td>
<td>Week 1 (days 1, 2, and 3 separated by 24–72 h)</td>
<td>Resistance exercise sessions (KE, DBP, SDC, and SCR—1 set of 10 comfortable reps)</td>
</tr>
<tr>
<td>Adaptation</td>
<td>Week 2 (days 4, 5, and 6 separated by 24–72 h)</td>
<td>Resistance exercise sessions (KE, DBP, SDC, and SCR—1 set of 10 comfortable reps)</td>
</tr>
<tr>
<td>Pretesting</td>
<td>Day 7 (48–72 h after day 6)</td>
<td>10RM assessment (DBP-KE or SDC-SCR, counterbalanced order)</td>
</tr>
<tr>
<td>Pretesting</td>
<td>Day 8 (48–72 h after day 7)</td>
<td>Test-retest reproducibility assessment for the exercises performed in day 7</td>
</tr>
<tr>
<td>Pretesting</td>
<td>Day 9 (48–72 h after day 8)</td>
<td>10RM assessment (DBP-KE or SDC-SCR, counterbalanced order)</td>
</tr>
<tr>
<td>Pretesting</td>
<td>Day 10 (48–72 h after day 9)</td>
<td>Test-retest reproducibility assessment for the exercises performed in day 9</td>
</tr>
<tr>
<td>Pretesting</td>
<td>Day 11 (48–72 h after day 10)</td>
<td>Functional assessment (TUG, CSS, or GS, counterbalanced order)</td>
</tr>
<tr>
<td>Pretesting</td>
<td>Day 12 (48–72 h after day 11)</td>
<td>Test-retest reproducibility assessment for the functional task performed in day 11</td>
</tr>
<tr>
<td>Pretesting</td>
<td>Day 13 (48–72 h after day 12)</td>
<td>Functional assessment (TUG, CSS, or GS, counterbalanced order)</td>
</tr>
<tr>
<td>Pretesting</td>
<td>Day 14 (48–72 h after day 13)</td>
<td>Test-retest reproducibility assessment for the functional task performed in day 13</td>
</tr>
<tr>
<td>Pretesting</td>
<td>Day 15 (48–72 h after day 14)</td>
<td>Functional assessment (TUG, CSS, or GS, counterbalanced order)</td>
</tr>
<tr>
<td>Pretesting</td>
<td>Day 16 (48–72 h after day 15)</td>
<td>Test-retest reproducibility assessment for the functional task performed in day 15</td>
</tr>
<tr>
<td>Training</td>
<td>Day 17 (48–72 h after day 16)</td>
<td>Beginning of the 16-week training protocol</td>
</tr>
<tr>
<td>Training</td>
<td>2-week training (1, 2, or 3 times per week)</td>
<td>4 resistance exercises (DBP, KE, SDC, and SCR—1 set of 10 reps at 70% 10RM)</td>
</tr>
<tr>
<td>Training</td>
<td>14-week training (1, 2, or 3 times per week)</td>
<td>10 resistance exercises (KE, DBP, SCR, LPD, SDC, SU, HA, TP, MP, and PF—1 set of 10 reps at 70% 10RM)</td>
</tr>
<tr>
<td>Posttesting</td>
<td>Day 18 (48–72 h after last training session)</td>
<td>10RM assessment (DBP-KE or SDC-SCR, counterbalanced order)</td>
</tr>
<tr>
<td>Posttesting</td>
<td>Day 19 (48–72 h after day 18)</td>
<td>10RM assessment (DBP-KE or SDC-SCR, counterbalanced order)</td>
</tr>
<tr>
<td>Posttesting</td>
<td>Day 20 (48–72 h after day 19)</td>
<td>Functional assessment (TUG, CSS, or GS, counterbalanced order)</td>
</tr>
<tr>
<td>Posttesting</td>
<td>Day 21 (48–72 h after day 20)</td>
<td>Functional assessment (TUG, CSS, or GS, counterbalanced order)</td>
</tr>
<tr>
<td>Posttesting</td>
<td>Day 22 (48–72 h after day 21)</td>
<td>Functional assessment (TUG, CSS, or GS, counterbalanced order)</td>
</tr>
</tbody>
</table>

KE = knee extension; DBP = bench press; SDC = seated dumbbell curl; SCR = standing calf raise; TUG = timed up and go test; CSS = chair sit and stand test; GS = gait speed test; LPD = lat pull-down; SU = sit-ups; HA = hip adduction; TP = triceps pushdown; MP = military press with dumbbells; PF = plantar flexion with dumbbells; reps = repetitions.
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nonbipartite matching technique was applied to match subjects before randomization in control and experimental groups. The only variable taken into account was the age—with that purpose, infinite distance between 2 subjects who should not be paired was fixed in 5 years. In brief, matched subjects before randomization differed by no more than 5 years.

**Functional Performance Assessment**

Functional performance was assessed by tests related to daily tasks. The following tests were performed: (a) Timed up and go test (TUG), the subject was asked to stand up from a standard chair and walk a distance of 3 m, turn around and walk back to the chair and sit down again (30). Timing began when the individual started to rise from the chair and ended when she was once again seated; (b) Chair sit-and-stand test (CSS) is considered a measure of leg strength in older adult women (23). The subjects were asked to stand up and sit down 5 consecutive times (43 cm chair), returning completely to a seated position between repetitions (4). Timing began when the individual started to rise from the chair and stopped at the end of the final repetition; (c) GS: this walking speed test is recommended for testing people aged 60 years and older (35). The subjects were asked to walk a distance of 4 m at the maximal speed. To minimize the effects of acceleration and deceleration, they began walking 1 m from the starting line and began to slow 1 m after the finish line (27). Therefore, the time to perform the test was measured within 2 m (second to third).

The tests were performed twice in each session and the best result was used for statistical analysis. All functional performance tests have been previously validated for the studied age group (23,27,30).

**Dynamic Strength Assessment (10RM)**

The tested exercises [DBP, KE, SDC, and SCR] were chosen because they engage important body segments needed for overall body strength, have a good relationship to tasks that involve functional mobility, and are frequently used as strength tests and included in training programs (18,27). The mass of all weight plates and bars used for measuring the 10RMs was determined with a precision scale. As for the KE and SCR, which were performed using resistance machines, the mass of the weight plates of each machine was determined after disassembling the machine's weight plate stack.

To minimize possible errors in the 10RM tests, the following strategies were adopted (29): (a) All subjects received standard instructions on the general routine of data assessment and the exercise technique of each exercise before testing, (b) the exercise technique of subjects during all testing sessions was monitored and corrected as needed, (c) subjects were given verbal encouragement during the tests.

Subjects performed a maximum of 5 10RM attempts of each exercise with 2- to 5-minute rest interval between successive attempts. The initial resistance used for baseline assessment corresponded to the highest resistance used during the 2-week familiarization period. For posttesting, the initial resistance used was the resistance used in the last week of training. No pause was allowed between the eccentric and concentric phases of a repetition or between repetitions. Subjects were not allowed to practice any exercises between the days of 10RM testing sessions.

**Resistance Training Program**

During the first 2 weeks of the 16-week training period, the experimental groups performed only the 4 tested exercises (DBP, KE, SDC, and SCR) [1 set of 10 repetitions at 70% of the resistance corresponding to the pretest 10RM]. In the third week, the remaining exercises were added and the complete exercise protocol including 10 exercises was performed in the following order: squat with dumbbells (DSQ), DBP, KE, SCR, lat pull-down (LPD), SDC, sit-ups (SU), hip adduction (HA), triceps pushdown (TP), and military press with dumbbells (MP). The DBP, KE, SDC, and SCR were from this point on performed with the pretest 10RM. For the other exercises, the resistance was defined individually based on the ability to perform 10 repetitions comfortably. The loads were increased by 5%, if the subjects were able to perform 12 repetitions of a given exercise in 2 consecutive sessions (3).

In the present study, we aimed to isolate, as much as we could, the effects related to training frequency. That is why we have chosen to work with a low-volume (single-set) program. Previous studies suggesting that training frequency would be a variable of minor importance, observed sedimentary older subjects. Our idea was that at least in programs designed for physically active seniors (although inexperienced in resistance training), the training frequency per se would be determinant of gains in strength and functional capacity. This would be easier to demonstrate by keeping the number of sets low, therefore, avoiding potential compensation effects of training volume within the sessions.

Moreover, we must notice that it is not easy to keep adherence of older subjects to exhaustive resistance training. This would be possibly the case of a program including 10 exercises performed with multiple sets and 3 times a week. We tried to prevent such risk by limiting the number of sets. Programs with higher number of exercises performed with low volume are more dynamic and ludic than programs involving few exercises and multiple sets. Additionally, to increase the number of exercises, while reducing the number of sets in each exercise, may induce coordinative adaptations in a greater number of movements. This is desirable in resistance training for the elderly.

All exercises were performed using standard exercise techniques. The KE, LPD, HA, TP, and SCR were performed using resistance training machines (Righetto™ Fitness Equipment, Sao Paulo, Brazil). The DBP, SDC, and MP were performed with dumbbells. To help assure safety and correct exercise technique, the movement velocity was fixed at 2 seconds for both concentric and eccentric phases of all
exercise. A 2- to 3-minute rest interval was allowed between the exercises. Training sessions were designed to last about 1 hour, with resistance training preceded by a 10-minute warm-up on cycle-ergometer at 50% of the maximal estimated heart rate (220-age). Subjects were allowed to drink whenever they desired throughout the training sessions.

Statistical Analyses

Data normality was checked by the Shapiro-Wilk test and the homogeneity of variances by the Levene’s test. Descriptive data were described as the mean ± the standard deviation. Typical error for the dependent variables was calculated using the standard deviation of the difference in scores (retest-test data) (16). Intraclass correlation coefficients (ICCs) for the test-retest trials were also calculated. Between- and within-group differences regarding pre- and posttraining assessments were tested by 2-way ANOVAs followed by Fisher post hoc test when indicated. Cohen’s d effect sizes for the significant differences between means were calculated. For all analyses the level of significance was set at \( p \leq 0.05 \).

### Table 2. Pretest subject characteristics.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>CG</th>
<th>EG1</th>
<th>EG2</th>
<th>EG3</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>10</td>
<td>10</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Age, yrs</td>
<td>68 ± 4</td>
<td>72 ± 5</td>
<td>66 ± 7</td>
<td>68 ± 4</td>
</tr>
<tr>
<td>Body mass, kg</td>
<td>58.3 ± 10.7</td>
<td>56.1 ± 15.0</td>
<td>63.5 ± 15.7</td>
<td>62.2 ± 10.1</td>
</tr>
<tr>
<td>Height, m</td>
<td>1.50 ± 0.01</td>
<td>1.49 ± 0.03</td>
<td>1.53 ± 0.05</td>
<td>1.54 ± 0.05</td>
</tr>
<tr>
<td>BMI, kg/m</td>
<td>25.9 ± 4.8</td>
<td>25.4 ± 6.9</td>
<td>26.4 ± 3.9</td>
<td>25.8 ± 2.5</td>
</tr>
<tr>
<td>PA freq, days/week</td>
<td>4 ± 1</td>
<td>4 ± 1</td>
<td>4 ± 2</td>
<td>4 ± 1</td>
</tr>
<tr>
<td>PA dur, min/day</td>
<td>55.0 ± 14.1</td>
<td>50.4 ± 11.0</td>
<td>53.2 ± 9.2</td>
<td>54.0 ± 12.9</td>
</tr>
<tr>
<td>PA vol, min/week</td>
<td>217.0 ± 20.0</td>
<td>219.6 ± 22.9</td>
<td>218.5 ± 18.0</td>
<td>217.5 ± 22.8</td>
</tr>
</tbody>
</table>

CG = control group; EG1 = group training one day/week; EG2 = group training two days/week; EG3 = group training 3 days per week; BMI = body mass index; PA freq = weekly frequency of habitual physical activity as reported in the National Health Foundation Prevalence Risk Study Questionnaire; PA dur = duration of each session of habitual physical activity as reported in the National Health Foundation Prevalence Risk Study Questionnaire; PA vol = physical activity volume (frequency × duration).

### Table 3. Pretest and posttest for the 10RM tests (mean ± SD) in control (CG, n = 10) and experimental groups (EG1, n = 10; EG2, n = 11; EG3, n = 10).

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre</th>
<th>Post</th>
<th>Δ%</th>
<th>Pre</th>
<th>Post</th>
<th>Δ%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bench press (kg)</td>
<td>Dumbbell curl (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CG</td>
<td>9.2 ± 1.6</td>
<td>9.6 ± 1.5</td>
<td>4.4 ± 0.6</td>
<td>8.8 ± 1.6</td>
<td>9.0 ± 0.7</td>
<td>2.3 ± 0.7</td>
</tr>
<tr>
<td>EG1</td>
<td>8.2 ± 1.8</td>
<td>13.0 ± 2.0†</td>
<td>56.5 ± 6.0†</td>
<td>7.8 ± 1.5</td>
<td>12.2 ± 2.3†</td>
<td>56.4 ± 6.1†&lt;sup&gt;2,3&lt;/sup&gt;</td>
</tr>
<tr>
<td>EG2</td>
<td>9.6 ± 2.2</td>
<td>14.4 ± 5.2†</td>
<td>50.0 ± 4.5†</td>
<td>8.4 ± 1.7</td>
<td>13.6 ± 2.6†</td>
<td>61.9 ± 5.6†&lt;sup&gt;a,c&lt;/sup&gt;</td>
</tr>
<tr>
<td>EG3</td>
<td>10.4 ± 0.9</td>
<td>15.6 ± 1.7†</td>
<td>52.0 ± 4.9†</td>
<td>9.2 ± 1.8</td>
<td>15.6 ± 0.9†</td>
<td>69.6 ± 5.4&lt;sup&gt;a,b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre</th>
<th>Post</th>
<th>Δ%</th>
<th>Pre</th>
<th>Post</th>
<th>Δ%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Knee extension (kg)</td>
<td>Stand calf raise (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CG</td>
<td>19.4 ± 2.3</td>
<td>19.8 ± 2.5</td>
<td>2.1 ± 0.3</td>
<td>11.4 ± 1.1</td>
<td>11.6 ± 0.9</td>
<td>1.8 ± 0.2</td>
</tr>
<tr>
<td>EG1</td>
<td>18.0 ± 3.7</td>
<td>25.6 ± 3.2&lt;sup&gt;a,b&lt;/sup&gt;</td>
<td>42.2 ± 5.0&lt;sup&gt;2,3&lt;/sup&gt;</td>
<td>12.0 ± 2.0</td>
<td>18.8 ± 1.9†</td>
<td>40.0 ± 3.9†</td>
</tr>
<tr>
<td>EG2</td>
<td>19.2 ± 4.6</td>
<td>29.6 ± 7.4&lt;sup&gt;†&lt;/sup&gt;</td>
<td>54.2 ± 6.4&lt;sup&gt;&lt;a,c&lt;/sup&gt;</td>
<td>12.2 ± 3.0</td>
<td>17.0 ± 3.7†</td>
<td>39.3 ± 4.5†</td>
</tr>
<tr>
<td>EG3</td>
<td>19.8 ± 4.9</td>
<td>32.0 ± 6.8&lt;sup&gt;†&lt;/sup&gt;</td>
<td>61.6 ± 4.9&lt;sup&gt;&lt;a,b&lt;/sup&gt;</td>
<td>11.8 ± 0.5</td>
<td>16.8 ± 1.5&lt;sup&gt;*&lt;/sup&gt;</td>
<td>42.4 ± 4.0†</td>
</tr>
</tbody>
</table>

Δ% = mean percent difference between pre and posttests.

<sup><a,c</sup>Superscript alphabets refer to statistical difference \( p < 0.05 \) compared to a given experimental group (e.g., “b” indicates a significant difference from EG2).

<sup>Statistical difference from pretest \( p < 0.01 \).

<sup>†Statistical difference from CG \( p < 0.01 \).

Results

Subjects’ Characteristics

Pretesting subject characteristics are depicted in Table 2. No significant differences between groups were shown for any of the determined characteristics (age, body mass, height, BMI, physical activity frequency, physical activity duration, and the standard deviation of the dependent variables was calculated using the standard deviation of the difference in scores (retest-test data) (16). Intraclass correlation coefficients (ICCs) for the test-retest trials were also calculated. Between- and within-group differences regarding pre- and posttraining assessments were tested by 2-way ANOVAs followed by Fisher post hoc test when indicated. Cohen’s d effect sizes for the significant differences between means were calculated. For all analyses the level of significance was set at \( p \leq 0.05 \).
physical activity volume – frequency × duration). The more prevalent types of physical activity in the whole sample were “walking” and “calisthenics” [stretching: 4.9%; walking: 61.0%; calisthenics: 26.8%; and hydrogymnastics: 2.4] with no significant difference between groups (p = 0.89).

**Study Compliance and Functional Independence**

There was no occurrence of training related injuries during the testing or training periods of the study. At the end of the 16-week training program 5 subjects from the experimental groups (1 from EG1, 2 from EG2, and 2 from EG3) had not attended 100% of the training and evaluation sessions (because of illness, work, or another undefined reason). Additionally, 2 subjects in the CG dropped out of the study. At the end of the study, the total number of subjects complying with all testing protocols and training programs was EG1 = 10, EG2 = 11, EG3 = 10, and CG = 10.

**Statistical Power and Test-Retest Reliability**

An achieved statistical power of 0.878 for an effect size of 0.3 was obtained by performing a post hoc power analysis (GPower™ version 3.0.10, Kiel, University of Kiel, Germany) based on the given sample size, p value, number of repeated measures and groups, which is an acceptable type II error. The critical F was 2.86 and the degrees of freedom were 3 and 27 for the numerator and denominator, respectively. The pretest protocol used to determine test-retest reliability of 10RM strength showed high ICC of 0.90 (p = 0.05), 0.93 (p = 0.03), 0.96 (p = 0.03), and 0.90 (p = 0.05), respectively, for DBP, SDC, KE, and SCR. The pretest protocol used to determine test-retest reliability of the functional tests also showed high ICC of TUG = 0.95 (p = 0.02), CSS = 0.85 (p = 0.02), and GS = 0.90 (p = 0.04). With regard to measurement error, the typical errors obtained for the dependent variables were DBP (1.61 kg), SDC (1.40 kg), KE (2.01 kg), SCR (1.60 kg), TUG (1.40 s), CSS (0.24 s), and GS (0.25 s).

**Muscle Strength**

Mean pretest and posttest values are presented in Table 3. No between-groups difference was detected (p = 0.68) for the 10RM at baseline. Significant main effects and interaction were found for the between (weekly frequency, p < 0.05) and within group comparisons (pre- vs posttraining, p < 0.001) in all exercises. At the end of the 16-week training, the EGs (EG1–DBP: p = 0.002, effect-size = 2.52, SDC: p = 0.004, effect-size = 2.27, KE: p = 0.006, effect-size = 2.20, SCR: p = 0.005, effect-size = 2.46; EG2–DBP: p = 0.002, effect-size = 1.22, SDC: p = 0.003, effect-size = 2.37, KE: p = 0.004, effect-size = 1.69, SCR: p = 0.017, effect-size = 1.43; EG3–DBP: p = 0.008, effect-size = 3.82, SDC: p = 0.002, effect-size = 3.66, KE: p = 0.003, effect-size = 2.06, SCR: p = 0.007, effect-size = 4.47) but not the CG (p = 0.67) showed significant strength increases in all exercises (≈40–70%). The post hoc tests showed that training frequency had significant influence on strength gains in some exercises, at least when comparing 3 times per week with
the lower frequencies. In KE and SDC, the 10RM showed significantly greater percent increases in EG3 compared with EG1 (KE: \( p = 0.004 \), effect-size = 1.20; SDC: \( p = 0.04 \), effect-size = 1.99) and EG2 (KE: \( p = 0.05 \), effect-size = 2.01; SDC: \( p = 0.03 \), effect-size = 3.08) and in EG2, compared with EG1 (KE: \( p = 0.05 \), effect-size = 1.69; SDC: \( p = 0.04 \), effect-size = 2.23). However, no differences between groups were found for the strength increase in DBP and SCR.

**Functional Performance**

Table 4 presents data for the functional tests. Pretesting no significant differences between groups were detected for the functional performance tests (\( p = 0.58 \)). Main effects and interactions showed that training frequency did significantly affect functional performance, especially when comparing 3 times per week with the other frequencies. The post hoc tests revealed that at the end of the 16-week training, all experimental groups improved functional performance. The comparison between groups showed that the training frequency significantly influenced the gains in CSS and GS tests but not in TUG performance. The CSS absolute performance was improved in EG2 (\( p = 0.007 \), effect-size = \(-1.55\)) and EG3 (\( p = 0.008 \), effect-size = \(-2.42\)) and the \( \Delta\% \) was significantly greater in these groups compared with EG1 (EG1 vs. EG2: \( p = 0.01 \), effect-size = \(-2.29\); EG1 vs. EG3: \( p = 0.02 \), effect-size = \(-3.01\)). The GS performance improved only in EG3 (\( p = 0.005 \), effect-size = \(-2.53\)) and the posttest time was significantly lower compared with EG1 (\( p = 0.002 \), effect-size = \(-3.00\)) and CG (\( p = 0.006 \), effect-size = \(-2.53\)). On the other hand, the \( \Delta\% \) in GS was significantly greater in EG3 compared with both EG1 (\( p = 0.03 \), effect-size = \(-3.01\)) and EG2 (\( p = 0.03 \), effect-size = \(-2.48\)).

**DISCUSSION**

The study compared the effect of 3 different training frequencies on strength and functional performance in physically active women aged 60 years and older. The main finding was that both strength and functional ability improved to a greater extent following training protocols with higher compared with lower frequency.

Increased frequency (and therefore training volume) provoked greater strength gains. This agrees with previous research on the effects of training volume manipulation (number of sets, repetitions, and exercises) on strength improvement (6,11,32,40). Our results are also in agreement with previous studies showing that training frequencies of less than 3 times per week produced significant increases in strength in sedentary seniors of both sexes (12,15). Additionally, the strength gains shown in the present study (39.3%–69.6% in 10RM) were higher or equivalent to those reported by previous studies using similar training volumes (11,32,38,40).

However, our findings disagree with those studies that demonstrated that increased training frequency would not result in increased strength (8,38). Taaffe et al. (38) trained 46 community-dwelling healthy men and women aged 65–79 years with 3 sets at 80% of 1 RM for 8 repetitions of 8 exercises targeting major muscle groups of the upper and lower body, either 1, 2, or 3 days per week. The programs performed once or twice weekly resulted in muscle strength gains similar to 3 days per week [1 RM mean percent change of 37.0 ± 15.2%, 41.9 ± 18.2%, and 39.7 ± 9.8%, respectively]. There are several differences between the study by Taaffe et al. (38) and ours. First, the training volume was lower in the present study (1 set vs. 3 sets). Second, the subjects’ training status before resistance training was different (present study physically active vs. sedentary). These differences preclude the comparison of the results obtained in the 2 studies but suggest that training volume or activity level before resistance training may influence the optimal training frequency in seniors. DiFrancisco-Donoghue et al. (8) showed that training once or twice per week produced similar strength gains in trained men and women aged 65–79 years performing 3 lower and 3 upper body exercises during 9 weeks. Training once weekly improved strength to the same extent as twice a week (\( = \)20 to 50%), even though the percentage gain was greater with training 2 times per week. The strength increase presently observed was higher (\( = 40 \) to 70%) than in the study by DiFrancisco-Donoghue et al. (8), which may be because training duration (9 vs. 16 weeks) and training volume (1-2 vs. 1-3 times per week).

Training volume and exercise specificity must be considered to allow comparisons between the present and previous studies. Although strength was tested in 4 exercises (DBP, KE, SDC, and SCR), the training program also involved complementary exercises that increased the total volume. A total of 5 exercises for the upper body (DBP, LPD, SDC, TP, and MP), 4 exercises for the lower body (DSQ, KE, SCR, and HA), and one exercise for the trunk (SU) were performed. There may have been an effect on strength because of the additional exercises involving muscle groups active in the tested exercises—it is feasible to think that the training volume for those muscle group increased, which is acknowledged to affect strength gains (1). The increase in strength observed for DBP (additional exercise TP), SDC (additional exercise LPD), KE (additional exercise DSQ), and SCR (no additional exercise) in the different training protocols ranged between 50% and 56%, 56% and 69%, 42% and 61%, and 39% and 42%, respectively.

On the other hand, it could be speculated that additional exercises would have little effect on strength gains exhibited by exercises that do not recruit accessory muscle groups. In practical terms, the effect of additional exercises on strength is difficult to ascertain. For example, strength in DBP was tested and an additional exercise for the elbow extensors (TP) was performed. Thus, the training volume for the elbow extensors was increased. For other muscles involved in DBP, such as anterior deltoid and chest, an additional exercise was not performed and so training volume for these
muscle groups was not affected. In our study, the percent increases in strength showed no clear increase pattern in strength with additional exercises recruiting accessory muscle groups to the tested exercises. Even when an additional exercise was added, the total training volume performed by a specific muscle group in each training session was still relatively low (1 set vs. 2 sets). The effect, if any, of an additional exercise for a particular muscle group in the present study would probably not change the major conclusion that increased training frequency does affect strength gains.

The results concerning functional performance revealed that CSS (EG3 ≡ EG2 > EG1) and GS tests (EG3 > EG 2 ≡ EG1) were affected by training frequency, whereas no significant influence was detected in TUG. Thus, not all functional tasks were influenced by training frequency. Some indication that training frequency affects functional performance has been shown (37) in community-dwelling adults aged 65–80 years. Training consisted of calisthenics in a group-based program performed 1 or 2 times per week. After 10 weeks of training, the group that trained once a week showed no effects on functional status indicators. However, subjects with initial low physical activity level showed improvement after the 2-times-per-week program, indicating that at least in subjects with initial poor fitness levels training frequency can be a determinant of increased functional ability.

An indication that training frequency affects functional performance was demonstrated by Nakamura et al. (25) using an experimental design very similar to our study. Sedentary senior women (aged 68 years) trained either 1, 2, or 3 days per week. Training lasted 12-weeks and consisted of both aerobic and resistance training (10 minutes warm-up, 20 minutes walking, 30 minutes recreational activities, 20 minutes resistance training, and 10 minutes cool-down). At the end of the training period, only the group that trained 3 days per week showed significant increases in body mass, dynamic balance [functional reach test], motor coordination (walking around 2 cones), and cardiorespiratory fitness [6-minute walking test]. These results suggested that training 3 days per week was necessary to improve functional performance. However, significant differences in muscle strength were not shown after training with different training frequencies.

This study demonstrated that a relatively high intensity and low-volume resistance training performed 3 days per week, resulted in greater strength gains in some exercises and functional tasks compared with training frequencies of 1 and 2 days per week. This could be interpreted in a way that strength gains directly result in functional performance gains. However, the training frequency of 2 days per week provoked significantly greater strength increases in some exercises compared with 1 day per week, but no significant difference in any functional tests was detected. Therefore, the relationship between strength and functionality may not be linear, that is, muscle strength improvement will not always change the performance in specific functional tasks (5).

An important issue concerning functional improvement is training specificity. Manini et al. (22) compared 10 weeks of either resistance, functional, or functional plus resistance training on strength and functional ability of senior subjects (mean age, 75.8 years). Those who performed functional training either 1 or 2 days per week reduced their timed performances in functional tasks, significantly more than those who performed only resistance training (resistance training 2.5%, functional plus resistance training 18.5%, and functional training 23%). On the other hand, strength gains were primarily found in groups that performed resistance training either 1 or 2 days per week (resistance training and functional plus resistance training). Therefore, the benefits of exercise among older adults seem to be related to tasks performed during training, regardless the number of training sessions performed per week.

In the present study, the specificity of resistance training may have affected the functional performance. As aforementioned, the functional tests were chosen because they have been validated and extensively used in the functional evaluation of senior subjects, have a relationship with functional independence, and are dependent on muscle strength and power (5,7,18,27). There are fewer upper body tests related to functional independence, and they are frequently more related to muscle endurance (for instance, biceps curl in 30 s) or complex motor control (moving objects, changing light bulbs, etc.), than to muscle strength (21,28,31). Hence, we have applied functional tasks that depended mainly on lower body strength, even though exercises for upper and lower body have been included in the training protocol.

It could be speculated from data in Table 2 that subjects in EG1 were older and lighter than those in the other training groups and that such difference could have affected the results. However, data dispersion for body mass was important in all groups, and it is difficult to state that a group was indeed heavier than the other. The groups were not statistically different for this variable. Significant differences were neither detected for age. The central point is that, at least within this single set program, the training frequency influenced gains in strength and functional performance (for some exercises and tasks) in a physically active sample of older subjects. Because the physical activity level was similar across groups, it is not probable that variations in body mass and age at baseline have affected the training results. The fact that the loads corresponding to 10RMs were very close between groups reinforces this opinion.

There are some limitations to the present study. There is a trend to generalize that training frequency is a secondary factor when training senior adults (see Ref. 2), albeit previous studies are controversial concerning the role of resistance training frequency in this population. The present results indicate that training frequency is an important issue in
active senior women. The effect of training frequency in inactive or sedentary senior women may be less of a factor in strength and functional performance gains because strength gains in sedentary subjects would occur with any increase in physical activity. Initial strength, fitness, and activity levels may in part explain the inconsistent results concerning the effect of training frequency, and other training variables (number of sets) when resistance training is performed by seniors. Finally, it has been previously demonstrated that young and older men and women respond to the same resistance training program with the same percent increase in maximal strength (20). It is therefore feasible that more sessions per week may result in greater improvements in both men and women, if they had similar activity backgrounds (active or sedentary). Additional research is warrant to investigate this issue.

In conclusion, gains in strength and functional performance of physically active senior women, after resistance training performed with relatively high intensity and low volume (only 1 set of each exercise), were influenced by the training frequency. Higher training frequencies elicited greater increases in the load corresponding to 10RM in specific exercises (knee extension and biceps curl), but not others (bench press and calf-raise), and improved the performance in some specific tasks (chair sit-and-stand and gait speed). Moreover, it seems that in active senior women strength gains do not directly result in functional ability improvement.

**Practical Applications**

From a practical perspective, the results of the present study indicate that training frequency may be an independent determinant of strength and functional increases due to resistance training in physically active senior women. Thus, if the goal is to increase strength and functional ability in active older persons, using a high intensity and low-volume training program, a frequency of 3 rather than 2 or 1 session per week should be applied.

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**References**

Resistance Training Frequency in Active Senior Women


