ORIGINAL ARTICLE

Comparison of once-weekly and twice-weekly strength training in older adults

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Background: Strength training has been shown to benefit the health and function of older adults.
Objective: To investigate whether one set of exercises performed once a week was as effective in increasing muscle strength as training twice a week.
Methods: 18 subjects (7 women and 11 men) aged 65–79 years were randomly assigned to two groups. Both groups performed one set of exercises to muscular fatigue; group 1 trained 1 day/week and group 2 trained 2 days/week on three lower and three upper body exercises for 9 weeks. The data were analysed using a mixed model 2×2 analysis of variance.
Results: A significant main effect of time ($p<0.001$), but not group, on one-repetition maximum scores was observed. No significant interaction was observed between time and group and therefore no difference in strength changes between training once a week versus twice a week after 9 weeks.
Conclusions: One set of exercises performed once weekly to muscle fatigue improved strength as well as twice a week in the older adult. Our results provide information that will assist in designing strength-training programmes that are more time and cost efficient in producing health and fitness benefits for older adults.

The American College of Sports Medicine's (ACSM) position statements on exercise provides extensive evidence for the role of strength training for the optimisation of health, function, independence and life expectancy.[1–3] Strength training has become a popular modality of the medical community in enhancing the health of older adults owing to the growing evidence of its beneficial effects.

Normal ageing results in a gradual reduction in muscle mass and strength.[1 4 5] A 30% reduction of strength generally occurs between 50 and 70 years of age and even steeper declines after the eighth decade. These declines in strength are associated with marked deficits in functional capacities.[1–4] Leg power has been shown to be strongly correlated with walking speed in elderly people.[4] Strength training in the older adult, besides increasing overall strength, has been shown to have positive effects on improving bone density, energy metabolism, insulin action and functional status.[1 3 4]

An effective strength-training programme is dependent on several variables, including; the load or percentage of the one-repetition maximum (1-RM) to be lifted, frequency of training and number of sets and repetitions to be performed.[4] The 1-RM is the amount of weight lifted during a single maximal effort through a complete range of motion that cannot be repeated a second time.[6–8] The safety of the 1-RM assessment has been established in elderly people and in a population of patients with cardiac and pulmonary problems.[6–8]

Frequency is the number of times of training per week. Although the ACSM recommends the minimal frequency of strength training to be twice a week, evidence supports a once-weekly frequency.[9–11] Taaffe *et al*[9] investigated the effect of training frequency on improving muscle strength in older adults (65–79 years of age). Subjects were randomly assigned to exercise one, two, or three times a week for 24 weeks, performing three sets of their 80% 1-RM. This study concluded that once-weekly resistance training was equally as effective in increasing the strength in older adults as two or three times weekly. Faigenbaum *et al*[10] established that once-weekly and twice-weekly training were equally effective in children in improving leg press strength during an 8-week training programme. Graves *et al*[11] showed that training once weekly was as effective as training 2 or 3 days a week over a 12-week period when improving lumbar extensor strength in young adults.

Controversy exists on the number of sets of a specific exercise to perform during strength training. Several studies[12–14] have shown one set of exercises performed to muscular fatigue to be equally effective as two or three sets in increasing strength. Carpenelli and Otto[15] and Feigenbaum and Pollock[4] in their extensive reviews of the literature have concluded that single-set programmes are equally effective as multiple-set programmes in increasing strength and hypertrophy. They also concluded that single-set programmes are recommended because they are less time consuming, more cost efficient, and produce similar fitness and health benefits. The ACSM position statement on exercise also concluded that the minimal standards for attaining muscular fitness are a single set.[2] Despite the evidence that single-set programmes are equally effective as multiple-set programmes, many researchers continue to use the multiple-set programmes when investigating the efficacy of strength-training programmes.

The frequency and number of sets to be performed must be taken into consideration when designing strength-training programmes for older adults. Taaffe *et al*[9] have shown that once-weekly training is effective in improving strength in older adults. However, they utilised a three set per exercise programme as opposed to the more efficient one-set programme. It would be more practical and efficient for older adults to train once a week performing one set of exercises if this would provide similar strength gains as two or three times a week.

The purpose of this study was to investigate whether one set of exercises performed once a week for each muscle group was as effective in increasing muscle strength as training twice a week. It is important to determine the minimal quantity of strength training required to have beneficial effects. The results

Abbreviations: ACSM, American College of Sports Medicine; ANOVA, analysis of variance; 1-RM, one-repitition maximum

Table 1 Subject characteristics (mean (standard error))

Characteristic	Group 1	Group 2
Age (years)	73.1 (1.6)	77.3 (0.7)
Height (cm)	168.5 (3.0)	169.9 (3.7)
Body mass (kg)	70.9 (3.5)	72.5 (2.5)

Group 1, 1 day/week; group 2, 2 days/week.

of this study will assist in providing further scientific evidence and sound rationales when designing strength-training programmes for the older adult that are more time and cost efficient.

METHODS

Subjects

The institutional review board at New York Institute of Technology (NYIT) approved the design of this study. Written informed consent was obtained from each subject before the start of the study. Table 1 presents the subject characteristics for the 7 women and 11 men who took part in the study, aged 65–79 years. This was a sample of convenience. Subjects were recruited from the wellness population at the Academic Health Care Center (NYCOM II), located on the NYIT campus in Old Westbury, New York, USA. Exclusion criteria for the subjects were: subjects who had participated in a strength-training programme within 6 months, any individual with pre-existing orthopaedic complications that would have affected any of the exercises involved in the study, and subjects who had cardiac and respiratory conditions that would have put them at risk for exercising.

Materials

Instrumentation included Cybex machines for leg press, leg extension, leg curl, chest fly, arm curl (Lumex, Lake Ronkoma, New York, USA), seated dip (Life Fitness, Franklin Park, Illinois, USA) and the Nu-step (Nustep, Ann Arbor, Michigan, USA). Hass *et al*[13] used a comparable protocol and strength training equipment in their investigation.

Procedures

The researchers were responsible for taking the medical history for each prospective subject to evaluate the presence of any of the exclusion criteria. All potential subjects were required to obtain medical clearance to participate in this investigation. They were required to review the consent form with their doctor, and obtain written permission on the doctor's prescription pad before participation in this investigation. Age, sex, height and weight were measured and recorded. A table of random numbers was used to randomly assign subjects to one of the two training groups (nine subjects in each group).

The initial visit consisted of a warm-up for 5 min on the Nu-step recumbent stepper. The method used to determine the 1-RM for each of the six exercises has been previously documented.[5 12] During testing for 1-RM, if an attempt was accomplished with relative ease, 10–20 lb was added for the lower extremities, and 5–10 lb for the upper extremities until the 1-RM was obtained. Subjects rested for 30 s between each attempt and 2 min between each exercise machine. The 1-RM was attained at between three and five attempts. The testing order was (1) leg press, (2) chest fly, (3) leg curl, (4) seated dip, (5) leg extension, and (6) arm curl. All 1-RM measurements were recorded in pounds for subsequent data analysis and for determining initial poundage to be used for the training period of the study.

Strength training

Subjects completed a 5-min warm-up on the Nu-step before each exercise session. The order of exercise was identical with the testing order. All subjects performed one set to muscular fatigue for each exercise at 75% of their 1-RM, which resulted in the 10–15-repetition range.[1] Once the subject reached muscular fatigue in >15 repetitions, the weight was adjusted accordingly for the next training session. Fatigue was determined by the subject's inability to complete the exercise in a full range of motion. The subject's repetitions for each lift were performed in a continuous cadence. The number of repetitions and the weight used for each exercise were recorded at each session. ACSM guidelines were used for the indications for terminating exercise.[16]

Subjects in group 1 trained once weekly for 9 weeks. Subjects assigned to group 2 trained twice a week, with a 48-h rest interval before the second training session, for 9 weeks. An effort was made to have subjects train on the same days of the week for the entire training programme. After 9 weeks of training, the 1-RM was retested on all the subjects using the same procedures as day 1. The 1-RM measurements were recorded and used for subsequent data analysis.

Table 2 Descriptive statistics (mean (standard error) in kilograms) for dependent variables at pre-test and post-test

Dependent variable	Group	Pre-test 1-RM	Post-test 1-RM	Absolute change (%)
Leg press	1, once/week	35.6 (4.5)	46.2 (5.1)	29.8
	2, twice/week	37.6 (3.4)	51.5 (4.0)	40.0
Leg extension	1, once/week	34.3 (4.0)	42.9 (3.5)	25.1
	2, twice/week	29.2 (3.6)	40.7 (5.4)	39.4
Leg curl	1, once/week	21.0 (2.7)	27.8 (2.5)	32.4
	2, twice/week	21.2 (2.6)	30.1 (4.8)	42.0
Chest fly	1, once/week	12.8 (2.7)	18.4 (3.1)	43.8
	2, twice/week	14.4 (3.1)	21.9 (4.2)	52.0
Arm curl	1, once/week	12.1 (2.3)	15.9 (2.2)	31.4
	2, twice/week	9.7 (2.5)	14.4 (3.1)	48.4
Seated dip	1, once/week	36.4 (3.8)	44.7 (3.2)	22.8
	2, twice/week	41.3 (4.3)	48.9 (4.2)	18.4

Statistical analysis

Using a two-group pre-test–post-test design, statistical analyses were performed using SPSS for Windows V.10. Descriptive statistics were calculated for age, height and body mass for both training groups. The independent variables were frequency of training and measurement time. The dependent variable was the 1-RM. Mixed-model analysis of variance (ANOVA) was performed to test the effects of group (once or twice a week training), the effects of time (pre-test *v* post-test), and the group × time interaction for each of the six exercises (leg press, leg extension, leg curl, chest fly, arm curl and seated dip). A priori sample size calculations needed to detect observed differences at a power of 80% required recruiting nine subjects for each group. Statistical significance for this study was set at $p \leqslant 0.05$.

RESULTS

Table 1 gives the means and standard errors for age (years), height (cm) and body mass (kg) for each group. Table 2 gives the means and standard errors of the pre-test and post-test 1-RMs and absolute change for the six dependent variables. The ANOVA indicated a significant main effect of time ($p<0.001$), which showed a significant difference between pre-test and post-test 1–RM scores for the six exercises for both groups (table 3). The main effect of group (difference in 1-RM scores between the groups) was not significant (table 3). There was no significant interaction effect between group and time for any of the six exercises (table 3). Table 3 shows the summary of the mixed-model ANOVA. Therefore, there was no difference in strength changes between training once a week versus twice a week, after 9 weeks.

DISCUSSION

We investigated the effects of training frequency in older adults on increasing muscle strength. The results of this study showed that one set of exercises performed once a week was equally as effective as one set of exercises performed twice a week on increasing the 1-RM of the leg press, leg extension, leg curl, chest fly, arm curl and seated dip in older adults. Strength training has been documented to benefit the health and function of older adults.[1] Participation in efficient and scientifically designed strength-training programmes is an effective intervention to reduce the functional declines associated with ageing.[1 4 9] An approximately 30% reduction in muscle strength occurs between the ages of 50 and 70 years.[1] Most of the reduction in strength is due to selective atrophy of type-II muscle fibres.[1] Strength training seems to be the only therapeutic intervention that can lessen the declines in strength and power seen in the older adult.

Table 3 Summary of mixed model analysis of variance results

Dependent variable	Source	F (p value)
Leg press	Group (G)	0.39 (0.543)
	Time (T)	659 (0.000)
	G × T	1.18 (0.293)
Leg extension	Group (G)	0.42 (0.527)
	Time (T)	26.6 (0.000)
	G × T	0.52 (0.480)
Leg curl	Group (G)	0.08 (0.780)
	Time (T)	29.74 (0.000)
	G × T	0.50 (0.492)
Chest fly	Group (G)	0.34 (0.569)
	Time (T)	20.44 (0.000)
	G × T	0.44 (0.515)
Arm curl	Group (G)	0.31 (0.584)
	Time (T)	37.01 (0.000)
	G × T	0.41 (0.531)
Seated dip	Group (G)	0.69 (0.416)
	Time (T)	60.53 (0.000)
	G × T	0.15 (0.707)

The results of this study compare favourably with those of Taaffe *et al,*[9] who used a similar population comparing strength training one, two, and three times per week. Their study concluded that once-weekly strength training was equally as effective in increasing the strength in older adults as two or three times weekly. They reported 37% improvement for once-weekly training and 41.9% for twice-weekly training for the eight exercises. The overall percentage change in the 1-RM for the six exercises in this study was 30% and 40% for groups 1 and 2, respectively. Although their study lasted 24 weeks compared with our 9 weeks, they measured the 1-RM every 4 weeks, and they stated that most of their strength improvements occurred within the first 8 weeks, which would make their results comparable to ours. Whereas they used three sets of exercises per muscle group, similar results were achieved in our experiment with one set of exercises performed to muscular fatigue. They concluded that the stimulus necessary to develop strength seems not to require high frequency, indicating a high level of residual plasticity in the neuromuscular system of older adults. Strength training must be performed for a minimum of 4 weeks to elicit muscle hypertrophy.[17] We hypothesise that the strength gains in this study reflect both neural and muscular hypertrophy contributions; however, we did not measure girth and body composition changes as a result of the training. Practice can also have an effect on strength changes; however, twice as many sessions were performed with the 2-day-a-week group, and there were differences in strength changes between the two groups. The results of this study indicate that a lesser frequency may achieve the same result as the recommendations of the ACSM[1–3] and Feigenbaum and Pollock.[4] They advocate a minimum frequency of twice a week for strength training.

The number of sets recommended to increase muscle strength remains controversial. There is a predominance of evidence supporting both the use of multiple sets and single sets performed to muscular failure. The results of this study compare favourably with Haas *et al*[13] and Starkey *et al,*[14] who concluded that one set was equally as effective as multiple sets in improving muscle strength in adults. Haas *et al*[13] reported similar body composition improvements between the single-set and multiple-set groups after 13 weeks of training. Ultrasound scans performed by Starkey *et al*[14] showed considerable increases in muscle thickness without any significant differences between one and three sets of exercises after 14 weeks of training. Although this study displayed excellent results with a single set performed to muscular fatigue, caution must be exercised owing to the rigorous nature of this exercise method. The individuals must be extremely motivated to push themselves owing to the effort and intensity required for the single set. There were occasional normal complaints of muscle soreness for 2 days after exercise in both groups, but it did not affect their daily routine or the next scheduled training session. The findings of this study support the single-set theory, as recommended by the ACSM.[1–3]

The limitations of our study were an unequal number of men and women in the groups, testing and training subjects with the same methods and equipment, the stability of baseline measures, and the lack of health-related information. The subsamples of men and women were too small in our study to make comparisons by sex. Future studies should consider

What is already known on this topic

- Normal ageing results in a gradual reduction in muscle strength.
- Previous research has shown that once-weekly training with three sets is effective in improving strength in older adults.
- It would be more practical and efficient for older adults to train once a week with one set if this would provide similar strength gains.

What this study adds

- One set of exercises performed once weekly to muscle fatigue improved strength as well as twice a week in older adults, and may possibly be the minimal quantity of strength training required to have beneficial effects to offset the declines in strength seen in older adults.

examining men and women separately to determine if there is an effect of sex on strength changes. Future studies should measure strength and power changes on different equipment other from that used for training. This may decrease the effect of practice and improve the validity of the results. Documentation of other health-related changes as a result of training such as function, quality of life, bone mass, muscle girth and body composition should be investigated.

In summary, one set of exercises performed once weekly to muscle fatigue improved strength as well as twice a week in older adults, and may possibly be the minimal quantity of strength training required to have beneficial effects to offset the declines in strength seen in older adults. The results of this study provide evidence for designing strength-training programmes for older adults that are more time and cost efficient. This study offers confirmation that substantial strength gains can be derived from less frequent activity, which may be a more acceptable programme for older adults.

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Competing interests: None declared.

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COMMENTARY

The investigators should be commended on their research regarding the frequency of strength training in the elderly. As was concluded, the fact that a once a week programme results in similar strength gains to a twice a week programme is very relevant with respect to time and cost efficiency. In addition, the strength gains observed in 9 weeks were comparable to those observed by Taaffe *et al* in a 24-week resistance training programme. This is also a very powerful finding in terms of time and cost efficiency.

Although these findings are relevant, they are limited in scope. The measure of interest in this study is strength, which, according to the International Classification of Functioning, Disability, and Health, is a measure of body function. Measuring change in body function or structure says little, if anything, about how an individual performs activities or functions in society. Although the twice a week training programme did not show greater strength gains when compared with the once a week programme, the twice a week programme possibly benefited the subject's ability to function and participate in society more than the once a week programme. Unfortunately, the investigators did not consider this. Measuring variables that deal with the person-concepts of activity, participation and disability greatly enhance the usefulness of research.

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