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Orientation and Familiarization to 1RM Strength Testing in Old and Young Women

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ABSTRACT

The purpose of this study was to compare the number of testing sessions required to achieve consistent 1 repetition maximum (1RM) strength measurements in untrained old and young women. Consistency of measurement was defined as consecutive 1 RM strength measures that increased by 1 kg or less. Untrained old (n = 6, age 66 ± 5 years) and untrained young (n = 7, age 23 ± 4 years) women were repeatedly strength-tested for bilateral concentric knee extension 1 RM strength until consecutive measurements were increased by no more than 1 kg. At least 48 hours of rest was allowed between 1 RM measurements. The old subjects required significantly more testing sessions (8–9 sessions) compared with the young subjects (3–4 sessions) to achieve the same absolute consistency of measurement ($p < 0.05$). Absolute increase in strength between the first and final testing sessions did not differ between groups (young = 11 ± 4 kg and old = 13 ± 2 kg) ($p > 0.05$). The relative increase was significantly greater in the older subjects (young = 12 ± 5%; old = 22 ± 4%) ($p < 0.05$). In conclusion, older subjects require more practice and familiarization and show greater relative increases in 1RM strength when compared with younger subjects of the same experience level. This is important to consider, especially when evaluating the magnitude of strength increase in response to resistance training.

Key Words: aging, knee extension, learning effect

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Introduction

Resistance exercise testing and training in older populations has received significant attention in the research literature. Most studies show that older individuals have a large capacity to increase muscle strength. In fact, some studies show that older populations, even the frail elderly, can show large and dramatic increases in strength (7, 8). Although virtually all studies suggest that older populations can increase strength, there is controversy regarding the magnitude of increase with studies ranging from minimal strength changes of 15% to over 200% increases in strength (2, 7, 8, 10). For example, studies have reported a training-induced increase in strength of 113% with only a 2.7% increase in corresponding muscle cross-sectional area over a 10-week program (7) or 174% increase in strength with a 9% increase in muscle cross-sectional area over only 8 weeks of training (8). There are many possible explanations for these disparities, including the initial strength of the populations studied; the frequency, duration, and intensity of the training program; the motivation of the subjects; and the method of assessment. Isometric, isotonic, and isokinetic tests are all methods of assessing strength in the elderly.

The one-repetition maximum (1RM), the heaviest weight that can be lifted once, is the most common measure of weight-lifting strength, at least in the general population (18). Many studies have shown increases in strength when tests are repeated over several days or even weeks (13, 14, 17, 19). Therefore, most testing protocols suggest that strength should be measured more than once; typically 2 or 3 testing sessions is recommended. Most of the current strength-testing protocols used with older people were originally tested and validated with young healthy individuals with previous weight-lifting experience. Therefore, the purpose of this study was to compare the number of testing sessions required to achieve consistent 1RM strength measurements in old and young women who did not have previous weight-lifting experience.

Methods

Subjects

Seven young women (mean 23 ± 4 years) and six older women (mean 66 ± 5 years) volunteered to participate in the study. The subjects were generally healthy and active and lived independently in the community. None had ever participated in resistance training exercises or been involved in aerobic-type exercise in the past 2 years. None had a history of a manual labor occupation. Despite their sedentary lifestyles, the sub-

Table 1. Strength testing data comparing results of the first testing session with the final testing session for old and young women. Values are mean ± *SE*.

	1 RM† (kg) on first test session	1 RM (kg) on final test session	% change in 1 RM (%)*	Absolute change in 1 RM (kg)	# test sessions required**
Old	62.4 ± 9	75.4 ± 10	22.5 ± 4	13.0 ± 2.2	8.8 ± 0.6
Young	120.7 ± 11	135 ± 12	12.5 ± 5.2	14.3 ± 5.6	3.6 ± 0.6

*† RM, repetition maximum.
* Significant: $p \leq 0.05$; ** Significant: $p \leq 0.01$.

jects were not obese and had normal body weights (mean ± *SD*, young = 61.8 kg ± 8.2; old = 61.4 kg ± 4.5). There were no statistical differences in body weight when comparing the young and old subjects ($p > 0.05$). Because the young and old subjects were matched for activity level and body weight, there were no obvious reasons, other than age, to believe that responses to knee extension strength testing should be markedly different. Written informed consent was obtained from each subject. The study was approved by the Syracuse University Institutional Review Board.

Strength Testing Sessions

All subjects participated in 2 orientation sessions designed to familiarize them with the study protocol including isotonic exercise on a seated knee extension dynamometer (MedX, Ocala, FL). Seated knee extension was chosen as the method of strength testing primarily because of the safe nature of seated exercise and its tolerability by the older subjects, but also because it isolates the quadriceps femoris. This dynamometer allows for increasing the load in 0.9-kg increments via a weight stack and includes an adjustable seat and lap belt restraint to help isolate the quadriceps femoris for knee extension exercise. The first session consisted of explanation of the testing procedures, review of exclusion criteria, signing of the consent form, adjustment of the seat height and restraint strap on the exercise equipment, and about 5 repetitions of a very light weight. The second orientation session consisted of recording of body weight and age, verification of the equipment adjustments, and performance of about 5–10 repetitions of a slightly heavier weight. Formal strength testing began on the third visit. After a warm-up consisting of 10 repetitions of a light weight, a rest, and 5 repetitions of a medium weight (light/medium weights were determined by the 2 orientation sessions), subjects were tested for the concentric bilateral 1RM, the heaviest weight that could be lifted for one repetition. Testing included single attempts at progressively heavier weights until the 1RM was identified. Depending on the subject, this typically required 3–8 attempts. Lifting the weight 90% or more of a subject's unloaded range of motion was required for a successful lift. Ninety percent completion of the range was accepted as a safe means of assessment, and one that reduced the hazardous stresses about the knee joint observed through 100% of the movement. Two minutes of rest was allowed between sets/trials, as this has been shown to be adequate for phosphocreatine replenishment in both young and old subjects over repeated sets of exercise (20). Subjects were tested over the course of several days, but were given at least 48 hours of rest between testing sessions. Typically tests were performed every 2 days, but not on weekends. If a subject's 1RM strength exceeded the previous test by more than 1 kg, she was required to return to the laboratory on another day to be tested again. When consecutive strength tests either decreased or did not increase by more than 1 kg, the highest value achieved was recorded as the 1RM. All testing was conducted by one investigator who was alone in the room with the subject. Verbal encouragement was provided for motivation. Every effort was made to provide similar types and amount of encouragement to all subjects.

Statistical Analyses

One-way analysis of variance (ANOVA) was run to test for group differences (young vs. old) for number of test sessions required, absolute change in 1 RM from first to last test session, and relative (%) difference in 1RM between first and last test sessions. Test–retest correlation was used to compare the final 2 strength measures for each subject as a measure of reliability. All analyses were run using the SuperANOVA software (Abacus Concepts, Berkeley, CA). A p value of 0.05 was used to reject the null hypothesis.

Results

There was a significant difference ($p < 0.0001$) between young and old for the number of testing sessions required to achieve strength measurements within 1 kg (Table 1). Older subjects required a mean of 8.8 testing sessions, with a range of 7–10 sessions depending on the individual. Younger subjects required a mean of only 3.6 testing sessions with a range of 2–5 sessions. The variability (standard error) was similar among groups (0.6 for each group). There was no significant difference between younger and older subjects for the absolute weight increase from testing session 1 to the final testing session ($p > 0.05$) (Table 1). Because the older women had lower absolute strength, the relative increase from session 1 to the final session was greater in the old compared with young women ($p < 0.05$) (Table 1). Strength on the final 2 testing sessions was evaluated for test–retest reliability;. the r^2 value was 0.94 ($p < 0.05$), and there was no significant difference between the final 2 strength values for either young or old women ($p > 0.05$).

Discussion

The major findings of this study were (a) older women required more than double the number of testing sessions (8.8 vs. 3.6) to achieve consistent (within 1 kg) concentric knee extension 1RM strength measurements, and (b) older women had a greater relative increase in strength (22%) over the course of the orientation period compared with young women (12%). Because the absolute increase was similar among young and old women, the differential relative increase also reflects the lower strength of the old women. It is important to note that none of the subjects in either group had previous weight-lifting experience. This study suggests that 3–4 testing sessions are required to achieve consistent strength measures in untrained younger women, when consistent is defined as repeat measurements within 1 kg. However, 8–9 testing sessions are required for the same absolute consistency in older women. Most previous research recommends 2 testing sessions for young subjects, but many of those studies used subjects who were familiar with weight-lifting exercises (18). Therefore our finding of 3–4 sessions for untrained young women seems reasonable. Our finding of 8–9 sessions required for older women is somewhat surprising, yet reasonable. Other studies have evaluated reliability of strength measurements using repeated measurements on the same individual, typically using 2 trials. These data are often analyzed with test–retest correlation, which is very sensitive to the range of the values observed and must be considered in the interpretation of correlation coefficients (1, 4). Furthermore, a correlation coefficient does not provide intuitively useful information regarding the trial-to-trial variability (18). For example, if all subjects exhibit similarly higher values on the second trial (learning effect), a very high correlation coefficient can be obtained, yet consistency of measurement is not obtained. Furthermore, test–retest correlation can be applied to only 2 trials.

Previous research has not addressed the specific issue of consistency of 1RM strength testing in young vs. older subjects. However, other studies have evaluated the reliability of strength testing in older populations using other types of testing. For example, isokinetic knee extension/flexion strength tests (5 trials on each of 2 days) have been shown to have intraclass correlation coefficients ranging from 0.03 to 0.90 for extensor muscles and 0.44 to 0.89 for flexor muscles (3). Test–retest correlations ranged from 0.22 to 0.74. However, this study measured strength over only 2 days, and cannot address the issue of what level of consistency of strength measure was ever reached, thus limiting its practical application. It is possible that if strength were measured on a third or fourth day, higher values would have been observed. Furthermore, this study did not demonstrate whether the testing reliability is different among different-aged subjects. Generally the reliability values reported in the literature are similar for isotonic, isometric, and isokinetic strength tests. Typically 5–10% measurement error is reported over 2 testing sessions (11, 18, 21, 22). In the current study, 1RM strength was found to be 75 kg for the older and 135 kg for the younger subjects. We are confident in these values to the nearest 1 kg, which represents an accuracy of measurement of 0.7–1.3%.

For the present study, we chose the value of 1 kg as the consistency standard, which, although rather strict, seems reasonable for research studies whose primary goal is to document changes in strength, especially if those changes are expected to be small effects. In community health and fitness environments, where such detailed strength measurements may not be required, fewer testing sessions would be needed. Indeed, even in some research situations repeat strength testing sessions may not be practical, such as in large-scale population studies. However, the underlying finding that older women require significantly more testing sessions than younger women to achieve the same level of reliability seems robust and should be considered when interpreting strength-testing results in the older population. The current data were collected on a small and specific subject population—female subjects using 1RM strength testing of the knee extensors. It is logical that these results should generalize to both genders and other muscle groups, but future research should confirm this by testing both genders and a wider range of ages and muscle groups. Another limitation and area for future study concerns the influence of everyday activity level on strength-testing outcome. Although it is relatively easy to match subjects on the basis of their formal training history, it is more challenging to quantify casual physical activity levels, which may influence 1RM strength testing.

It is interesting to speculate why older women would require considerably more familiarization sessions than young women. General impaired neuromuscular performance in old age has been widely reported. Fewer studies have evaluated the specific neuromuscular parameters that might differ with age. It has been reported that older subjects have a decreased ability to modulate muscle reflexes (12), decreased ability to perform simultaneous motor tasks (16), and a greater presynaptic inhibition of motor units (15). Others have suggested that motor control is impaired with age; in particular a decrease in variability of firing rate has been observed in older subjects (6) and the firing rate/recruitment threshold relation has been reported to be disrupted in older individuals (6).

Practical Applications

This study addresses 2 important practical applications—first, interpretation of research results when selecting strength training programs for older individuals, and second, conducting consistent and reliable strength tests in a community health and fitness setting.

There is considerable controversy in the research literature regarding the magnitude of resistance-training-induced strength increase possible for older individuals, with studies ranging from minimal strength changes of 15% to over 200% increases in strength (2, 7–10). There are many possible reasons for such discrepancies, including population studied, training protocol selected, and motivation of the subjects. Clearly the strength-testing protocol used is also an important determinant in the outcome of resistance-training studies. It is well known that the testing protocol should be very specific to the training mode, be well standardized between pre- and posttraining measurements, and utilize a control group to control for learning effects. Although occasionally mentioned [(5), for example], it has not been widely appreciated that the number of testing or familiarization sessions may have profound impact on the strength-testing results, and therefore in the interpretation of results of training studies. Furthermore, the current study demonstrates age-related differences in the response to strength testing, whereby older women require more testing sessions to achieve a 1-kg accuracy in testing compared with young women. This affects the interpretation of resistance-training studies of the elderly. It is likely that training-induced strength increases have been overestimated in the aging population, especially when comparisons are made against younger subjects. Minimally, investigators should report the number of testing sessions utilized in resistance training studies. Ideally, investigators should report whether they observed a plateau of strength in response to subsequent strength-testing sessions. If this plateau is not observed, then the overall increase in strength is likely to be reported as higher than if the strength-testing plateau is observed. The strength and conditioning specialist should consider the consistency of strength test results when comparing various training programs, as it is particularly likely to overestimate training-induced strength gains in an older population.

In summary, both groups increased their strength by approximately 12 kg between the initial and final testing sessions. Because of strength differences between the groups, this represented a 12% increase in the younger women, and a 22% increase in the older women. However, the older women required twice as many testing sessions to achieve the same absolute reliability in strength testing. Those who intend to perform 1 RM strength testing on older subjects should be sure to verify the reliability of their methods and increase the number of practice/testing sessions if necessary. Controlling the reliability in methodology of strength testing is critical, especially when making comparisons of various training programs and comparing individuals of various ages.

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