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Single- vs. Multiple-Set Strength Training in Women

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ABSTRACT

The aim of this study was to compare the effects of single-set and multiple-set strength training in women. Twenty-seven women (aged 20–40 years) with basic experience in strength training were randomly allocated to either a single-set group ($n = 9$), a 3-set group ($n = 9$), or a nontraining control group ($n = 9$). Both training groups underwent a whole-body strengthening program, exercising 2 days a week for 6 weeks. Exercises included bilateral leg extension, bilateral leg curl, abdominal crunch, seated hip adduction/abduction, seated bench press, and lateral pull-down. The single-set group's program consisted of only 1 set of 6–9 repetitions until failure, whereas the multiple-set group trained with 3 sets of 6–9 repetitions until failure (rest interval between sets, 2 minutes). Two times before and 3 days after termination of the training program, subjects were tested for their 1 repetition maximum strength on the bilateral leg extension and the seated bench press machine. Data were analyzed using a repeated-measures analysis of variance, Scheffé tests, *t*-tests, and calculation of effect sizes. Both training groups made significant strength improvements in leg extension (multiple-set group, 15%; single-set group, 6%; p 0.05). However, in the seated bench press only the 3-set group showed a significant increase in maximal strength (10%). Calculation of effect sizes and percentage gains revealed higher strength gains in the multiple-set group. No significant differences were found in the control group. These findings suggest superior strength gains occurred following 3-set strength training compared with single-set strength training in women with basic experience in resistance training.

Key Words: resistance training, training volume, training intensity

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Introduction

In the theory and practice of strength training, there is increasing controversy regarding the effects of single- vs. multiple-set strength training on maximum strength. Practical experience during decades of ''trial and error'' has convinced most, however not all, athletes, bodybuilders, and fitness enthusiasts that using multiple-set strength training is superior to single-set strength training. Nevertheless, interpretation of scientific results is controversial. In a recent review, Carpinelli and Otto (4) claimed that there is no reason to use more than one set, since analysis of scientific results shows only a small tendency toward a superiority of multiple-set training. In contrast, Stone et al. (21) concluded that multiple-set strength training has clear advantages over single-set training. More recent studies also revealed inconsistent findings (10, 17). Because of the variety of differences in the design of relevant studies (i.e., training duration, training status of the subjects, application of periodized models and circuit training in multiple-set training, test modalities, different warm-up strategies for multiple- and single-set training), conclusions made only on the basis of the available studies comparing single- and multiple-set training may be somewhat misleading.

To clarify this discussion, identification of the critical physiological stimulus for maximizing strength gains offers an alternative approach. It is generally accepted that training at high intensity and, therefore, high muscle tension is one important factor for improving maximum strength (2, 13). However, from a physiological point of view, it seems that maximization of strength gains also depends on some kind of fatigue stimulus. Carey Smith and Rutherford (3) found that concentric-only resistance training with submaximal loads and the production of a higher metabolic cost can be more effective in increasing maximum strength than eccentric-only resistance training using maximal loads and a resulting lower metabolic cost. Schott et al. (19) found in a related study that long fatiguing isometric contractions (four 30-second contractions) induced greater gains in maximum strength than shorter, less fatiguing isometric contractions (4 sets of 10

Table 1. Physical characteristics of the subject (mean ± *SEM*).*

Group	Age (y)	Height (cm)	Body mass (kg)
SS ($n = 9$)	29.1 ± 9.2	162.8 ± 8.8	70.5 ± 13.2
MS ($n = 9$)	24.4 ± 2.9	168.6 ± 2.9	62.0 ± 4.4
CON ($n = 9$)	25.3 ± 3.1	168.3 ± 4.4	63.6 ± 8.4

* SS = single-set group; MS = multiple-set group; CON = control group.

contractions, each lasting 3 seconds). Further, the results of Shinohara et al. (20) support the importance of the fatigue-related process in maximum strength adaptation. Four weeks of fatiguing strength training using tourniquet ischemia produced superior strength gains compared with normal strength training with the same load.

According to these results, maximal strength gains may depend not only on high muscle tension but also on a related fatigue stimulus. In particular, the fatigue-factor favors the importance of training volume and therefore of multiple sets in strength training.

The purpose of this study was to investigate the effects of a 1- and 3-set whole-body strengthening program on maximum strength in women with training experience. Based on the cited physiological results, our hypothesis was that women who are experienced in basic strength training exercises will respond better to a 3-set training program than to a 1-set training program.

Methods

General Design

To further address the question of whether differences in training volume of short-term strength training programs affect strength gains, we compared the effects of 6 weeks of 1-set and 3-set whole-body strength training on maximum strength in female subjects. Both 1-set and 3-set strength training programs have been shown to improve maximum strength (4, 21). In an effort to reduce the influence of initial neural adaptations on the longitudinal strength effects (6), we used subjects with basic experience in strength training. Furthermore, to familiarize the subjects with the test procedures, 2 pretest sessions had to be performed.

Subjects

Twenty-seven female members of a ladies gym (Amiga, Frankfurt am Main, Germany) with a background of at least 6 months of regular strength training volunteered for the study. The initial physical characteristics of the 27 participants are shown in Table 1. Each subject was informed of the risks and benefits of the study and subsequently signed an informed consent in accordance with the guidelines of Goethe University's Institutional Review Board.

Study Design

The study involved 2 pretest sessions in the week before the beginning of the training period, a 6-week training period, and a posttest 3 days after termination of training. On conclusion of the pretests, the subjects were randomly assigned to 1 of 3 groups: a single-set group ($n = 9$), a multiple-set group ($n = 9$), and a control group ($n = 9$).

Testing

All test sessions included a 1 repetition maximum (1RM) assessment for the bilateral leg extension and the seated bench press. The 1RM testing was conducted using the methods described by Kraemer and Fry (11). In the posttest session, validation of a successful 1RM trial was assessed by a tester who was unaware of the group dependency of the respective subject. All tests were preceded by a general warm-up that included 5 minutes of stationary cycling followed by light flexibility exercises for the knee extensors and flexors, the chest, and the shoulder girdle.

Between-day analysis of the 2 pretest sessions revealed correlation coefficients of $r = 0.91$ and 0.97 for the 1RM bilateral leg extension and the seated bench press, respectively. Coefficients of variation were 5.5% for the bilateral leg extension and 3.7% for the seated bench press.

Training

Training was carried out 2 times a week for 6 weeks. Subjects performed a whole-body strengthening program (bilateral leg extension, bilateral leg curl, abdominal crunch, seated hip adduction/abduction, seated bench press, lateral pull-down). The advantage of using a whole-body program was to simulate a real practical training situation and to induce a better hormonal anabolic environment presumably produced by utilization multiple exercises compared with application of a single exercise (12).

Before commencement of each strength training session, a general warm-up consisting of light aerobic and flexibility exercises was conducted independently to a point that each volunteer felt well prepared for exercising with heavy weights. The single-set group trained using 6–9 repetitions per exercise at each training session. The multiple-set group performed 3 sets of 6–9 repetitions for each exercise. Rest intervals between sets in the multiple-set group were 2 minutes. No further warm-up sets were allowed in either group. If a subject was able to perform 9 or more repetitions of the respective exercise in one training session, an additional load of 2.5–5.0 kg would be added for the next training session. The subjects of the multiple set group were not allowed to increase the training load

Table 2. Means (±*SD*) of 1RM (in kilograms) in bilateral leg extension.*

Leg extension	PRE	POST
MS	43.7 ± 6.1	50.6 ± 7.6†
SS	44.8 ± 6.8	47.8 ± 7.9†
CON	44.1 ± 7.7	44.0 ± 8.6

* 1RM = 1 repetition maximum; PRE = pretest; POST = posttest; MS = multiple-set group; SS = single-set group; CON = control group.

† Significantly different from pretest.

Table 3. Means (± *SD*) of 1 RM (in kilograms) in seated bench press.

Bench press	PRE	POST
MS	26.9 ± 3.5	29.7 ± 4.6†
SS	31.7 ± 9.0	33.0 ± 9.3
CON	28.1 ± 2.4	27.2 ± 2.9

* 1RM = 1 repetition maximum; PRE = pretest; POST = posttest; MS = multiple-set group; SS = single-set group; CON = control group.

† Significantly different from pretest.

within one training session if they had been able to realize more than 9 repetitions in the first set.

Subjects trained under supervision of their own gym instructors, but no verbal encouragement was given during training. At the end of each training session, subjects were each instructed in the same manner to increase weights for the next session if possible.

The subjects of the control group were not allowed to conduct any resistance training. However, they continued to perform their normal endurance training routines.

Statistical Analyses

Pretraining and posttraining 1RM values were compared using repeated-measures analysis of variance. Significant results were followed by Scheffé post hoc comparisons to identify where the differences occurred. Percentage gains in the training groups were analyzed with the use of unpaired *t*-tests. Statistical significance was accepted at $p < 0.05$.

Furthermore, importance of longitudinal changes were assessed by calculating effect sizes according to the procedures proposed by Thomas et al. (22). Effect sizes of 0.2 represented small differences, 0.5 represented moderate differences, and 0.8 represented large differences. All of the presented percentage data were calculated on the basis of mean individual percentage changes.

Results

All subjects completed 100% of the training sessions. Table 2 shows the pretest and posttest means for 1RM strength for the bilateral leg extension. Before training, 1RM means of the groups did not differ significantly ($p < 0.05$). Both training groups made significant strength improvements in leg extension (multiple-set group, 15%; single-set group, 6%; $p < 0.05$). No significant differences were detected in the control group. Moreover, a significant interaction was observed ($p = 0.00$). Further analysis showed that the percentage gains in the multiple-set group were significantly higher than in the single-set group ($p < 0.05$).

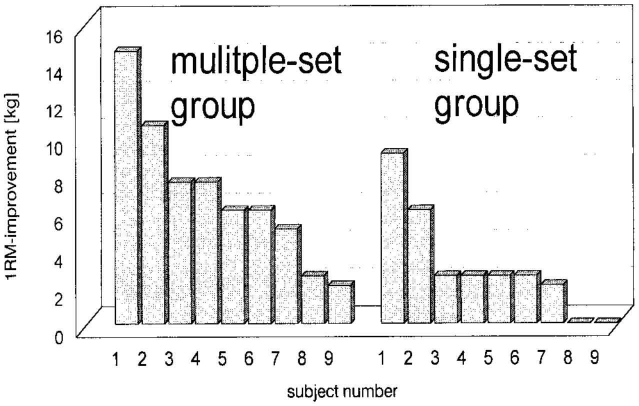

Figure 1. Order of individual strength gains (in kilograms) in bilateral leg extension.

Results for the seated bench press can be seen in Table 3. Before training, the means of the 3 groups showed no statistically significant difference. After training, only the multiple-set group showed a significant increase in maximal strength (10%; $p < 0.05$). No significant differences were detected in the control group. A significant interaction was observed ($p = 0.001$). As in the bilateral leg extension, percentage gains in the multiple-set group were significantly higher than in the single-set group ($p < 0.05$).

Calculation of effect sizes showed moderate-to-large strength gains in the multiple-set group (leg extension, 1.0; seated bench press, 0.7) and small-to-moderate strength increases in the single-set group (leg extension, 0.4; seated bench press, 0.3).

Discussion

In the present study, multiple-set strength training induced significantly higher gains in maximal strength of the 2 tested exercises, bilateral leg extensions and the seated bench press. Consequently, our data indicate that multiple sets in women with basic experience in resistance training (3–6 months) will improve strength adaptations. The individual improvements in the 2 training groups in the bilateral leg extension shown in Figure 1 further substantiate this conclusion.

In accordance with scientific results, single-set training induced significant strength gains in the bilateral leg extension. However, no statistically significant increase was found in the seated bench press. This surprising result may be due to the higher baseline strength in the single-set group (Table 3) and/or difficulties in detecting the real strength improvements because of angle-specific adaptations. During the training of the bench press exercise, most subjects in both groups tended not to fully lower the weight during the eccentric portion of each training repetition before continuing with the subsequent concentric movement. Consequently, since the end point of the bench press 1RM test began from a strongly stretched end point, compared with what the subjects were used to, we believe that strength increases in the seated bench press may have been masked and therefore underestimated for both groups. This phenomenon could, therefore, explain the lower relative strength gains in the seated bench press compared with leg extension in both groups.

To find possible explanations for the observed superiority of multiple-set strength training in our study, some considerations about the characteristics of the training stimuli should follow. First, one should realize that both groups fulfilled the requirement of high training intensity (see Introduction), since all subjects worked in each training session with their actual 6–9RM load. Therefore, it can be assumed that the different training responses were due to the additional 2 sets in the multiple-set group. Multiple sets and higher training volume in strength training seem to induce several physiological processes that differ clearly from the single-set stimulus.

As stated previously, the fatigue stimulus seems to be one of the key factors in strength adaptations. This method has been adopted by strength training practitioners and appears to be substantiated by the fact that most strength training methods are based on the repeated lifting of a weight within a set until failure. The experimental evidence for the effectiveness of this strategy was presented by Rooney et al. (16). They observed that training with repeatedly lifted weights without resting (6–10 repetitions with the 6RM load) is superior to working with the same repetition-load combination, allowing a 30-second rest between the single repetitions. Such observations clearly show the importance of the fatigue stimulus in strength adaptations.

In multiple-set strength training, single sets are interspersed with rest intervals, which allow adequate regeneration of the neuromuscular system. The timing of such a rest interval depends on the training loads and intensity. For example, working with a 3RM load requires rest intervals of 5 minutes or more, whereas training with a 12RM load requires rest intervals of only 2–3 minutes (18). The basis for these recommendations are, on the one hand, observations that show that shorter rest intervals do not allow for enough recovery to keep the training intensity high. On the other hand, longer rest intervals seem to reduce the performance by presumably decreasing the general warm-up state. The effectiveness of these usual rest interval recommendations was partially confirmed by scientific investigations. Robinson et al. (15) found that a 3-minute rest between sets was more effective in increasing maximum strength than a rest interval of 30 seconds. Furthermore, Pincivero et al. (14) observed higher strength increases when training with a break of 160 seconds compared with a rest interval of 40 seconds.

These specific load-regeneration cycles seem to induce several physiological regulation processes, which in turn may be the reason for the higher efficiency of multiple-set training in our study.

In 3-set strength training, the second and the third sets begin under prefatigued conditions since the rest intervals between sets do not allow for a full recovery of the muscles. Working under prefatigued conditions may induce motor unit rotation (7) such that motor units formerly not recruited will be activated. If appropriate, this mechanism could result in a greater overall muscular stress and, subsequently, marked increase in the adaptation of the contractile elements. Furthermore, motor unit rotation may induce better neural adaptations because of the higher number of activated motor units.

In addition, it can be speculated that in multiple-set training it is not only fatiguing mechanisms that play an important role. In different resistance training studies, we investigated and made exact documentation of the variations in each training repetition of a training program. For example, after a general warm-up, we observed that in a 3-set training program, the highest power and velocity values frequently were detected in the second and third sets (in most cases in the second set). The same holds true for the total work per set. This phenomenon was independent of the training status of subjects. Therefore, we believe that subjects practicing strength training optimize their movement execution (coordination) within multiple sets of one training session. This phenomenon might also be due to the subconscious loss of fear (i.e., with respect to muscle injury) after having performed one set. Furthermore, it seems probable that an increase in power performance in the last sets of a multiple set program may be partially induced by potentiation mechanisms induced by working with high loads (9).

Taken together, fatigue in multiple-set strength training may be viewed as a perturbation technique, not only reducing the force-generating capabilities on the contractile level but also leading to some kind of neural reorganization (5), which could have a positive influence on strength adaptations.

Another reason for higher strength gains with multiple-set strength training might be a greater anabolic hormone response with a higher training volume (8), mediating better strength gains. However, since high-anabolic-hormone responses can be attained with a lot of training stimuli (i.e., endurance training), the importance of this factor is difficult to assess (1).

Finally, the training status of our subjects should be considered. Despite the fact that our subjects had basic experience (3–6 months) in strength training, we believe that neural adaptations in terms of optimization of intermuscular and intramuscular coordination (reduction of antagonistic activity, increase in agonistic muscle activity, better interplay between synergistic muscles) are still possible. In particular, the number of repetitions in multiple-set strength training may influence the optimization of intermuscular coordination and thus increase lifting ability.

Since most of the available studies were discussed in detail by Carpinelli and Otto (4) and Stone et al. (21), we want to refer only to one recent study that revealed no superiority of multiple sets (10). The application of a multiple-set circuit training program in the study of Hass et al. (10) does not seem to be an adequate solution. Such a strategy does not correspond to the effective situation where one exercise per muscle is loaded with multiple sets with rest intervals of about 2–3 minutes. Therefore, the study of Hass et al. (10) only shows that higher training volume with unusually long rest intervals (10–15 minutes) seems to induce similar effects as a single-set training.

Another confusing fact in their study is that subjects were included in the final analysis having finished only 85% of all training sessions. Our experience in many studies has shown that strength gains are generally very small if subjects are not motivated to join all training sessions (unpublished observations, 1998). Because nothing is said about the distribution and the reasons that subjects failed to show up to all training sessions, the worthiness of the study is somewhat limited. Furthermore, the problems in adherence to the multiple-set program observed in the study of Hass et al. (10) are not surprising, since the study was conducted in a health and fitness center where single-set training is regarded as the strength training method of choice (clearly demonstrated by the fact that all subjects had been performing single-set training for an average of 6.2 years and that this center is equipped with MedX machines). Consequently, the participants of the multiple-set group in their study may have been of the opinion that such training was less adequate than their usual training method, which may have induced the poor motivation and compliance.

Finally, we believe that when clarifying the problem regarding the effect of different training methods, one should be aware of the fact that specific imposed demands generally induce specific adaptations. Because of the specificity of adaptations, it seems unlikely that different training stimuli induce identical adaptations. In the field of strength training, such a realization is fundamentally substantiated by a well-designed study from Dudley et al. (6). They found that resistance training with normal eccentric-concentric muscle actions produced higher strength gains than pure concentric training. Furthermore, concentric-only training with 8–10 sets induced higher strength gains than concentric-only training with 4–5 sets. These results emphasize that both the quality and the quantity of resistance training are critical factors that influence the extent of adaptations.

Practical Applications

Regarding the practical importance of our findings, we found the results of an oral questioning of the subjects immediately before the posttest to be very informative. We asked the subjects how they would assess their training program. Most single-set group subjects felt that they liked the program, especially because of the short length of the training sessions. In contrast, most of the subjects of the multiple-set group said that they will continue to use the 3-set program since it is very effective.

Taking the results of the strength testing and oral questioning into account, recommendations regarding the training volume in short-term training programs should take the main aim of a subject into consideration. If someone focuses primarily on aerobic exercises and weight reduction, a single-set resistance training may be a time-efficient supplement for increasing strength. In such cases, where subjects have reservations about strength training, a short program may help to avoid a high-resistance training dropout rate. However, if someone has the desire to maximally increase strength, a multiple-set training program should be recommended.

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