ORIGINAL RESEARCH

Outcome Effects of Single-Set Versus Multiple-Set Training—An Advanced Replication Study

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The starting point of this review is the assumption that single-set training (SST) can be regarded as an equal alternative to multiple-set strength training. On the basis of 72 primary studies, the meta-analysis dealt with the problem of single-set vs. multiple-set training (MST). The effectiveness of these training methods was examined depending on various interventions. Apart from qualitative decision aspects, the effectiveness was checked on the basis of effect size. Generally speaking, it can be stated that MST, depending on factors like age, training experience, duration of the study, etc., offers several advantages over single-set regimes ($F = 3.71; df = 1; p = 0.06; \eta^2 = 0.02$), especially when combined with periodization strategies, and it can be applied very successfully for increasing maximal strength in long-time effects. Therefore, the outcome effects of both methods are the same in short-time interventions. For longer-time interventions ($F = 15.74; df = 1; p < 0.05; \eta^2 = 0.12$) and for advanced subjects with the goal of optimizing their strength gain, however, multiple-set strategies are superior ($F = 7.32; df = 1; p < 0.05; \eta^2 = 0.06$).

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INTRODUCTION

Strength training is an essential part of training programs for many types of competitive athletes, for rehabilitation and the prevention of orthopedic or muscular injuries, as well as for older adults. The typical design of individual training programs usually is based on adjusting training parameters, such as training intensity, frequency per week, number of sets, number of exercises, and rest between sets according to the trainee’s needs (Fleck and Kraemer 2004). Whereas the effects of different training intensities for varied methods and rest periods between sets have been well studied (Güllich and Schmidtbleicher 1999; Robinson et al. 1995; Willardson and Burkett 2008), there is considerable demand for research focusing on the effects of different training volumes, especially the number of sets per exercise (Stone et al. 1998). A discussion has been going on in scientific literature for several years, especially in the early 1990s, as to which number of sets per exercise might be best (Byrd 1999; Carpinelli and Otto 1998; Galvao and Taaffe 2004; Munn et al. 2005; Schlumberger and Schmidtbleicher 1999; Wolfe et al. 2004). The bottom line of the discussion is that if single-set training (SST) is equally effective as multiple-set training (MST) in terms of inducing an increase in strength and muscle mass, the former would be the most efficient kind of training considering the reduced training volume and time spent on training (Brown 1999; Carpinelli 2002). Feigenbaum and Pollock (1999) point out that a very important advantage of SST is its effectiveness in terms of achieved improvements in relation to the amount of time spent on training. Furthermore, for all subjects, SST produces the same health and fitness benefits as MST programs. In this context, in 1998, the American College of Sports Medicine (ACSM) originally issued the suggestion that a single-set intervention of 8 to 10 exercises would result in similar strength improvements as following a training of higher volume, e.g., 3 sets per exercise (ACSM 1998). A meta-analysis by Rhea, Alvar, et al. (2003) as well as by Peterson et al. (2004), however, found that MST was more effective in trained individuals, and the absolute effect was significantly higher than in SST interventions. Many other original studies have shown that MST produces superior strength gains, muscular hypertrophy, athletic performance, local muscular endurance, as well as higher growth hormone concentration when compared with SST (Craig and Kang 1994; Kraemer et al. 1995; Kraemer et al. 2000; Kramer et al. 1997; Mulligan et al. 1996; Rhea, Alvar, et al. 2002; Rønnestad et al. 2007). So, in 2002, the ACSM rerecommended the guidelines for resistance training prescription, adding the following (Kraemer et al. 2002):
1. In order to stimulate further adaptation toward specific training goals, progression in the type of resistance training protocol used is necessary.  
2. Higher volume, multiple-set programs are recommended for maximizing hypertrophy.

In their concept about effectiveness and time consumption, Munn and colleagues (2005) point out that training with one set is less time consuming than training with three sets where the same exercises are being performed. Thus, although three sets of resistance exercise clearly produce greater strength gains in the early phases of training, a one-set protocol might sometimes be preferable to a three-set protocol if subject compliance or time prioritization is a concern. In addition, a shorter resistance exercise protocol would be advantageous in community-based programs, permitting a larger number of individuals to train with the available equipment or device (Galvao and Taaffe 2005). Nevertheless, Fleck and Kraemer (2004) suggested that after the neuromuscular system adapts to a strength stimulus, an increase in training volume is needed for additional adaptations to occur. A clear implication of the statement by Munn and coworkers (2005) as well as by Fleck and Kraemer (2004) is that the use of a single-set method may be appropriate for beginners and untrained individuals in the early phase of a training period (Rutherford and Jones 1986). Although the efficiency of SST, especially for recreational or noncompetitive trainees, is not questioned (Schlumberger and Schmidtbleicher 1999), the “costs” must also be taken into consideration. Therefore, the purpose of the present review was to compare the effectiveness and efficiency of a single-set program with a multiple-set one. Furthermore, it was hypothesized that the duration of the study (early neuronal adaptation phase vs. muscular hypertrophy phase at a later stage), the training experience (trained vs. untrained subjects), the age of the subjects (young people [≤18 years], middle-aged [19–59 years], and older adults [≥60 years]), and the application of periodization strategies (nonperiodization vs. linear or undulating periodization) have the same influence on the effectiveness in SST and MST programs. We also discuss the practical relevance of the potential difference between SST vs. MST interventions by the use of effect sizes in strength training research (Rhea 2004). The aggregation of the empirical data and the quantitative integration of the results were accomplished by means of a meta-analysis to estimate the efficacy in strength training (Peterson et al. 2005; Rhea 2004, 2004a; Rhea, Alva et al. 2003; Wolfe et al. 2004).

**METHOD**

**Literature Search**

The search for literature was limited to exercise training studies published in 1985–2008. Primary data were aggregated by using computer databases and research systems like Medline, PubMed, Medpilot, Sport Discus, ViFa:Sport,
ERIC (Fröhlich and Schmidtbleicher 2008). Furthermore, hand searches of relevant journals, dissertations, anthologies, abstracts/supplements, and other references were conducted. Most of the relevant articles came from scientific journals that published studies on strength training research, e.g., *Journal of Strength and Conditioning Research* (55.2%), *Medicine and Science in Sports and Exercise* (14.9%), *Leistungssport* (9%), *Strength and Conditioning Journal* (6%), *Sports Medicine* (3%), *Deutsche Zeitschrift für Sportmedizin* (3%), *British Journal of Sports Medicine* (1.5%), *Research Quarterly for Exercise and Sport* (1.5%), *American Journal of Sports Medicine* (1.5%), etc. Description terms that were used to find relevant studies online in German and English included “Einsatztraining”, “Einsatz-Training”, “Mehrsatztraining”, “Mehrsatz-Training”, “single set”, “single-set”, “multiple set”, “multiple-set” in combination with or without “training” or “resistance training” (Fröhlich 2006).

Coding of Studies

Each of the studies was read and coded by a previously determined, yet open system of codification. Descriptive information about each study was followed by aspects of testing procedures and training methods, information on methodology, and evaluation of the primary study, as well as the author’s conclusions (see Fröhlich 2006; Rhea 2004). The codified data were described qualitatively (e.g., exercises used, study design, etc.) and quantitatively (e.g., training frequency, duration of the study, etc.) considering substantial aspects (e.g., relative characteristics of the subject population), distorting factors (e.g., research methods), and extrinsic aspects (e.g., language of publication; Peterson et al. 2004; Rhea 2004; Rustenbach 2003). A random selection of the studies was assessed by a second and third coder. Disagreement between the coders was resolved by consensus (reapplication of the coding system and inclusion of categories).

Statistical Analysis and Calculation of Effect Size

The statistical analysis included factors such as the mean value, standard deviation, frequency distribution, confidence intervals (CI), and median. The interference-statistical calculation of significance was done using analyses of variance (ANOVA) and analyses of covariance (ANCOVA). Precondition tests were carried out applying the usual methods (KS test for Gaussian distribution, Levene test for homogeneity of variance and homogeneity of regression). The quotient of overall variability attributed to a certain factor was determined via partial eta² ($\eta^2$). Calculation of effect size (ES = treatment effects) was analyzed for dependent samples (cases that supplied only $t$ values or degrees of freedom/sample size, respectively, or the level of significance) by $g = t/\sqrt{N}$ (Rustenbach 2003). Pre–post calculation of effect size for the training experiment
followed, if there was no data of a control group by $g_{Hedges} = (\bar{x}_1 - \bar{x}_2) / S_{\text{pooled}}$ with calculating $S_{\text{pooled}}$ by

$$S_{\text{pooled}} = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}}.$$ 

Effect size in studies with control groups was calculated by assessing the difference of mean values in the experimental group (ME) compared with the mean values in the control group (MC) divided by the standard deviation in the control group (SC). The ES formula was applied as follows: $ES = (ME - MC) / SC$ (Wolfe et al. 2004). The level of significance was specified at $P < 0.05$. All calculations were carried out using SPSS for Windows (16.0).

Methodical Criticism

In some meta-analytical studies, a median of the respective variables (e.g., 1-RM, muscle strength endurance, increase of muscle circumference, reduction of body fat, hormonal changes, etc.) was calculated and regarded as the “overall effect size” (Winett 2004). The following meta-analysis analyzes changes of the effect size of the factor “maximal strength,” normally 1-RM. Therefore, the comparison of the results of SST and MST in this study is a comparison of changes of maximal strength. A positive effect size thus indicated an improvement in strength following the training period. This approach was chosen because in the various primary studies, the operationalization of muscle strength endurance, muscle cross-sectional area, reduction of body fat, hormonal changes, cardio-pulmonary, and metabolic demands, etc., were assessed using several different approaches and different ranges of subject populations (Rhea 2004b). Furthermore, the training status in the categories “trained subjects” vs. “untrained subjects” in the primary studies was categorical. There was no or only little operationalization information about training status (e.g., frequency of training in the last months) in the primary studies. In addition to this, effect sizes (outcome effects) were calculated only for group training experiments and for study duration $\geq 4$ weeks. Further conclusions cannot be drawn from the available data.

RESULTS

Study Selection

A total of 72 studies were located and retrieved that addressed the issue of SST vs. MST interventions (see the Appendix). Most of the studies were published in scientific journals ($N = 59; 81.9\%$). The rest of the primary studies were published in anthologies ($4.2\%$), as abstracts/supplements
(8.3%), as columns (4.2%), and as monographs/theses (1.4%). Most studies were in English (N = 63; 87.5%). A review process was conducted for 88.7% (N = 63) with a mean impact factor of about 1.7 ± 0.9 (N = 61). The study design of the primary studies was as follows: (a) randomized controlled trial (RCT; N = 19; 26.8%), (b) randomized studies without control group (RT; N = 26; 36.6%) and 36.6% (N = 26) of the primary studies applied, and (c) quasi-experimental study design as well as cross-over design, single case study or scientific overview. This meta-analysis is based on the data of a total of 2,428 subjects. Because of a statistical distortion in two studies (621 [meta-analysis by Wolfe et al. 2004] and 220 [abstract/supplement by Buskies and Palandt 2003] subjects, respectively), the number of subjects in the primary studies was reduced to 1,587. The average age of all subjects was 28.0 ± 15.0 years (min = 8.5; max = 73.2; median = 21.5; there was no information as to the subjects’ age in the two distorted studies). Subjects of the primary studies were 53.4% male (N = 31 studies) and 12.1% female (N = 7 studies), and in 34.5% of all studies, both male and female subjects were included (N = 20 studies). More than half (54.5%) of the primary studies looked at trained subjects (N = 30 studies), and in 45.5% of the studies, the subjects were untrained (N = 25). In 57.7% (N = 41) of the primary studies, periodization strategies (e.g., linear, daily, or weekly undulating strategies) were applied (no periodization strategies 42.3%; N = 30). Single-set training (SST) methods and MST methods were directly compared in 31 of the primary studies (N = 43.1%). Of the primary studies, 56.9% (N = 41) referred to the topic of SST versus MST, but they did not offer a statistically relevant comparison. The relative intensity (percent 1-RM) ranged between 40% and 95%, while most studies applied relative intensities of 70% to 85%. The average training frequency as to the number of workouts within one microcycle (usually a week) was 2.8 ± 0.7 (N = 53; Fröhlich et al. 2008). The mean number of training sessions per study was 37.3 ± 23.9 (N = 53; Fröhlich et al. 2008). Of the primary studies, 81.9% (N = 59) contained information concerning which method of strength testing was applied. In most of the studies, 1-RM-tests were carried out (69.4%; N = 50). Isometrical and/or isokinetical tests of maximal strength as well as calculations of maximal strength from submaximal strength tests (e.g., 8-RM or 12-RM) were applied less frequently.
Main Effects
Across all designs, different interventions, and categories, the effect size of 1-RM ranged from 0.05 to 5.16, and the mean intervention effect size from pre-test to post-test was 0.98 ± 0.70 with a 95% CI = 0.87–1.10. According to Rhea's (2004a) categories to differentiate effect sizes in strength training research, the degree to which resistance training produced beneficial positive changes in muscular strength (1-RM) ranged from trivial (<0.25 highly trained subjects) to large (>2.0 untrained subjects), with a moderate to wide overall outcome. In addition, 54 effect sizes were calculated for single-set interventions (ES = 0.83 ± 0.61; 95% CI = 0.65–1.02), and 100 effect sizes were estimated for MST settings (ES = 1.10 ± 0.74; 95% CI = 0.92–1.20). A general significant difference between SST and MST was not found (F = 3.71; df = 1; p = 0.06; η² = 0.02). The outcome effects in MST were yet 27.2% higher than in SST interventions.

Subject Characteristics
A 3 × 2 covariance analysis was performed to determine the age effect (young people, middle-age, and older adults) between SST and MST. Cofactors were study duration and training experience. The analysis of simple main effects revealed that there were neither significant differences between single-set and multiple-set (F = 2.52; df = 1; p = 0.12; η² = 0.02), nor between the age categories (F = 1.74; df = 2; p = 0.18; η² = 0.03). No significant interaction of age category and the number of sets was found (F = 1.32; df = 2; p = 0.27; η² = 0.02).
We also analyzed the outcome of training status in the categories “trained” vs. “untrained,” and the number of sets performed. There was a significant difference (main effect) per training to the factor training experience (F = 14.27; df = 1; p < 0.05; η² = 0.10), which means that untrained subjects gained more maximal strength from either training method than trained subjects. Furthermore, we found a significant difference (main effect number of sets) between SST and MST (F = 7.32; df = 1; p < 0.05; η² = 0.06). The interaction of the factors training experience and number of sets is shown in Figure 1.

Subgroup Analysis
Whether or not periodization strategies were applied had the following influence on the results (ANCOVA with cofactors study duration and training experience): (a) main effect number of sets (F = 3.16; df = 1; p = 0.08; η² = 0.03); (b) main effect periodization (F = 2.56; df = 1; p = 0.11; η² = 0.02); and (c) interaction number of sets by periodization (F = 2.41; df = 1;
Effect sizes of periodization strategies in multiple-set training interventions (1.13 ± 0.85) are 21.4% higher than those of nonperiodization strategies (0.93 ± 0.50).

Concerning the duration of the primary studies, there is a significant difference between single-set and multiple-set studies ($F = 15.74; df = 1; p < 0.05; \eta^2 = 0.12$). Furthermore, the duration of the study (main effect 2) had a significant influence on the effect sizes ($F = 9.18; df = 4; p < 0.05; \eta^2 = 0.24$). Interaction between duration of the study and number of sets ($F = 3.97; df = 4; p < 0.05; \eta^2 = 0.12$) is shown in Table 1.

**TABLE 1** Effect Sizes of Single-Set and Multiple-Set Interventions for Different Study Durations

<table>
<thead>
<tr>
<th>Study duration</th>
<th>1–6 weeks</th>
<th>7–12 weeks</th>
<th>13–18 weeks</th>
<th>19–24 weeks</th>
<th>25–30 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-set</td>
<td>0.76 ± 0.32</td>
<td>1.02 ± 0.71</td>
<td>0.89 ± 1.07</td>
<td>0.76 ± 0.69</td>
<td>1.24 ± 0.34</td>
</tr>
<tr>
<td>Multiple-set</td>
<td>0.87 ± 0.38</td>
<td>1.05 ± 0.62</td>
<td>1.23 ± 0.64</td>
<td>0.81 ± 0.47</td>
<td>3.42 ± 2.04</td>
</tr>
</tbody>
</table>

*Note:* (Mean ± SD).
DISCUSSION

Main Aspects

Seventy-two primary studies were analyzed. The subject populations were very heterogeneous. Subjects included postmenopausal women (Kemmler et al. 2004), college students (Stone et al. 2000), beginners (Buskies and Palandt 2003), and recreational athletes (Hass et al. 2000). The subjects’ age ranged between 8.5 and 73.2 years. This heterogeneity was mirrored in the variables sex and training experience. In this context, the garbage-in and garbage-out criterion in meta-analysis was affected (Bortz and Döring 2006). The quality of the description of study characteristics like training parameters, training methods, testing methods, etc., varied considerably from study to study, so that only 54 effect sizes for single-set training and 100 effect sizes for multiple-set training could be calculated. Within these primary studies, a general significant difference between the results of single-set and multiple-set training could not be found. The statistical $p$-level was marginally missed ($p = 0.06$), but the practical relevance between the two training methods is high (Fröhlich 2006). The outcome effect for MST was 27.2% higher than for SST (Borst et al. 2001; Greiwing and Freiwald 2005; Kraemer 1997; Kraemer et al. 2000; Kramer et al. 1997; Marx et al. 1998; Munn 2005; Rhea, Alvar et al. 2002; Schlumberger, Stec, and Schmidtbleicher et al. 2001). Similar conclusions were drawn by De Hoyos et al. (1998), Galvao and Taaffe (2005), Munn et al. (2005), and Sanborn et al. (2000). They all summarized that training with multiplesets produces greater changes in strength than single-set interventions. Galvao and Taaffe (2005) point out that MST produces greater changes in strength and muscle endurance than single sets in healthy older adults. Nevertheless, low-volume training resulted in substantial improvements in strength, albeit not to the same level as the multiset regimen, and it should be incorporated when time available for exercise is limited. An original study by Kramer et al. (1997) found increases in strength for the squat that were 50% higher for multiple-set than for single-set interventions. Current studies by Kelly et al. (2007), Landin and Nelson (2007), and Ronnestad et al. (2007) demonstrated that MST is superior to SST with regard to strength gains. Willardson (2007) described the effects between one set to failure vs. multiple sets not performed to failure and demonstrated that the latter approach was superior for increasing maximal strength and power (Sanborn et al. 2000). In contrast, studies by Hass et al. (2000), Messier and Dill (1985), Ostrowski et al. (1997), as well as Vincent and colleagues (1998) found comparable improvements for single-set and multiple-set methods. Messier and Dill (1985) suggested that for a training period of short duration, Nautilus circuit weight training (single-set interventions) appears to be equally effective for untrained individuals. Similar results were found by Hass et al.:
After 13 wk of training, both groups had significantly improved their muscular strength, muscular endurance, and body composition. However, there were no significant differences between groups in the improvement of muscular strength or muscular endurance. Furthermore, both groups experienced similar improvements in body composition. (2000, p. 241).

In contrast to this, the studies by Paulsen et al. (2003) and Starkey et al. (1996) found higher effect sizes for SST than for MST. These studies, however, each tested isometrical and isokinetical strength gains using special training equipment, which must be taken into account when transferring these results to other training settings. In contrast to these findings, Kelly et al. (2007) concluded that performing three sets of isokinetic knee extensions was more effective than performing a single set for increasing peak torque.

Subgroup Aspects

In this review, age in the categories “young people,” “middle-aged subjects,” and “older adults” is not a factor with a significant influence on the efficiency of SST vs. MST. In this context, Galvao and Taaffe (2005) found that for 28 community-dwelling men and women aged between 65 to 78 years, that resistance training with only one set enhances muscle function and physical performance, but muscle strength and endurance gains are greater with higher-volume methods. The meta-analyses by Rhea, Alvar et al. (2003) and Wolfe et al. (2004) found no differences in strength gains between men and women. In these studies, the strength increases of the subjects were analyzed by categorizing subjects according to their age (15 to 25 years, 37 to 41 years, and 47 to 65 years), but no significant influence of the factor age was found (Wolfe et al. 2004, p. 43). It is well documented that an individual’s strength level varies considerably at different ages (Fleck and Kraemer 2004), but significant differences between the effects of single-set versus higher volume could not be found. The higher training volume of multiple-set interventions is believed to have a positive effect on the factor coordination, which may be advantageous for trainees with an emphasis on improving coordinative factors, e.g., during prepubertal phases. Beginners and formerly untrained people make similar progress from SST as from MST and successfully can increase strength levels with either training method (Landin and Nelson 2007; see overview by Galvao and Taaffe 2004). A clear implication that emerges from this statement is that the use of single-set programs may be appropriate for those who are beginners or untrained during the initial training period (Wolfe et al. 2004). The same aspect is stressed by Schlumberger and Schmidtbleicher (1999), who point out that MST will offer no advantages over single sets for beginners since strength increases during this initial phase mainly are due to coordinative and neuromuscular factors (Fleck and Kraemer 2004). Lavin (1999) agrees with this view:
Increases in strength in untrained subjects in the first 8–12 weeks of a resistance-training program are mostly due to neural recruitment. After this, the muscle begins to hypertrophy. Most of the research that claims that performing a single set to failure is as effective as multiple-set training has been done on untrained subjects within the first 8 weeks of a new program. During this phase of training, beginners will react to almost any stimulus (p. 17).

After this initial phase, muscular hypertrophy is an important factor for strength increases. Since these adaptations do not only depend on high resistance and high intramuscular tension, but also on depleting intramuscular energy levels, training intensity and training volume, as well as the time under tension are important factors for muscle hypertrophy (Fröhlich et al. 2007; Kraemer 2002; Zatsiorsky 1995). Craig and Kang (1994) underline the relevance of the factor training volume for increasing endogenous levels of human growth hormone: “The results indicate that total work may be more important than exercise intensity in stimulating hGH production during resistance training” (Craig and Kang 1994, p. 273). Another advantage of MST is that usually it results in a high accumulation of lactate, which seems to be beneficial for inducing muscular hypertrophy: “The higher plasma lactic acid accumulation following the progressive protocol, as opposed to the lactic acid response of single-set trials, suggests that muscle glycogen was utilized to a greater extent during the progressive routine” (Craig and Kang 1994, p. 274). In a study that had 10 women do either multiple sets or single sets, Mulligan et al. (1996) found that multiple sets resulted in an increase of growth hormone, lactate, and the catabolic hormone cortisol after the workout (0, 15, and 30 minutes), whereas only two of these hormones (growth hormone and cortisol) were elevated right after the workout (cortisol) and 15 minutes after the workout (cortisol and growth hormone). Therefore, the authors concluded that hormonal responses also must be taken into consideration when comparing these two methods. Kraemer (2002) even believed that there is a direct relationship between the number of sets and the progress made from a training program.

It must be emphasized, however, that training intensity as one of the most decisive parameters of strength training programs could not be included the analysis. This was due to the fact that most of the primary studies lacked sufficient information as to which degree of training intensity the sets were taken to and which percentage of relative intensity was used for that. This makes it even more difficult to prove a potential superiority of either SST or MST. Peterson et al. (2004) and Rhea, Alvar, et al. (2003) found that a relative intensity of as little as 60% of the 1-RM were enough to increase strength levels for beginners or untrained subjects. More advanced athletes should increase relative intensity to 80%–85% of their 1-RM (Kraemer 2002). Periodized MST results in higher increases of strength levels than nonperiodized SST (Landin and Nelson 2007). Which kind of periodization
models (linear, daily undulating, weekly undulating) produce the highest effect (outcome) has not been adequately analyzed (Buford et al. 2007; Rhea, Phillips, et al. 2003). A current study by Niknafs and Kok (2008) detected no significant difference in maximal strength or strength endurance between linear and undulating periodization models in untrained men.

Fleck and Kraemer (2004), Fleck (2002), Kraemer and Fleck (2007), as well as Willoughby (1993) point out the importance of periodization strategies for advanced trainees and competitive athletes. Stone et al. (2000) compared the effects of 12 weeks of a “nonperiodized linear model,” a “step-wise periodized model,” and an “overreaching periodized model” in terms of increasing the squat 1-RM. In contrast to the “nonperiodized model,” both periodized programs resulted in a significant increase of the subjects’ 1-RM for the squat. Similar results were found by Rhea et al. (2002a), who concluded that for recreationally trained individuals who used daily undulating periodization training, three sets of training are superior to one set for eliciting maximal strength gains. Sanborn and colleagues (2000) agree with this. They pointed out that training protocols with multiple sets and variation in volume, training intensity, and exercise speed can enhance performance to a greater extent than a single-set intervention to failure protocol.

CONCLUSION

The aim of this meta-analysis was to compare the efficiency of SST versus MST for increasing maximal strength levels. The results correspond to a great extent with those found in many overview studies in this context, such as the studies by Peterson et al. (2004, 2005), Rhea, Alvar, et al. (2003), and Wolfe et al. (2004). Generally speaking, it can be stated that MST, depending on factors like age, training experience, duration of the study, etc., offers several advantages over SST regimes, especially when combined with periodization strategies, and it can be applied very successfully for increasing maximal strength in long-time effects. Therefore, the outcome effects of both methods are the same in short-time interventions. For longer-time interventions and for advanced subjects with the goal of optimizing their strength gain, however, MSS are superior. For untrained subjects SST shows equal effects.

REFERENCES


**APPENDIX: ANALYZED PRIMARY STUDIES IN ALPHABETICAL ORDER**