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# Effects of Single vs. Multiple Sets of Weight Training: Impact of Volume, Intensity, and Variation

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**Reference Data**
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ABSTRACT

This study examined the effects of a single set of weight training exercise to failure and 2 multiple-set protocols (not to failure) on the 1-RM parallel squat. Forty-three men were randomly assigned to 1 of 3 weight training protocols emphasizing leg and hip strength: SS = single set to failure of 8–12 reps; MS = 3 × 10 reps; MSV = multiple-set program using a varied set and rep scheme. Relative intensity (% initial 1-RM), intensity (average mass lifted), and volume load (repetitions × mass) differed between groups over 14 weeks. Body mass, body composition, and the 1-RM parallel squat were assessed at baseline and at Weeks 5 and 14. Results showed no significant changes in body mass or body composition. The 1-RM squat increased significantly in all groups. Differences in 1-RM between groups indicate that MS and MSV increased approximately 50% more than SS over the 14 weeks. Results suggest that multiple sets not performed to failure produce superior gains in the 1-RM squat.

*Key Words*: strength, exertion, exercise

## Introduction

An increase in isometric or dynamic maximum strength (17) can be an obvious benefit of weight training. However, some controversy exists as to what training protocol most effectively increases maximum strength. Part of the controversy involves the number of sets per exercise. The use of one set to muscular failure per exercise has been advocated for isolated and multijoint exercises on both free weights and machines for more than 20 years (10). Although little objective evidence is presented, some proponents have suggested that training with one set of an exercise to muscular failure (8–12 reps) is adequate for maximizing muscular growth and strength gains (4, 26). Thus, if increasing maximum strength is the primary goal of training, the duration of a weight training session could be shortened (26).

The use of multiple sets in resistance exercise has been shown to produce superior maximum strength gains (3, 25). Conversely, other studies (9, 19) found limited volume effect of one vs. multiple sets in a single exercise. Fleck and Kraemer (5) suggest that the neuromuscular system will adapt to a given strength stimulus (e.g., one set to failure), and that once this adaptation occurs, a multiple presentation (multiple sets) becomes a superior stimulus. Thus, over a reasonable period of months or years, multiple-set programs should produce strength gains faster than those obtained by using one set (1, 13), due to a greater dose of training stimuli (3).

In addition to multiple sets per exercise, some researchers have advocated variation in volume and intensity in order to produce optimal gains in maximum strength (5, 6, 23, 27). Fleck and Kraemer (5) suggest that a key to continued gains in maximum strength is variation in the exercise stimulus. Thus, a strength training schedule using programmed volume and intensity variation may produce superior results compared to schedules not using varying stimuli.

The purpose of this study was to compare the effects of using a single set to muscular failure and 2 multiple-set weight training protocols—with and without programmed variation in volume and intensity—not to muscular failure over 14 weeks in moderately trained men. Comparisons were made on a measure of dynamic maximum strength (1-RM parallel squat) and body mass and composition using moderately trained men. Comparisons were also made on training volume load, intensity, and relative intensity.

## Methods

The subjects were 53 male college students ($M \pm SEM$, 20.3 ± 1.9 yrs). All were fully informed of the procedures and signed a consent form prior to participation in accordance with institutional review board procedures. They were selected on the basis of familiarity with the parallel squat. Subjects were recreational weight trainers who had to be able to squat at least their body mass with good technique in order to be considered moderately trained. They were randomly assigned to 1 of 3 training groups. No significant differences were observed between groups for initial 1-RM squat or physical characteristics.

Subjects had to complete 90% of the training days to be included in the results of the study. Ten withdrew before completion due to illness or injury unrelated to the study. The physical characteristics of the 43 who completed the experiment were ($M \pm SD$), height 181.5 ± 6.1 cm, and baseline body mass, 79.0 ± 10.0 kg. Single set (SS) ($n = 16$) trained using 1 set to failure. Multiple sets of 10 (MS) ($n = 14$) trained using 3 sets of 10 reps (after warm-up) for 14 weeks. Multiple sets varied (MSV) ($n = 13$) trained using multiple sets in which training intensity and volume was varied over the 14 weeks.

The subjects trained 3 days a week for 14 weeks. On Monday and Friday they performed parallel squats, push presses, bench presses, and crunches. On Wednesday they performed midthigh clean pulls, leg curls, bent-over rows, and crunches. They performed the exercises in the order listed below and in accordance with their assigned training protocols:

| • *Monday & Friday* | • *Wednesday* |
|---|---|
| 1. Squat | 1. Pull from mid-thigh |
| 2. Push press | 2. Leg curl |
| 3. Bench press | 3. Bent-over row |
| 4. Crunch | 4. Crunch |

The programs consisted of both major and assistance type exercises. Major exercises were multisegment lifting movements such as the squat, which are generally used in both athletic and nonathletic training programs. Assistance exercises involved smaller muscle mass (crunches, leg curls, and bent-over rows). They were designed to strengthen specific isolated muscles (23). Subjects chose their own rest periods (typically 2–3 min) between sets and exercises. All training sessions were timed with a stopwatch and were monitored by two or more experienced investigators.

SS performed 1 set to failure (8–12 reps) of each exercise. Failure was the point at which the movement could not be completed or the subject's technique failed, increasing the risk for injury. One very light warm-up set of 10 reps was performed prior to the one set to failure. Subjects in this group selected a target weight that would allow them to complete at least 8 reps but no more than 12. If a subject could perform more than 12 reps, the weight was increased at the next training session.

MS performed 3 sets of 10 reps at a target weight preceded by 2 warm-up sets. MSV used a training program in which volume and intensity were varied throughout the 14 weeks for the major-muscle-group exercises. Assistance exercises were performed for 3 sets of 10 reps for the first 2 weeks and then for 5 reps thereafter. Training protocols were as follows:

- *Group 1*: one set to failure
  1 warm-up set (50% of target), 10 reps
  1 target set to failure, 8–12 reps.
- *Group 2*: multiple sets of 10 reps
  1 warm-up set, 10 reps, 50% of target
  1 warm-up set, 10 reps, 75% of target
  3 sets, 10 reps at a target weight
  warm-up sets only for major exercises.
- *Group 3*: multiple sets with variations, sets and reps for major exercises at target weight
  Weeks 1–5, respectively: 1, 3, 3, 3, & 3 sets; 10, 5, 5, 3, & 3 reps
  Week 6: tests
  Weeks 7–10, respectively: 1, 3, 3, & 3 sets; 10, 5, 5, & 3 reps
  Weeks 11–14, respectively: 1, 3, 3, & 3 sets; 10, 5, 3, & 2 reps
  Week 15: tests.

Subjects in MS and MSV used heavy loads (RM loads) on Monday and light loads on Friday. The initial RM values for the first heavy training day were set by the instructors based on previous experience and were adjusted throughout the study to maintain RM values. Great care was taken to ensure that MS and MSV did not train to failure. Monday's RM target weights for MS and MSV were reduced by 10% on Fridays to ensure that all sets and reps could be accomplished and to reduce the potential for overtraining (23).

The training protocols provided a clear comparison of multiple sets (not to failure) vs. one set to failure. SS was chosen to examine the use of relatively low volumes of resistance training. MS was chosen because it offers a relatively high volume of training and is commonly used in a variety of contexts (e.g., bodybuilding, preparation phase training) (14, 23). MSV used cyclical variations in volume and intensity and did not represent a typical mesocycle-length periodized protocol in that the initial high volume phase was deleted. However, cyclical variation in volume and intensity may provide an added stimulus for performance gains (5, 15, 23, 27). Subjects kept a training log which the investigators collected after each training session. Volume load (repetitions × mass lifted), intensity (average mass lifted), and relative intensity (% of initial 1-RM) were calculated from training data.

The training variables analyzed included volume load (repetitions × mass lifted), intensity (average mass lifted), and relative intensity (% of initial 1-RM) of the target sets for the squat. The mean of each training variable was analyzed by week and by phase (Phase 1 = 0–5 wks; Phase 2 = 7–14 wks; Phase 3 = 0–14 wks).

### *Experimental Tests*

Testing was completed at 0 and at 5 and 14 weeks. The 1-RM parallel squat was used to test for maximum dynamic strength (21) and was measured using the methods outlined by Stone and O'Bryant (23). The reliability of the 1-RM squat was $r = 0.93$. It was included as a specific test for maximum strength because it was performed as a regular exercise in training and is an excellent measure of lower body strength. Lack of specificity in testing maximum strength may have clouded the interpretation of a previous study (19). Furthermore, the squat is commonly used in both athletic and nonathletic training programs. Additional maximum strength comparisons were made by dividing the 1-RM squat by body mass and lean body mass.

Body mass was measured on a medical scale with the subjects in shirts and shorts, no shoes. Body composition was estimated from skinfolds taken on the right side by an experienced tester at 7 sites (8, 18). Subjects were measured by the same tester at all testing sessions.

Data were analyzed using a group × trials (G × T) repeated measures ANOVA. Significant interactions were analyzed using gain scores and a $t$-test with a Bonferoni adjustment. Alpha level was set at $p < 0.05$.

## Results

All groups increased significantly across time in the absolute squat, squat/body mass, and squat/lean body mass. Significant G × T interactions occurred for all squat variables. From Weeks 0 to 14, MS and MSV increased significantly more than SS on all 1-RM squat variables. From Weeks 0 to 5, MS increased significantly more than SS on all variables. From Weeks 5 to 14, MSV increased significantly more than SS on all variables. Results for the squat are shown in Table 1. Compared to MS and MSV, SS achieved approximately 50% of the maximum strength gains as measured by the 1-RM squat over 14 weeks. These results suggest that multiple sets increase the 1-RM squat at a faster rate than 1 set to failure.

Volume of training can be estimated by volume load. Significant differences for volume load occurred between SS and MS at all weeks. Significant differences for volume load occurred between SS and MSV at Weeks 2, 3, 8, 9, 12, and 13. MS and MSV were significantly different at all weeks (Figure 1). Volume loads for MS were significantly larger than for SS and MSV at all phases. SS and MSV were not significantly different during any phase (Table 2).

**Table 1**
**Improvement in the Squat (*M* ±*SD*)**

| Test period | SS *M* | SS ±*SD* | MS *M* | MS ±*SD* | MSV *M* | MSV ±*SD* |
|---|---|---|---|---|---|---|
| *Squat (kg)* | | | | | | |
| Wk 0 | 101.9 | 20.6 | 98.5 | 27.7 | 111.2 | 25.6 |
| Wk 5 | 108.5 | 18.5 | 113.6 | 31.8 | 123.3 | 23.0 |
| Wk 14 | 114.1 | 18.7 | 123.7 | 43.2 | 135.7 | 20.6 |
| *Squat/body mass (kg)* | | | | | | |
| Wk 0 | 1.30 | 0.3 | 1.27 | 0.2 | 1.36 | 0.3 |
| Wk 5 | 1.39 | 0.2 | 1.45 | 0.2 | 1.50 | 0.2 |
| Wk 14 | 1.45 | 0.2 | 1.56 | 0.3 | 1.66 | 0.2 |
| *Squat/lean body mass* | | | | | | |
| Wk 0 | 1.51 | 0.3 | 1.47 | 0.3 | 1.61 | 0.3 |
| Wk 5 | 1.61 | 0.3 | 1.68 | 0.3 | 1.77 | 0.2 |
| Wk 14 | 1.68 | 0.2 | 1.81 | 0.4 | 1.97 | 0.2 |

*Note.* Significant time effect, all groups; significant interactions for all variables.
Wks 0–14: MS & MSV > SS; Wks 0–5: MS > SS; Wks 5–14: MSV > SS. SS = single set to failure; MS = mult. sets of 10 reps; MSV = variation in volume & intensity.

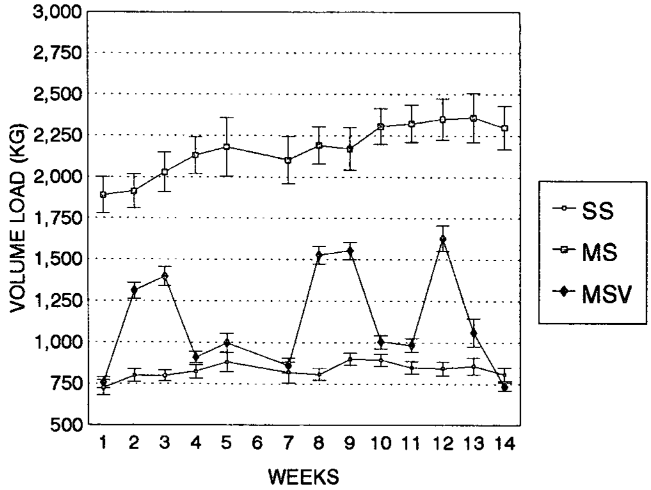


**Figure 1.** Target volume load (kg). MS > SS and MSV: Wks 1–14; MSV > SS: Wks 2, 3, 8, 9, 12, 13.

**Table 2**
**Training Variables by Phase**

| Variable | SS *M* | SS ±*SD* | MS *M* | MS ±*SD* | MSV *M* | MSV ±*SD* |
|---|---|---|---|---|---|---|
| *Volume load (kg)* | | | | | | |
| Phase 1 (0–5 wks) | 750[a] | 144 | 1936[c] | 529 | 1005 | 175 |
| Phase 2 (7–14 wks) | 787[a] | 134 | 2185[c] | 564 | 1103 | 187 |
| Phase 3 (0–14 wks) | 769[a] | 136 | 2061[c] | 539 | 1054 | 179 |
| *Intensity (kg)* | | | | | | |
| Phase 1 (0–5 wks) | 69[b] | 13 | 64 | 17 | 91 | 16 |
| Phase 2 (7–14 wks) | 74[b] | 12 | 73[c] | 18 | 104 | 18 |
| Phase 3 (0–14 wks) | 72[b] | 12 | 69[c] | 17 | 97 | 17 |
| *Relative intensity (% 1-RM)* | | | | | | |
| Phase 1 (0–5 wks) | 75[a,b] | 3 | 66[c] | 9 | 84 | 7 |
| Phase 2 (7–14 wks) | 81[b] | 6 | 75[c] | 12 | 97 | 11 |
| Phase 3 (0–14 wks) | 78[a,b] | 4 | 70[c] | 10 | 91 | 9 |

SS = single set to failure; MS = mult. sets of 10 reps; MSV = variation in volume & intensity.
Signif. different: [a]SS from MS; [b]SS from MSV; [c]MS from MSV.

Intensity of training can be estimated by the average mass lifted. No significant differences occurred for intensity between SS and MS. Significant differences did occur for intensity between SS and MS vs. MSV at Weeks 2–5, 8–10, and 12–14 (Figure 2). The intensity for MSV was significantly greater than for SS and MS at all phases. SS and MS were not significantly different during any phase (Table 2).

Relative intensity of training can be estimated by the % of initial 1-RM. Significant differences occurred for relative intensity between SS and MS at Weeks 1–3 and 11; between SS and MSV at Weeks 1–5, 8–10, and 12–14; and between MS and MSV at Weeks 2–5, 8–10, and 12–14 (Figure 3). The relative intensity was significantly different between all groups at all 3 phases, except during Phase 2 where SS and MS were not significantly different (Table 2).

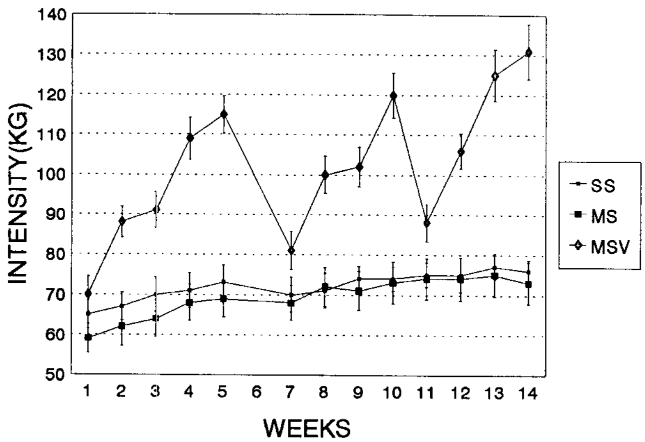


**Figure 2.** Target intensity (kg). MSV > SS and MS: Wks 2–5, 8–10, 12–14.

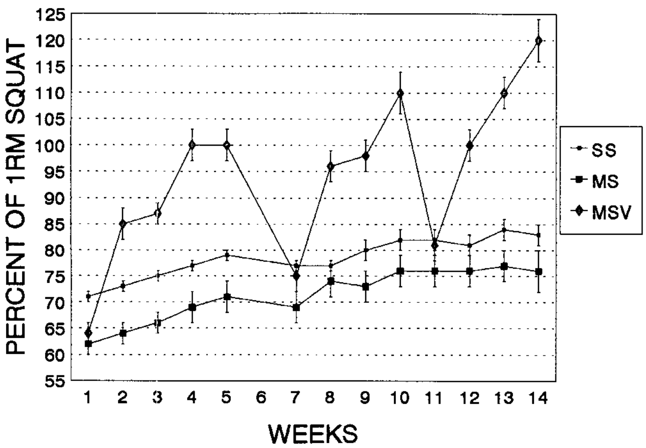


**Figure 3.** Target relative intensity (% initial 1-RM). SS > MSV: Wk 1; MSV > MS and SS: Wks 2–5, 8–10, 12–14.

**Table 3**
**Body Mass and Body Composition**

| | SS | | MS | | MSV | |
|---|---|---|---|---|---|---|
| Test period | *M* | ±*SD* | *M* | ±*SD* | *M* | ±*SD* |
| *Body mass (kg)* | | | | | | |
| Wk 0 | 78.4 | 8.4 | 76.8 | 10.1 | 82.0 | 12.1 |
| Wk 5 | 78.3 | 7.6 | 77.4 | 10.3 | 82.1 | 11.9 |
| Wk 14 | 78.6 | 8.1 | 78.3 | 10.4 | 82.3 | 12.1 |
| *Body fat (%)* | | | | | | |
| Wk 0 | 13.6 | 4.0 | 13.1 | 3.9 | 15.6 | 4.9 |
| Wk 5 | 13.4 | 4.5 | 13.2 | 4.0 | 15.3 | 5.1 |
| Wk 14 | 13.5 | 4.2 | 13.3 | 4.4 | 15.8 | 5.6 |
| *Lean body mass (kg)* | | | | | | |
| Wk 0 | 67.5 | 5.5 | 66.5 | 7.5 | 68.9 | 8.0 |
| Wk 5 | 67.6 | 5.4 | 67.0 | 7.3 | 69.2 | 8.1 |
| Wk 14 | 67.9 | 5.9 | 67.6 | 7.2 | 68.9 | 7.7 |

SS = single set to failure; MS = mult. sets of 10 reps; MSV = variation in volume & intensity.

Body mass and body composition measures did not change significantly over time. Although no significant group interactions were found, the relatively large change in MS for body mass and LBM could affect relative strength measures (Table 3).

## Discussion

The results indicate that training with multiple sets, not performed to failure, are superior to a single set to failure for increasing the 1-RM squat. It is generally believed that relative intensity is a primary factor in maximum strength gains (1, 11). However, in this study, during Phase 1 (Weeks 0–5) the MS gained 1-RM squat strength at a faster rate than the other 2 groups despite the use of a significantly lower relative intensity. Although not noted consistently, the finding of an initial volume effect on the 1-RM squat has also been observed by O'Bryant (15, 16). Furthermore, the volume load for MS was markedly higher than for SS and MSV.

It is possible that the MS' greater volume of training allowed them more practice, resulting in greater increases in the 1-RM. However, this is unlikely because they had been previously training and were familiar with the squat. This indicates that, during the initial phase of training, the volume of work performed may be a primary factor in maximum strength gains and supports the use of high volume preparation phases at the beginning of a resistance training program (5, 23).

After Phase 1, MSV showed faster increases in the 1-RM squat than SS, while MS produced gains between these 2 groups. MSV achieved higher training and relative intensities than SS and MS. During Phase 2 (Weeks 7–14), MSV and MS achieved volume loads that were 40% and 178% higher, respectively, than SS. This suggests three possibilities:

First, training volume may have affected the rates of gain in the 1-RM squat during Phase 2 of training (2). However, this does not totally explain the differences in rates of 1-RM gain. If volume load was a more important factor than intensity or relative intensity, then MS, which used the highest volume load during all phases, should have produced the greatest gains in the 1-RM squat; this did not occur.

Second, after the initial phase of training, intensity and relative intensity began to affect the rate of maximum strength gain to a greater degree than volume load. This finding is in disagreement with the observations of Baker et al. (2), who suggest that training volume is a more important factor than intensity in eliciting strength gains in the squat.

Third, it is also possible that the greater gains in 1-RM squat for MSV during Phase 2 are due to variation in volume and intensity which were not part of the program in the other groups (5, 23, 27). With few exceptions (2, 9), weight training protocols using programmed variation have shown superior increases in the 1RM squat compared to nonvariation protocols over a mesocycle length (15, 16, 24, 25, 27).

Weight training can significantly alter body composition (22). The present study noted no significant differences. This could be attributed to the initial trained state of the subjects. Baker et al. (2) suggest that an increase in lean body mass (LBM) is the main reason for strength gains in weight trained individuals. However, the results of this study indicate that substantial increases in the 1-RM squat can be made without significant increases in LBM. The observed increase in 1-RM squat may be due primarily to increased neural activation and may be related to training intensity (23). Hakkinen et al. (7) have suggested that relative intensites of 80% or more of the 1-RM are needed to maximize neural activation. The greater rate of improvement in MSV during Phase 2 may be related to enhanced neural activation as a result of their higher relative intensities (>80%) compared to the other two groups (<80%) (15, 23).

The results of the present study are similar to those of previous studies using initially untrained subjects (12, 25), demonstrating that multiple sets produce superior gains in leg and hip maximum strength compared to single-set protocols. Thus, in training programs targeted to improving dynamic maximum strength, these data indicate that multiple sets produce superior results.

Combining an initial high volume training protocol with subsequent higher intensity and variation in volume and intensity could produce superior results. Support for this approach to training can be found in the concept of periodization. Periodized short-term protocols (mezocyle length of several months) begin with a high volume initial phase and then move to a higher intensity phase usually coupled with considerable day-to-day and week-to-week variation (15, 20, 21, 23). Studies with a periodized protocol have generally shown superior strength increases in various measures of hip and leg maximum strength using untrained (15, 16, 21, 25), trained (15), and previously trained subjects (27).

The results of this study indicate that multiple sets, not performed to muscular failure, yield superior gains in 1-RM squat strength compared to one set to failure in moderately trained sujects. The results also indicate that, during the initial phase of training, volume is more important than intensity in increasing the 1-RM squat. Furthermore, after the initial phase of training, variation and intensity factors may be more important than volume considerations.

## Practical Applications

From a practical standpoint, the results of the present study suggest that a relatively high volume load used during the initial phase of training can facilitate initial gains in maximum strength in moderately trained subjects. After this initial phase of training, a protocol with a higher intensity as well as variation in volume and intensity can facilitate strength gains. Support for this contention is found in the concept of periodization (15, 16, 20, 21, 23, 25, 27).

Training session time may be a factor in some cases. Short workouts may be an advantage for some people. The time taken to complete training sessions was measured with stopwatches during each week of the experiment. The time taken to complete the training sessions for SS (1 set to failure) ranged from 30 to 40 min and was typically 40–50 min for the multiple-set groups. Thus, if time is a factor, fewer sets may save time but can also diminish the improvements. From a practical standpoint, if increased maximum strength is a primary goal, then a reduction in sets to save 10–20 min may be counterproductive. This argument may be especially important for athletes in whom strength and power development are primary goals.

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