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# The effectiveness of single-set vs. multiple-set training – A meta-analytical consideration

Keywords: single-set, multiple-set, hypertrophy training, strength training, training volume

## Introduction

As one of the most popular kinds of physical activity, strength training does not only improve muscular fitness and health (ACSM, 2002; Feigenbaum & Pollock, 1999), it is also an essential part of training programs for many kinds of competitive athletes (Kraemer & Häkkinen, 2002). The design of individual training programs is usually based on adjusting training parameters such as relative intensity, training intensity, frequency, number of sets, number of exercises, and rest between sets according to the trainees's needs. Whereas the effects of different training frequencies (Carroll et al., 1998; Wirth & Schmidtbleicher, 2002), relative training intensities (Fleck & Kraemer, 1997; Zatsiorsky, 1995) and rest periods between sets (Robinson et al., 1995) have been well-studied, there is considerable demand for research focussing on the effects of different training volumes, especially the number of sets per exercise (Philipp, 1999b; Stone et al., 1998). There is a discussion going on in the scientific literature for several years as to which number of sets per exercise might be best (Gießing, 2000; Heiduk et al., 2002; Philipp, 1999a; 1999b; Schlumberger & Schmidtbleicher, 1999). This meta-analysis was carried out in order to supply data for an unbiased evaluation of the available data on this matter.

### *Theoretical background*

In recent years several articles that deal with practical, physiological and methodological aspects of single-set training and multiple-set training as well as advantages and limitations of either method have been published in the journal "Leistungssport". More articles on the same subject have been published in the "Journal of Strength and Conditioning Research" focussing on the results of several empirical studies (Peterson et al., 2004; Rhea et al., 2003; 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 increases in strength and muscle mass, this would make it the most efficient kind of training considering the reduced training volume and time spent training (Brown, 1999; Carpinelli, 2002; Feigenbaum & Pollock, 1999; Philipp, 1999a). Carpinelli (2002, p. 323) refers to the reason for the alleged superiority of MST:

> "The genesis of the belief that multiple sets of each exercise are superior to a single set for maximal strength gains is one very poorly controlled 40 year old strength training study by Berger. The evidence to support the performance of multiple sets is extremely weak. Most of the evidence suggests that single and multiple sets produce similar increases in strength."

Feigenbaum and Pollock (1999, p. 38) 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 training:

> "Single set programs are less time consuming and more cost efficient, which generally translates into improved program compliance. Further, single set programs are recommended for the above-mentioned populations because they produce most of the health and fitness benefits of multiple set programs."

Kieser (1998, p. 28) claims that SST produces at least similar results as MST but requires much less time which – according to Kieser makes SST superior to MST. Although the efficiency of SST, especially for recreational or non-competitive trainees, is not questioned (Schlumberger & Schmidtbleicher, 1999, p. 10), the "costs" (goals which may not be achieved because of a less-than-optimal training program) must also be taken into consideration. This question can only be answered considering different priorities, preferences and the general framework of a given training program. Improvements in terms of maximal strength, muscle strength endurance, muscle hypertrophy as well as hormonal reactions as the result of SST and MST respectively have to be considered. The aspect of time-efficiency can only be answered individually, structurally and methodologically.

*Definition, characterization and analysis of SST and MST*

The terminological inconsistency concerning the terms SST and MST has been described by Gießing et al. (2005a, p. 9-10.) and Heiduk et al. (2002). Gießing et al. (2005a) have suggested definitions that clearly distinguish the differences between both training methods. Figure 1 shows that SST as well as high intensity training (HIT) are both defined as kinds of low volume training (LVT) whereas MST is defined as a kind of high volume training (HVT):

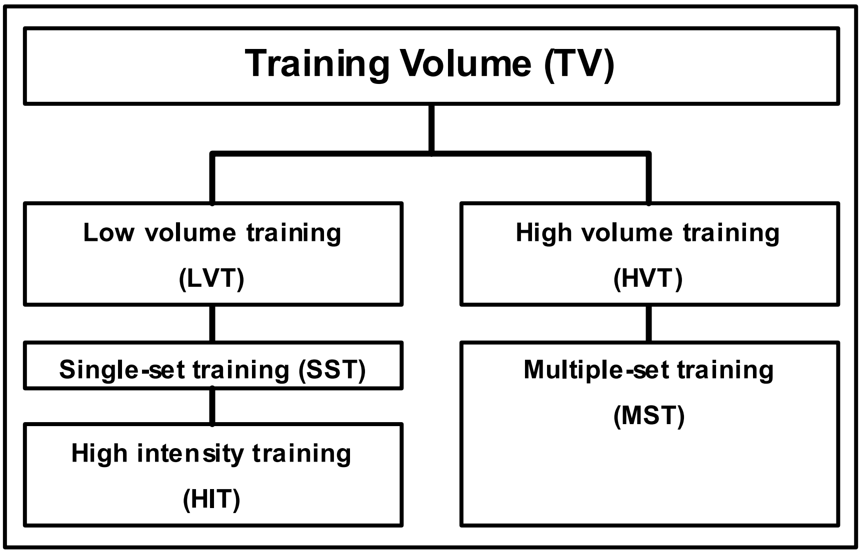


*Figure 1: Characterisation of training methods by the factor training volume (according to Heiduk et al. (2002, p. 5) and Gießing et al. (2005, p. 11))*

It has to be stated that the terms "SST" and "MST" require some clarification. Apart from the factor training volume the number of sets per target muscle (not per exercise), training intensity (Gießing et al., 2005b), range and speed of motion, and time under tension (TUT) have to be taken into consideration (Gießing et al., 2005a, p. 11), as well as the factors duration, exercised used, training experience of the subjects, testing procedures, whether or not periodization was applied, and how the effects of the training are transferred (Brown, 1999, p. 17; Kemmler et al., 2004, p. 689). However, the most important information in this context is to know the trainee's individual goals.

> "One set or more, is there a difference? To answer this question, we must know the trainee´s goal." (Stone et al., 1998, p. 22)

In the past there have been different interpretations of the terms "SST" and "MST" with some referring to the number of sets per exercise and others referring to the number of sets per "muscle group". Since "muscle group" is an unscientific term that describes regions of the body rather than actual muscle groups (muscles that contract synergistically when performing certain movements, e.g. the leg extensor muscles contracting synergistically when performing squats or leg extensions), it has become generally accepted that SST is defined as follows:

> "One set per exercise is performed which includes the possibility of performing more than one exercise per muscle group." (Gießing et al., 2005a, p. 17)

MST is defined as

> […] "two or more sets per exercise with a break of at least 30 seconds between two sets of the same exercise. One or more exercises per muscle group may be performed." (Gießing et al., 2005a, p. 17)

Since several studies have compared SST and MST (Rhea et al., 2002; 2003; Wolfe et al., 2004), this article deals with an analysis of the available data and puts an emphasis on the following questions: (a) Is either one method more efficient than the other one? (b) Is this potential difference of practical relevance for trainees? (c) How important are factors like the subjects' sex, training experience, duration of the study, or periodization?
The aggregation of the empirical data and the quantitative integration of the results were accomplished by means of a meta-analysis (Beelmann & Bliesener, 1994).

**Method**

*Aggregation of primary data*

Primary data was aggregated by using data bases and research systems like SPOLIT, SPOFOR, SPOMEDIA (Bundesinstitut für Sportwissenschaft), medline und medline alert (Deutsches Institut für Medizinische Dokumentation und Information), pubMed (National Library of Medicine), Medpilot (Deutsche Zentralbibliothek für Medizin) as well as the main library for sports science of the Deutsche Sporthochschule in Cologne. German and English keywords were: "Einsatztraining", "Einsatz-Training", "Mehrsatztraining", "Mehrsatz-Training", "single set", "single-set", "multiple set", "multiple-set " in combination with or without "training".

*Codification and evaluation of the contents and methodology of the primary data*

The primary data was codified by a priori determined yet open system of codification (Rustenbach, 2003). Descriptive information about the respective study was followed by aspects of testing procedures and training methods, information on methodology and evaluation of the primary study as well as the authors' conclusions (cf. Table 1). The description of the codified data was done 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)

(Rustenbach, 2003, p. 41). Internal and external validity, constructural validity and statistical validity was collected using a scale rating from “low = 0“, “medium = 1“, and “high = 2“.

*Table 1: Scheme of codification and characteristics of the studies*

| scheme of codification | characteristics of the studies |
| --- | --- |
| descriptive information | author(s), year of publication, kind of publication, title of the journal, peer review and impact factor, language of publication, study design, number of subjects, average age of subjects, sex, further characteristics of subjects |
| information about testing and training | number of test exercises, number of training exercises, kinds of exercises used, information about training parameters (intensity, volume, duration of rest between sets/exercises, number of sets, training frequency per week, training frequency altogether, periodization, duration of the study (weeks), testing method (1-RM, RM, PMF, PMF+, isometrical/isokinetic Fmax, anthropometrical data) |
| information about training methods | rating of methodology, rating of the results, rating of internal and external, statistical validity und constructural validity, information about the statistical testing criteria and process of testing |
| the author(s)’ conclusion | interpretation and conclusion by the author(s)’ |

*Primary studies and their findings*

Altogether the results of 52 (see appendix) studies dealing with SST and MST could be included in this analysis. These studies were published within the last 20 years, most of them having been published within the last six years. 80.8 % of these studies were published in scientific journals (N = 42). The rest were published in anthologies (N = 3), abstracts (N = 4) and columns (N = 3).
84.6 % of the primary studies were published in English (N = 44) and 15.4 % were published in German. These studies include many different kinds of studies: single-case study (1.9 %), cross-over-design (5.8 %), meta-analysis (5.8 %), quasi-experimental design (5.8 %), reviews of the literature (23.1 %), randomised studies without control groups (28.8 %) and randomised studies with control groups (28.8 %). This shows that a large variety of study could be included with an emphasis on randomised studies (Moher et al., 2001).

*Statistcal analysis and calculation of effect size*

The statistical analysis included factors like mean value, standard deviation, frequency distribution, confidence intervals, median. The interference-statistical calculation of significance was done using t-test and ANOVA. Calculation of effect size 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, p. 95). Pre-post calculation of effect size for the

training experiment followed, if there was no data of a control group by $g_{Hedges} = (x_1 - x_2)/s_{pooled}$ with calculating $s_{pooled}$ by $s_{pooled} = \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}}$.
Effect size in studies with control groups was calculated by assessing the difference of mean values in the experimental group in comparison to those in the control group divided by the standard deviation in the control group (Wolfe et al., 2004, p. 36).

*Methodical criticism*

In some meta-analytical studies a median of different dependent variables (e.g. 1-RM, muscle strength endurance, increase of muscle circumference, reduction of body fat, hormonal changes etc.) is calculated and regarded as the "overall effect size", Winett (2004, p. 11) points out:

> "In a meta-analysis, for example, an overall mean for all the effect sizes from studies with multiple set protocols can be compared to an overall mean for all the effects sizes for single set protocols to determine if there is a statistically significant difference between them."

The following meta-analysis analyses changes of the effect size of the factor "maximal strength". Therefore, the comparison of the results of SST and MST in this study is a comparison of changes of maximal strength. This approach was chosen because in the different primary studies the operationalisation of muscle strength endurance, muscle circumference, reduction of body fat, hormonal changes, cardio-pulmonary and metabolic demands etc. was assessed using several different approaches and different ranges of subject populations. In addition to that, effect sizes were only calculated for group training experiments. Further conclusions cannot be drawn from the available data.

*Operationalisation of the dependent variable "change of maximal strength"*

Changes of maximal strength were tested by determining 1-RM, isometrical maximal strength and/or isokinetic maximal strength or as the difference between post-test and pre-test in absolute numbers or percentages. The problems which may occur when measuring maximal strength have to be considered (Gießing et al., 2005a; Fröhlich & Marschall, 2001).