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Results of an empirical study using bioelectrical impedance analysis

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1 Introduction

Training programs are comprised of the training parameters volume, intensity, duration, and frequency. All of those parameters do interact with each other. If one parameter increases, at least one of the others is usually reduced since recuperation capacity is limited. Following the model of supercompensation, recuperation from a workout is needed to make progress in terms of inducing the intended physiological adaptations.

When referring to strength training the parameters duration, volume and frequency are easily defined. The duration of a workout is defined as the time span between starting and finishing a workout. Training frequency is usually the number of workouts within a given space of time, e.g. a week. Training volume is usually defined as the sum of all sets performed within one workout or one week etc.

Training intensity, however, is a term that needs further consideration. When referring to cardio training, intensity is measured by the trainee's momentary heart rate and its percentage of the maximum. If a runner whose maximum heart rate is 200 beats per minute, has a heart rate of 142 beats per minute while running, then them momentary training intensity is 71%. If the heart rate increases or decreases, so does the training intensity. When referring to strength training, the definition of the intensity parameter needs further clarification.

2 Training intensity and its implications for strength training programs

It was generally accepted that increases in muscular hypertrophy can best be achieved by applying high training volumes and moderate training intensity, allowing eight to fifteen repetitions. High training volume usually means performing several exercises per muscle group and multiple sets of each exercise. It was recommended to take sets to "failure", an expression which was often used to point out the fact that due to momentary muscular fatigue further repetitions could not be performed. Therefore, training intensity is often defined as "high" although only moderate resistance is applied. The reason is that the term "intensity" has only recently been redefined. It not only describes *relative intensity* (RI) which means the percentage of weight that can be used for a single repetition (% of the 1Repetition Maximum), it also refers to *training intensity* (TI) which is defined as "the possible momentary muscular effort being exerted" (Mentzer; 1996; 46). Consequently, training intensity is a vital aspect in designing, analysing, or evaluating training programs. The distinction whether or not sets were taken "to failure" was usually added to the information used to describe a training program. However, "training to failure" turned out to be an expression that needed further clarification. Some authors interpreted it as completing as many repetitions as possible with a given resistance whereas others understood the term "muscular failure" as a degree of local muscle exhaustion that makes it impossible to continue moving the weight at all. The generally accepted definition of training intensity now distinguishes four different degrees of training intensity:

degrees of training intensity	
nRM	non repetition maximum Terminating a set at a fixed number of repetitions or a certain rate of perceived exertion when additional repetitions are possible.
RM	repetition maximum Terminating a set after the final repetition that can be completed in proper form.
PMF	point of momentary muscular failure Terminating a set when concentric failure has been reached, i. e. the final repetition cannot be fully completed due to fatigue.
PMF+	point of momentary muscular failure plus HITM Training beyond failure by applying high intensity training methods (HITM) like forced repetitions, drop set, cheating etc.

The four degrees of training intensity (Gießing et al.; 2005; 11).

In addition to high intensity training, a high-volume approach of several sets of each exercise was believed to be superior for inducing muscular growth. Whereas references regarding the necessity of high training intensities are supported by results of recent research, there is evidence questioning the necessity of high training volumes for inducing muscular hypertrophy.

The debate whether three or more sets of each exercise were really the best way to train for muscular hypertrophy was first put into question by Arthur Jones in 1972. In his "Nautilus Bulletin" Jones questioned the alledged superiority of multiple set training by pointing out that high training intensity was much more important than high training volume, i.e. several sets of each

exercise. He claimed that once muscular failure was reached in one set, additional sets of the same exercise would not offer any further benefit and might even interfere with recuperation.

3 Reasons for the alleged superiority of multiple-set training

The outstanding increases in muscle mass achieved by bodybuilders applying high volume training seemed to prove the superiority of multiple-set training over single-set training. However, this theory was based on conventional wisdom rather than the results of empirical research.

An early study, conducted in the 1960s appeared to confirm the alledged superiority of multiple-set training. This study by Berger (Berger; 1962; 168-181) found greater improvements in strength when each exercise was executed three times than when only one set was performed. Yet the difference between single-set training and three-set training was only a few percent. The study showed a three per cent difference in strength when three sets were done instead of only one. According to this study, increasing training volume by 300% offered an additional benefit of roughly 3%. The results of this study were often understood to be supporting the notion that "the number of sets used in a workout is directly related to training results" (Fleck & Kraemer; 1987; 57). However, several aspects had been overlooked when interpreting the results of the Berger study. One fact that was discovered only later was a minor mistake of transposed digits by Berger (Kieser 1998; 50-51; Philipp; 1999b; 27-33). Another aspect that had been overlooked and contributed to the alledged superiority of multiple-set training is the fact that this study actually showed no proportinal relationship between the number of sets performed for each exercise and the strength increases that can be achieved by that number of sets.

The data presented by Berger (Berger; 1962) clearly show that the subjects who did only *one* set per test exercise improved their strength more than those subjects who did *two* sets (Berger; 1962; 172). Another fact worth mentioning is that Berger himself failed to prove the superiority of multiple-set training in later study (cf. Philipp; 1999b; 31). Nevertheless, several authors have suggested that high training volumes, i.e. training programs consisting of multiple-set training were better for gaining muscle mass than low training volumes like in single-set routines.

One reason why multiple-set trainng is still believed to produce results superior to those produced by single-set training is popularity of multiple-set training among bodybuilders and the results bodybuilders get from this kind of training:

> *"While scientific training studies have typically employed 1 to 4 sets per muscle group per session, elite bodybuilders are reputed to perform from 9 to 24 sets per muscle group in a single training session. Consequently it is generally accepted that high training volumes, say, 3-6 sets per exercise for 3-4 exercises (...) represent the best way to achieve myogenic increases." (Ostrowski et al.; 1997; 148).*

In the meantime several studies examined the question how the results of single-set training compare to those of traditional multiple-set training.