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Evidence-based guidelines for resistance training volume to maximize muscle hypertrophy

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Abstract

The manipulation of resistance training (RT) variables is widely considered an essential strategy to maximize muscular adaptations. One variable that has received substantial attention in this regard is RT volume. This paper provides evidence-based guidelines as to volume when creating RT programs designed to maximize muscle hypertrophy.

Introduction

Muscle mass is important from a human health standpoint, as it plays a significant role in locomotion, force production, and glucose disposal (7). Low levels of muscle mass may lead to an increased risk of several diseases such as type II diabetes, metabolic syndrome, and cardiovascular disease (15, 34). Moreover, there is a positive correlation between muscle mass and many aspects of athletic performance (3) and overall muscle size is a primary consideration in bodybuilding competition (13). Resistance training (RT) is the primary form of exercise that is used to induce gains in muscle mass.

The manipulation of RT variables is widely considered an essential strategy to maximize exercise-induced muscular adaptations (17). One RT variable that has received a great deal of attention in this regard, particularly with respect to enhancing muscle hypertrophy, is the volume of training. RT volume is commonly defined as the total amount of work performed and can be expressed in several ways. The number of sets performed for a given exercise is perhaps the most common way this variable is reported in the hypertrophy literature (31). Another popular method for quantifying RT volume is the total number of repetitions performed per exercise (i.e. sets multiplied by repetitions) (33). Finally, volume load (VL) has been proposed by some to be perhaps the most appropriate metric, whereby the total number of repetitions is multiplied by the amount of weight used in an exercise across sets (27). There is evidence that VL is a good proxy measure for muscular work (21). Displacement can also be considered in the volume equation, as those with longer limbs ultimately perform more work than those with shorter limbs (11). All of these measures can be considered viable ways to gauge RT volume since no consensus currently exists as to a definitive metric. Assuming all other variables are kept constant, increasing volume will necessarily increase time-under-tension, which has been proposed as an important driver of anabolism (6). Table 1 summarizes the basic advantages and disadvantages of each method of quantifying RT volume.

Controversy continues to exist as to how much volume is needed to maximize muscle hypertrophy. The American College of Sports Medicine position stand recommends that novice individuals perform 1 to 3 sets per exercise of 8 to 12 repetitions with a moderate load (70-85% 1RM) while advanced individuals should perform 3 to 6 sets per exercise of 1-12 repetitions with a loading range of 70-100% 1RM (1). With respect to advanced trainees, the wide loading range was recommended to target both mechanical and metabolic (hypoxic) stimuli to maximize muscle growth in a periodized fashion. These guidelines are consistent with a recent survey of 127 competitive bodybuilders, which found that over 95% of respondents employed 3-6 sets per exercise in their training programs (10). Despite this apparent congruity between science and practice, some fitness professionals have challenged current opinion, claiming that a single set, when taken to muscular failure, is as effective as higher RT volumes. For example, a recent review attempted to make the case that training volume was unrelated to muscular gains, postulating the performance of a single set per exercise is sufficient to maximize hypertrophy more efficiently than higher-volume routines (8).

The primary rationale of those challenging the need for higher volumes is that many studies on the topic have failed to show statistically significant differences in hypertrophy between conditions. Indeed, when observing the individual studies that compare single-set training with multiple-set training, we sometimes see no statistically significant differences between the training conditions. For example, Mitchell et al. (22) compared two groups of 18 untrained men, of which one performed 3 sets of knee extensions per training session, while the other performed only 1 set per training session. Following the intervention, no significant between-group differences were noted; however, the group that trained with 3 sets increased thigh cross-sectional area by 6.8% while the 1-set group increased thigh cross-sectional area by 3.1%. Despite an inability to detect statistically significant findings, the effect size difference of 0.27 favoring the higher volume condition indicates results were potentially meaningful from a practical perspective. Similar findings have been reported in resistance trained men. In the seminal work by Ostrowski et al. (26), 3 groups were compared with subjects randomized to perform either 1, 2 or 4 sets per exercise. Muscle cross-sectional area data for the quadriceps muscle showed a 6.3%, 4.6% and 12.3% increase in size for the 1, 2, and 4 sets per exercise groups, respectively. Although findings did not reach statistical significance, the effect size difference of 0.29 between the highest and lowest volume conditions again suggests a hypertrophic benefit for greater training volumes.

The previous examples highlight the fact that examining only statistical significance disregards the small sample sizes associated with RT research tend to make them underpowered to detect statistical probability (an a priori alpha level of 0.05) when an actual effect may, in fact, exist (i.e. type II error). In an attempt to enhance statistical power and objectively quantify the effects of volume on muscle hypertrophy, Krieger (18) pooled the results of all studies comparing single- versus multiple-set training and analyzed the combined effect sizes by meta-regression. A total of 8 studies met inclusion criteria at the time of the literature search (October 2009). Results showed a significantly greater hypertrophic benefit to performing multiple versus single sets; however, the magnitude of effect was modest (effect size difference of 0.10), possibly because of the low number of studies included in the analysis. The relatively small difference in effect sizes raised the question of the practical meaningfulness of multi-set routines, as they are more time-demanding than single-set RT schemes.

Recently, Schoenfeld et al. (31) set out to update the previous meta-analysis (18), given a plethora of new research on the topic since publication of that paper. The researchers chose to analyze volume on the basis of the number of sets performed per week per muscle group, surmising it to be a more relevant measure of training volume. A total of 15 studies meeting inclusion criteria showed a significant benefit to performing higher versus lower training volumes. Moreover, a clear dose-response relationship between the number of sets per muscle per week and muscle growth was found when RT volume was stratified into <5, 5–9, and 10+ sets per week, with graded increases seen in percentage gains across categories (5.4%, 6.6%, and 9.8%, respectively). The effect size calculation for the highest category showed a moderate magnitude of effect (0.52) while that for the lowest category showed a small effect (0.31). Importantly, subgroup analysis revealed that conclusions strengthened when direct measures of muscle growth such as magnetic resonance imaging and ultrasound were separated from less accurate indirect measures such as dual energy X-ray absorptiometry, and air displacement plethysmography (BodPod). These findings lend strong support to the claim that volume is a primary driver of muscle hypertrophy. It should be noted that the data were insufficient to determine whether more than 10 weekly sets per muscle provided additional hypertrophic benefits and, if so, at what point a threshold exists.

Wernbom et al. (33) suggested that a plateau of hypertrophic adaptations might occur after a certain point of volume, and moreover, the authors hypothesized the possibility of a decline in these adaptations when increasing training volume beyond that point. While lacking in empirical evidence, it is possible that the dose-response relationship between RT volume and muscle hypertrophy follows an inverted U-shaped curve, whereby excessive RT volume would lead to negative adaptations. A recent study that tested the effects of German Volume Training provides further insights on the topic (2). The researchers compared two groups, of which, one performed 31 sets per training session and the other 21 sets per training session. Following six weeks of RT, increases in trunk and arm lean body mass favored the lower-volume, 21-set group. These findings suggest that volume should be increased only up to a certain point, and anything above might actually impair recovery. Curiously, no significant increases in muscle thickness were found across groups; however, a limitation is that the study lasted only 6 weeks. Currently, there is a paucity of studies that have investigated such high RT volumes, thereby opening up an avenue for future research to explore the upper threshold of RT volume for gains in muscle mass.

Several studies have shown that VL may be an important factor concerning muscle growth. Schoenfeld et al. (28) found similar increases in muscle thickness of the elbow flexors performing 7 sets of 3 repetitions versus 3 sets of 10RM, which equated for VL between conditions. Thus, even though the heavier load condition performed more than double the number of sets as the moderate load condition, both groups achieved comparable improvements in hypertrophy. These findings are consistent with other research that equated VL in heavy versus moderate load training protocols (16). Subsequently, Schoenfeld et al. (30) found significantly greater growth in the quadriceps in an 8-week study that equated the number of sets, as opposed to VL, in heavy (3 sets of 3RM) versus moderate (3 sets of 10RM) load training (30). While this study would seem to reinforce the relevance of VL, conflicting findings have been reported whereby heavier load training showed greater improvements in some markers of hypertrophy despite a lower total VL (19). Alternatively, VL seems to be of little consequence to low-load RT protocols, as studies show similar muscle growth when comparing training with low versus moderate loads despite a substantially higher VL in the low-load conditions (22, 24, 29). The amount of load used is a potentially confounding factor when considering RT volume; the evidence seems to show that the use of heavier loads requires performance of a greater number of sets to maximize the growth response, although this does not appear to be the case with lighter loads. For low-loads with higher repetitions, it is evident that higher VL is needed to reach peripheral fatigue and thus induce a sufficient training stimuli. Therefore, it is necessary to emphasize that while training volume is an important variable, ultimately, the interplay between external load and volume will likely determine the adaptive response. On the point of training load, some studies indicate a preferential growth of type I and type II muscle fibers with low-load and high-load training, respectively (25, 32). For the individual whose sole goal is maximize muscular development (e.g. bodybuilder), the findings suggest that both loading schemes should be combined, making this a potentially important variable to consider in addition to training volume. On the other hand, those whose goal is to maximize strength should stick primarily with heavier loads as this type of training has greater transfer to the ability to produce force.

Practical Applications

There is compelling evidence that RT volume is a primary driver of hypertrophy, with higher volumes showing greater increases in muscle growth. It therefore follows that those seeking to maximize hypertrophy should train with multi-set protocols. Based on current literature, 10+ sets per muscle per week would seem to be a good starting point as to programming volume in those with hypertrophic-oriented goals. Volume should then be manipulated based on individual response. That said, substantial gains can nevertheless be achieved with volumes as low as 4 or fewer sets per muscle per week. For those who are time-pressed, lower volume routines represent a viable option to balance efficiency with results.

Given that consistently training with high volumes has been purported to hasten the onset of overtraining (9), it can be hypothesized that periodizing volume may enhance hypertrophy. Therefore, the ongoing discussion of high versus low RT volume does not need to be binary; rather, a combination of both approaches might be an optimal long-term strategy that would allow constant progression. Progressively increasing from lower (e.g. 10 sets per muscle per week) to higher (e.g. 20 sets per muscle per week) RT volumes over a period of several months may help to promote a state of functional overreaching, which would, in turn, result in a supercompensation of muscle proteins while reducing the potential for overtraining. When approaching such high volumes of training, individuals might consider distributing the total volume into two separate daily training sessions. There is some evidence to suggest that this strategy might produce superior results in comparison to training only once per day (12). As periods of high volume RT are not easily sustainable over longer periods, a lower volume phase might also be incorporated. It has been shown that during these periods a decrease in training volume by ~65% is sufficient for maintenance and, in some cases, even continued increases in muscle mass (5). However, this seems to be somewhat dependent on age, as older adults appear to require a higher dose of RT volume than the young to maintain myofibrillar hypertrophy (5). Other factors also need to be considered when prescribing RT volume. Specifically, when working with athletes, it may be hypothesized that lower RT volume would be more beneficial due to other sport-specific training demands. Table 2 presents a hypothetical approach to periodizing volume over time; note that the suggested volume levels should be individualized based on needs and abilities.

Inter-individual responsiveness to RT remains a complex topic for practitioners as evidence indicates that some individuals experience more dramatic changes in muscle mass than others. In a large-scale study, Hubal et al. (14) reported a broad range of hypertrophic responses to RT, with changes in muscle size varying between -2% to +59%. Interestingly, when observing the overall results, the frequency of high responders was greater than that of low responders. It is possible that so-called “non-responders” to training may benefit from an increased RT volume. Such a beneficial effect has been shown in aerobic endurance training research whereby participants who responded poorly to an initial 6-week low-volume protocol showed robust improvements in cardiorespiratory fitness after undertaking a subsequent 6-week protocol with an increased volume of training, so much so that none of the participants were classified as a “non-responder” after the ensuing higher-volume trial (23). Whether similar results would be seen in RT remains speculative, but intriguing findings in this regard come from Marshall et al. (20) who examined the relationship of RT volume in low responders to changes in dynamic muscular strength. Following 6-weeks of RT, the researchers reported that both high and low responders were identified from all randomized training groups (i.e. 1-set, 4-set, and 8-set groups). However, the number of low responders was highest for the 1-set group. In contrast, a greater number of high responders were from the 4-set and 8-set groups. While it cannot be inferred from these findings whether higher volume RT would elicit hypertrophic improvements in low responders, they do provide a logical rationale for practical experimentation in those who respond poorly to gaining muscle mass with lower volume RT protocols.

Finally, it is known that hypertrophy can manifest in a regional specific manner, both from an intra- and inter-muscular standpoint (4). In this way, some aspects of a given muscle or the individual heads of the muscle will show greater growth than other segments. If and how volume plays a role in this process remains to be determined and presents an interesting area of experimentation and research.

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Table 1. Advantages and disadvantages of different methods for quantifying volume

Method	Advantage	Disadvantage
Number of sets	The easiest way of tracking volume.	This method does not take into account the number of repetitions and external load. Thus, it provides only limited insights into the total amount of work performed in a training session.
Sets x repetitions	In comparison with the number of sets, this method provides more insights into the total amount of work performed.	This method does not take into account load, and therefore, even if the number of total repetitions is the same, the total volume load might differ based on the weight used.
Sets x repetitions x load	This method is likely the most appropriate as it considers all variables.	It can provide conflicting findings based on external load, as with low-load training, higher total volume load is needed for hypertrophy.

Table 2. A theoretical example how training volume can be periodized thorough a year

Weeks 1-12	Weeks 13-24	Weeks 25-36	Weeks 37 and 38	Weeks 39-46	Weeks 47-52
7-10 sets	10-15 sets	15-20 sets	2-3 sets	20-25 sets	5-7 sets
Goal: to stimulate hypertrophy with lower training volumes and acclimate the body for higher volumes.	Goal: progressively increasing the rate of hypertrophy with moderate training volumes.	Goal: progressively increasing the rate of hypertrophy with higher training volumes.	Goal: deloading phase aimed at promoting recovery.	Goal: to promote a state of functional overreaching with a high volume mesocycle.	Goal: reduction of training volume by ~65% for supercompensation of muscle proteins and maintenance of muscle mass.
*All sets are expressed as per week per muscle group					