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REVIEW ARTICLE

Effect of resistance training set volume on upper body muscle hypertrophy: are more sets really better than less?

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Summary

Background Resistance training (RT) for upper body muscle hypertrophy (UBMH) typically entails high volumes of sets per muscle group per training session. The majority of RT regimens does not discriminate between upper and lower body muscle groups, while these groups may respond differently to RT set volumes in terms of maximum skeletal muscle mass gain. Recent studies have examined the effect of different set volumes on the extent of UBMH to formulate optimal RT regimens and to make RT programmes more time-efficient.
Objective To analyse the effect of the number of RT sets on the extent of UBMH on the basis of recent literature.
Results and conclusion The analysis suggests that, statistically, high set volumes (≥3) are not significantly better than low set volumes (<3) in regard to UBMH in untrained subjects. For trained subjects, the literature is lacking in well-designed studies comparing low and high training volumes, as well as analysing upper and lower body muscles separately. Therefore, it is not possible to conclude that high volume of sets offers better results than low volume of sets for UBMH, and vice versa.

Introduction

Resistance training (RT) focusing on upper body muscle hypertrophy (UBMH) usually entails high volumes of sets (i.e. ≥3 sets) per muscle group per training session. Though recommending relatively low volumes for untrained persons, the American College of Sports Medicine recommended high set volumes for trained persons and athletes (ACSM, 2009). This is reflected in the practices of well-trained individuals and elite bodybuilders, as well as a common feature in RT-based health promotion programmes in untrained subjects. In practice, the use of low volumes (<3 sets) is rare and the most commonly employed training volumes are six to 20 sets per muscle group and sometimes even higher (30–49 sets) in a single training session (Hackett *et al.*, 2013), but without scientific justification.

It has been suggested that a large volume of RT stimulus promotes more extensive metabolic stress and mechanical tension resulting in more substrate depletion, metabolite accumulation and muscle damage (Schoenfeld, 2010) (Fig. 1). These factors in turn trigger anabolic responses during recovery that lead to muscular hypertrophy (Helms *et al.*, 2015). However, some reports suggest that an optimal endocrine response to RT is impaired when the volume of sets is too high, as observed in the testosterone:cortisol ratio in Ostrowski's study (Ostrowski *et al.*, 1997). For example, extensive RT has been associated with a decrease in the number of androgen receptors (Ratamess *et al.*, 2005), which may mediate muscular hypertrophy (Vlahopoulos *et al.*, 2005). Although the exact relationship between endocrine signalling and androgen receptor expression is partly elusive in terms of the hypertrophic response (Schroeder *et al.*, 2013), endocrine signalling

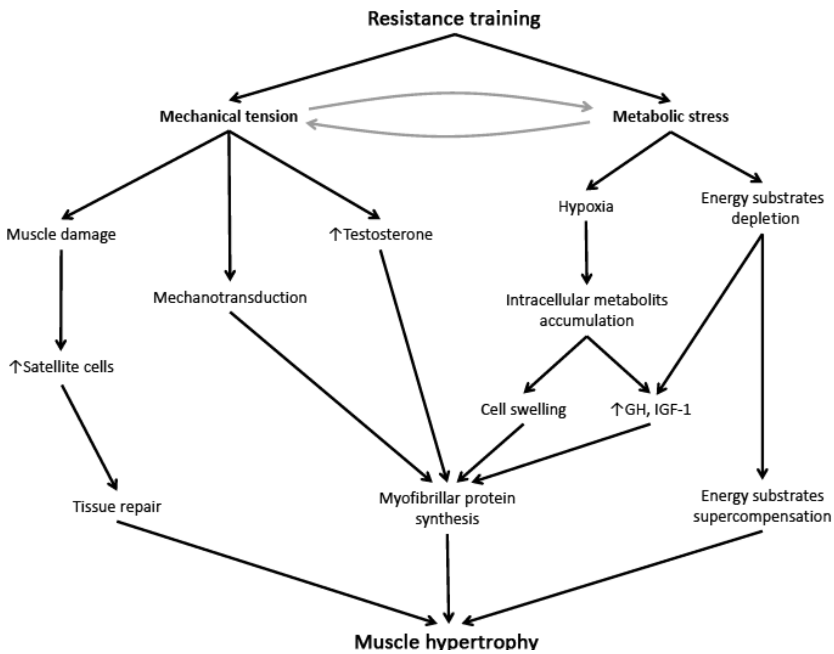

Figure 1 Biological and biochemical responses to resistance training in relation to muscular hypertrophy. With respect to resistance training, the signalling cascades occur within a functional range of the initial triggers (mechanical and metabolic stress), which in turn relies on the intensity of the resistance training (Schoenfeld, 2010, 2013). Subthreshold levels of stress invoke little or no signalling, while too much damage may impair signalling and muscle hypertrophy. Abbreviations: EMG, electrical activity produced by skeletal muscle; GH, growth hormone; IGF-1, insulin-like growth factor 1.

unequivocally plays an important role in muscle regeneration and adaptation through mass gain. Higher magnitude of muscle microdamage caused by high volume or intensity, however, may not be important for the hypertrophic response as it has been shown that only after attenuation of muscle damage is myofibrillar protein synthesis associated with change in muscle size (Damas *et al.*, 2016).

According to the principle of general adaptation proposed by Selye (1984), stress factors trigger biological adjustments that disrupt homoeostasis and stimulate a response in order to restore the state of dynamic balance. The adjustments occur in proportion to the magnitude of the stress; weak stimuli do not disturb homoeostasis, while very strong stimuli may exceed the adaptive capacity of the body, leading to (permanent) structural and/or functional damage (La Scala Teixeira & Guedes Junior, 2013). Analogously, the hypertrophic response to RT embodies biological adjustments to stress. Optimal muscle stimulus results in an optimal hypertrophic response, while subthreshold or excessive muscle stimulus will mute or debilitate the hypertrophic response, respectively. This concept has been inappropriately used to promote a range of complex approaches to RT (Buckner *et al.*, 2017), mainly in terms of volume of RT. Accordingly, the volume of sets per muscle group per workout session constitutes an important variable in the degree of muscular hypertrophy induction. The optimal stress response (Fig. 1) should therefore be determined in relation to the volume of sets for specific muscle groups. In practice, this information will serve to actualize time-efficient strategies for RT so as to maximize UBMH while enhancing training consistency and compliance (Hass *et al.*, 2000; Phillips & Winett, 2010; Steele *et al.*, 2015).

A number of reviews and meta-analyses over the recent years have evaluated the effects of set volume on muscular hypertrophy. The use of higher set volumes is generally propagated in guidelines (ACSM, 2009), comprehensive reviews (Wernbom *et al.*, 2007) and meta-analyses (Krieger, 2010; Schoenfeld *et al.*, 2017) But, with the exception of Wernbom's study, the other studies did not report the analysis of upper and lower body muscles separately, and lower body muscles are suspected to require larger training volumes to optimize adaptation (Wernbom *et al.*, 2007). Since the publication of the reviews and meta-analyses, several studies with different populations (untrained, trained, men, women and elderly) have been published. A critical update on the topic is hence warranted. Thus, the aim of this current opinion was to critically appraise the effect of different set volumes per muscle group per workout session on the extent of muscular hypertrophy, with specific focus on UBMH.

Methods

An extensive literature search was performed using PubMed and Scielo databases. Searches were performed using the following terms, in English and in Portuguese, alone or in combination: 'strength training', 'resistance training', 'hypertrophy', 'muscle thickness', 'cross-sectional area', 'low volume training' and 'volume sets'. The date of publication was not used as a criterion for inclusion and exclusion of studies. The publications obtained were screened for studies that included humans. Studies comparing protocols with different set volumes and analysing the effects on UPMH were preferably included, regardless of the sample's characteristics, the weekly training frequency, the training loads, the duration of the intervention and the method used to analyse muscular hypertrophy. Additional studies and books regarding resistance training and hypertrophy were included to complement the theoretical basis and discussion of the paper.

Current knowledge on the effect of set volumes on muscular hypertrophy

In the American College of Sports Medicine (ACSM's) resistance training position stand (ACSM, 2009), the number of sets recommended for muscle hypertrophy varies from one to six sets per exercise (1–3 for novice and intermediate; 3–6 for advanced subjects). The level of evidence was 'A' for novice and intermediate subjects; however, the scientific support for increasing the volume of sets in advanced subjects presented level of evidence 'C'. For advanced subjects, three studies were cited, but all these studies used body composition assessment methods to compare the effects between low and high volumes of sets training programmes on lean mass, and none of these directly analysed UBMH.

The meta-analysis by Krieger (2010) focused on set volume per exercise and not per muscle group. Of the eight analysed papers, only four measured UBMH, of which three used imaging techniques (magnetic resonance imaging, ultrasound) to objectively assess the changes in muscle mass. The most recent meta-analysis (Schoenfeld *et al.*, 2017) considered the effect of weekly set volume on muscular hypertrophy per muscle group. Of note, the inclusion of both upper and lower body muscle groups in this meta-analysis has been criticized (Arruda *et al.*, 2017). However, they did include body half (i.e. upper and lower) measured as a predictor in their meta-regression and reported that there was no significant interaction between weekly set volume and this variable, though did not present separate effects for upper and lower body muscle groups. Of the 15 articles included in the meta-analysis, 11 employed imaging techniques and seven of these 11 studies analysed upper body muscle groups. Further, Schoenfeld *et al.* (2017) examined 'weekly' set volume per muscle and not set volumes within a single session. Although of course weekly set volume may be an important way of conceptualizing this variable, many people may wish to understand from a practical perspective what set volumes within sessions might be the most appropriate approach to use: that is, how best to distribute this volume across weekly sessions. In general, the meta-analyses (Krieger, 2010; Schoenfeld *et al.*, 2017) suggested that higher set volumes induce greater effect size (ES) on muscle mass, although it is impossible to draw conclusions about the optimal stress response to RT in specific muscle groups on the basis of the included studies.

Wernbom *et al.* (2007) evaluated the effects of different training variables on hypertrophy of upper body muscles (elbow flexors) and lower body muscles (quadriceps), including the studies with untrained and physically active subjects. The data related to quadriceps revealed that higher set volumes (≥10 sets) per training session produced the best response in terms of muscle mass than lower volume routines (three, four, five to six and seven to nine sets), which justifies the use of high set volumes for lower limb muscle hypertrophy, at least in the case of quadriceps. For the number of sets per upper body muscle group and the hypertrophy response following traditional RT (free weights and machines), the authors analysed the results of 16 original studies comprising 24 subject cohorts that included untrained and moderately trained individuals. Data were reported as per cent increase in muscle cross-sectional area per day (CSA). The data showed that four to six sets per muscle group per training session (CSA of 0·24%) were more effective than ≥9 sets (CSA of 0·18%), which is in contrast to the results that measured quadriceps CSA. Corroboratively, other investigations showed that lower extremity respond differently than upper body muscles to higher RT set volumes (Ostrowski *et al.*, 1997; Rønnestad *et al.*, 2007).

Upper body muscle hypertrophy: high set volume versus low set volume

Given that most studies on RT-induced muscle hypertrophy response compare routines with one set versus three sets per muscle group, we classified <3 sets per muscle group per training session as 'low volume' and ≥3 sets per muscle group per training session as 'high volume'. Most recent studies concerning the effect of set volume on UBMH per muscle group have been conducted by Pinto's group in distinct cohorts (Radaelli *et al.*, 2013a,b, 2014, 2015).

Studies by Pinto's group (Radaelli *et al.*, 2013a,b) in 20 elderly women (60–74 years of age) who had not participated in a resistance training programme for at least 3 months examined elbow flexor muscle thickness by ultrasound following a 2× /week RT regimen during 13 weeks using either one ($n = 11$, 64·6 ± 3·1 years) or three ($n = 9$, 63·9 ± 2·3 years) sets per exercise. Study participants completed two exercises for the elbow flexors (lateral pull-down and bilateral elbow flexion) and thus performed two and six sets for the elbow flexor muscle group. Both RT regimens had a significant effect on elbow flexor muscle thickness at the end of the 13-week trial, but neither significant difference was found between the two-set group (11·2 ± 6·0% increase is muscle thickness) and the six-set group (12·5 ± 6·0%) nor relevant effect size (−0·21).

In a subsequent study, Radaelli *et al.* (2014) examined the temporal changes in muscle thickness during 6, 13 and 20 weeks in elderly women following the same protocol (one set per exercise, $n = 11$, 63·7 ± 3·5 years; three sets per exercise $n = 9$, 62·9 ± 2·3 years). Gains in elbow flexor muscle thickness were significant in both groups at 6 weeks (two sets, 4·4 ± 5·0%; six sets, 5·1 ± 4·8%), 13 weeks (two sets, 8·6 ± 2·8%; six sets, 12·5 ± 5·6%) and 20 weeks (two sets, 15·9 ± 5·9%; six sets, 14·5 ± 4·5%), but there were no significant differences between the groups at any time point.

More recently, Radaelli *et al.* (2015) compared the effects of 6 months of RT at a frequency of 3× /week between single and multiple set regimens (one, three and five sets) on elbow flexor and extensor muscle thickness in untrained but active young adult men (24·4 ± 0·9 years). The protocol included two exercises for the elbow flexors (lateral pull-down and bilateral elbow flexion) and three exercises for the elbow extensors (bench press, shoulder press and bilateral elbow extension). Thus, the one-, three- and five-set groups performed two and three sets, six and nine sets, and 10 and 15 sets per muscle group for the elbow flexors and extensors, respectively. For the elbow flexors, the group performing two sets (ES = 0·10) did not exhibit significantly increased muscle thickness. Muscle thickness was increased in both the six-set (ES = 0·73) and 10-set (ES = 1·10) groups. Intergroup analysis showed that the gain in flexor muscle thickness proceeded in the order of 10 sets >6 sets >2 sets over the course of 6 months. Elbow extensor thickness only improved significantly in the 15-set group (ES = 2·33) and was significantly greater than both the three-set (ES = 0·05) and nine-set (ES = 0·05) groups.

Papers by other groups (Gentil *et al.*, 2013; de França *et al.*, 2015) allowed the comparison of different set volumes per muscle group by comparing multijoint (MJ) RT exercises to MJ RT exercises combined with additional single-joint (SJ) RT exercises (designated ‘MJ + SJ’). The MJ + SJ group therefore performed additional sets per muscle group owing to the SJ component. Gentil *et al.* (2013) examined the effects of MJ and MJ + SJ exercises on muscle thickness in untrained men (22·68 ± 2·33 years of age) during 10 weeks of RT at a frequency of 2× /week. The MJ group performed only bench press and lateral pull-down exercises, whereas the MJ + SJ group performed additional bilateral elbow flexion and elbow extension. Each group performed three sets per exercise (i.e. MJ comprised three sets while MJ + SJ comprised six sets). As reported in the previous studies, significant gains in elbow flexor muscle thickness were measured at the end of the RT period, but there was no significant difference between the MJ (6·46% muscle thickness increase) and the MJ + SJ (7·04%) groups in terms of muscle thickness gains.

de França *et al.* (2015) adopted a similar MJ (n = 10, 29·4 ± 4·6 years of age) versus MJ + SJ (n = 10, 27·7 ± 6·6 years of age) RT approach (4× /week for 8 weeks), but in trained young men. Subjects in the MJ group performed three sets of incline bench press, flat bench press, decline bench press, weighted push-ups, and shoulder press (elbow extensor exercises) as well as v-bar lateral pull-down, seated row machine, supinated grip lateral pull-down, seated row using a pulley and upright row (elbow flexor exercises) for 15 sets per muscle group (in this case classified into muscles affected by extensor versus flexor RT). Subjects in the MJ + SJ group additionally performed bilateral elbow extensions using a pronated and neutral grip and standing and seated dumbbell curls for 21 sets per muscle group (i.e. extensor versus flexor). In agreement with the previous studies, there were significant increases in flexed arm circumference and arm muscle circumference, but no significant intergroup changes (MJ, 1·72% and 1·33% increase in flexed arm and arm muscle circumference, respectively; MJ + SJ, 1·45% and 3·17% increase, respectively). Although this study (de França *et al.*, 2015) did not analyse the effect of different set volumes on muscular hypertrophy per muscle group and used very high set volumes, the results contrast the elbow extensor findings of Radaelli *et al.* (2015) in that an increase in set volume did not translate to an exacerbation of muscular hypertrophy.

Discussion and conclusions

As early as 1997, Ostrowski’s findings (Ostrowski *et al.*, 1997) contradict the popular beliefs that high volumes of sets were needed to provide maximal hypertrophic responses in the upper limbs of trained subjects. This study encouraged the development of other studies to identify a possible optimal dose–response relationship between volume of sets and hypertrophy. Recent studies examining the effect of set volume per muscle group on UBMH generally found no significant difference between low (<3) and high (≥3) sets per muscle group, at least in elderly women as well as untrained men. These findings corroborate the principle of general adaptation (Selye, 1984), which affirms that there is an optimum dose of stimulus for the desired training-induced responses occur, and this dose seems to be lower than proposed in guidelines (ACSM, 2009), at least for UBMH. Although all studied subjects experienced yields in muscle mass following RT, in some cases the patterns in UBMH were ambiguous relative to other studies in the context of set volume effects. For instance, in the study of Radaelli *et al.* (2015) there was a directly proportional stress–UBMH response relationship for the elbow flexors (i.e. contradictory to the other studies), whereas such a relationship was less pronounced for the elbow extensors. For the elbow extensors, there was a set volume threshold within the high set volume cohort for achieving muscular hypertrophy (i.e. 15 sets yielded greater muscle mass than nine sets, which did not differ from three sets). On the other hand, de França *et al.* (2015) found no added value in increasing set volume in the high set volume cohort (i.e. no difference between 21 sets and 15 sets), although this may have stemmed from the fact that the 21 sets RT programme induced too extensive damage for optimal UBMH (Fig. 1). It is currently unclear which are the exact reasons that underlie these outlier findings, and more high-powered, focused research is still required to fill up these knowledge gaps.

No studies were retrieved involving elderly men and young women. Although hormonal factors contribute to different absolute results between sex and age groups, studies found that the relative effects of RT on muscle hypertrophy do not differ between men and women (Leenders *et al.*, 2013) as well as the young and elderly (Roth *et al.*, 2001). Although we might assume that the results obtained in the studies reviewed here and the conclusions drawn are applicable to subjects of the opposite sex, regardless of age, this needs confirmation in future studies.

The main findings of this brief review are that there are few well-conducted studies comparing the UBMH responses between training programmes with different set volumes. In addition, the studies present a great heterogeneity of groups and there is a lack of studies with trained subjects. Another important factor that limits concise conclusions is that there is no consensus in studies about what constitutes low set or high set volumes.

In the final analysis, recent literature, albeit contrasting in some respects, suggests that UBMH can be achieved in young and elderly untrained subjects by RT using low set volume (<3 sets) per muscle group per training session at a frequency of 2× /week, as suggested in the ACSM's guidelines (ACSM, 2009). Although larger set volumes may yield additional benefits in terms of ES and relative changes, there is presently insufficient evidence to support putative notions that larger volumes (≥3 sets) are statistically superior to low set volumes for UBMH for these individuals. For trained subjects, the literature is lacking in well-designed studies comparing low (<3 sets) and high training volumes (≥3 sets), as well as analysing upper and lower body muscles separately. Therefore, based on the evidence available to date, it is not possible to conclude that high volume of sets offers significantly better results than low volume of sets for UBMH, and vice versa. There is, moreover, little evidence to support higher set volume recommendations advocated by some authors (up to 20 sets) (Lin & Chen, 2012) and the RT routines followed by well-trained persons and bodybuilders (up to 49 sets). As lack of time is the main reason of people not exercising (Gomez-Lopez et al., 2010), the findings described in this current opinion paper are important as they support a time-efficient approach to RT and render RT practically feasible. Nevertheless, more studies are needed to further elucidate the relationship between set volume and UBMH for specific muscle groups, especially, in trained subjects.

Conflict of interest

The authors declare no conflict of interest.

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