Original Article (short paper)

Is the weekly sets volume training performed by trained subjects in accordance with training recommendations guidelines for muscle hypertrophy?

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Abstract — Aim: the aim of this study was to analyze the weekly sets volume (WSV) performed by trained men and women for each muscle group in muscle hypertrophy programs. **Methods:** One hundred and five resistance training practitioners of both sex (42 women, 29.8±5.7 years; 63 men, 28.5±5.7 years) consented to the analysis of their current training programs. Their training plains were analyzed by a researcher that used the following equation to determine the WSV performed for each muscle group: "number of exercises per muscle group per training session X number of sets per exercise in each training session X weekly training frequency per muscle group". The median values by each muscle group were compared within and between genders. **Results:** Between group analysis demonstrated that men performed higher WSV for upper body (UB) muscles than women (47.2±14,6 vs. 18.2±7.4 sets). Conversely, women performed a higher WSV for lower body (LB) muscle groups than men (23.8±11.2 vs. 11.5±7.0 sets). The training volume for the abdominal muscles did not differ between groups. When comparing the WSV for the UB, LB and core musculature within groups, men perform higher training volumes for the UB compared to the LB and core, while women train the LB with a higher volume compared to the other musculature**. Conclusion:** For some muscle groups, the WSV is higher than recommended in the literature for muscle hypertrophy. Men emphasize the UB training, while women emphasize training the LB. Moreover, the WSV performed by subjects of both genders is disproportionate between different muscle groups.

Keywords: strength training, resistance training, cross sectional area, muscle mass, bodybuilding

Introduction

The manipulation of resistance training variables to maximize muscle hypertrophy has received ample attention in the scientific community in recent decades[1,2,3,4], since different combinations of variables can have a direct influence on the volume, intensity and density (amount of volume and intensity applied in the time unit) of training, with a consequent impact on muscular adaptations. Exercise selection determines which muscles will be targeted for development, while other variables such as recovery intervals, intensity, volume, muscular actions and speed of movement determine the emphasis of the desired neuromuscular adaptation (eg. maximal strength, hypertrophy, power or local muscle endurance)[5,6]. Therefore, increasing the volume by systematically increasing the number of sets for the same muscle group in the session and week becomes one of the most common strategies to increase the training stimulus.

The dose-response relationship between the number of sets performed for each muscle group and changes in muscle mass has been widely investigated in recent research[4,7,8]. Although several systematic reviews[9], meta-analyses[4,7] and position stands[10] have sought to provide guidelines as to the optimal number of sets for maximizing hypertrophic responses, we do not find studies have attempted to analyze whether these recommendations are in line with the training programs of the general public. The aim of the study was to quantify weekly training volume performed by resistance-trained subjects whose primary goal was to increase muscle mass, determine if differences exist between men and women and between distinct muscle groups, and compare the results with current resistance training recommendations.

Materials and methods

Experimental Approach to the Problem

In order to verify the weekly volume performed per muscle group, the current training programs of 105 resistance-trained

volunteers were analyzed. The analysis considered the participation of each major muscle group in the exercises performed in each training session, the amount of sets per exercise and the weekly training frequency. Data were analyzed both separately by muscle group and by body segment (upper body, lower body and abdominals).

Participants

One hundred and five subjects of both sex (42 women, 29.8 ± 5.7 years; 63 men, 28.5 ± 5.7 years) consented to allow analysis of their current resistance training programs. All subjects were members at one of nine gyms and sports club in Guarulhos, SP, Brazil, were considered experienced in resistance training defined as having maintained a training routine for at least 6 consecutive months, and had a stated primary goal of increasing muscle mass. After confirming exercise participation with the owners/managers of the establishments, subjects signed a free and informed consent form to allow analysis of their training programs. All ethical criteria for research involving human subjects were carried out according to the Declaration of Helsinki and the project was approved by Nove de Julho University's Ethics Committee (CAAE: 65878017.9.0000.5511; approval report number: 2.014.579)

Weekly sets volume

Analysis of the weekly volume performed per muscle group was calculated by follow equation:

Number of exercises per muscle group per training session X Number of sets per exercise in each training session X Weekly training frequency per muscle group

The study analyzed the muscle groups most frequently targeted in the training programs for muscle hypertrophy: pectoral (pectoralis major), dorsal (latissimus dorsi), deltoid, biceps brachii, triceps brachii, gluteals, quadriceps, hamstrings, triceps surae and abdominal muscles. For each muscle group, specific exercises (e.g. French press for the triceps brachii) were considered, plus those in which the participation of the muscle group is evident, even if it is not considered the primary mover or agonist (eg, bench press for the triceps brachii). All variations of the exercises were considered, regardless of the modality used (free weights, machines, pulley systems or body weight). Thus, the list of exercises considered for each muscle group is shown in Table 1.

Table 1. Exercises included in the analysis per muscle group

Muscle group	Exercises included in the analysis
Pectoral	Bench press (all the variations with wide grip) Fly (all the variations) Crossover/peck deck Pullover Push-ups
Latissimus dorsi	Pulldown (all the variations) Rowing (all the variations with closed grip) Pullover
Deltoid	Shoulder press (all the variations) Upright row Raise (lateral, frontal) Rowing (all the variations with wide grip) Bench press (plane and inclined) Pulldown (all the variations)
Biceps brachii	Elbow curl (all the variations) Pulldown (all the variations) Rowing (all the variations) Upright row
Triceps brachii	Elbow extension (all the variations) Bench press (all the variations) Shoulder press (all the variations)
Gluteals	Hip extension (all the variations) Squat (all the variations) Leg press Deadlift (all the variations) Lunge (all the variations) Hip thrust

Quadriceps	Knee extension (all the variations) Squat (all the variations) Leg press Deadlifts (traditional and sumô) Lunge (all the variations)
Hamstrings	Knee curl (all the variations) Stiff-deadlift Nordic hamstrings
Triceps surae	Ankle extension (all the variations)
Abdominals	Trunk flexion (all the variations) Front plank

Statistical Analyses

The descriptive analysis was presented in median (Med) and interquartile ranges (IQ), minimal value (Min), maximum value (Max) and variations range (Var). The Shapiro-Wilk test revealed the data were not normally distributed and thus the Mann-Whitney test was employed to verify differences between groups (men and women), the Friedman test to verify differences within groups (muscle groups), and the Wilcoxon test for post-hoc analysis. The significance level was 5% (P≤0,05). Data analysis was made in IBM SPSS v.20 (Armonk, NY).

Results

Weekly volumes as a function of sets performed per each muscle group were different between men and women (P≤0,05), except for the abdominal muscles. Of the five analyzed upper body (UB) muscles (pectoral, latissimus dorsi, deltoid, biceps and triceps brachii), the men showed higher weekly training volumes for all muscle groups when compared with women. Alternatively, women showed higher weekly training volume for all lower body (LB) muscles (gluteus, quadriceps, hamstrings, triceps surae) than men (Table 2).

When all the UB, LB and core (abdominals) muscles were grouped, the UB as well as LB training volume was different between groups, however there was no significant difference in the volume for core muscles. In the within group analysis, men showed higher training volume for UB than LB and core muscles, and for core than LB muscles. The women only showed higher training volume for LB than UB muscles (Figure 1).

Women showed a greater weekly training volume for the gluteals, followed by the quadriceps and deltoids (Table 3). In the men, the muscle groups that showed the highest training volume were the deltoids and the arm muscles (biceps brachii and triceps brachii) (Table 4).

Table 2. Weekly sets volume performed per muscle groups

Muscle group	Men					Women					*P*-value
	Med	IQ	Min	Max	Var	Med	IQ	Min	Max	Var	
Pec	30.0	8.0	12	48	36	10.5	4.5	0	32	32	<0.001
Lat	24.0	10.0	16	48	32	12.0	5.8	0	24	24	<0.001
Del	80.0	28.0	6	128	122	28.0	12.0	0	70	70	<0.001
Bic	51.0	18.0	22	76	54	20.0	8.5	0	56	56	<0.001
Tri	54.0	20.0	24	72	48	18.0	13.0	0	48	48	<0.001
Qua	16.0	12.0	0	40	40	30.0	18.5	16	56	40	<0.001
Ham	8.0	6.0	0	18	18	16.0	9.3	0	28	28	<0.001
TS	8.0	2.0	0	24	24	8.0	8.5	0	26	26	0.042
Glu	12.0	16.0	0	40	40	41.0	21.5	8	92	84	<0.001
Abd	20.0	12.0	0	48	48	20.0	8.0	0	60	60	0.678

Med: median; IQ: interquartile ranges; Min: minimal value; Max: maximum value; Var: variations range; Pec: pectoral; Lat: latissimus dorsi; Del: deltoid; Bic: biceps brachii; Tri: triceps brachii; Qua: quadriceps; Ham: hamstrings; TS: triceps surae; Glu: gluteus; Abd: abdominals

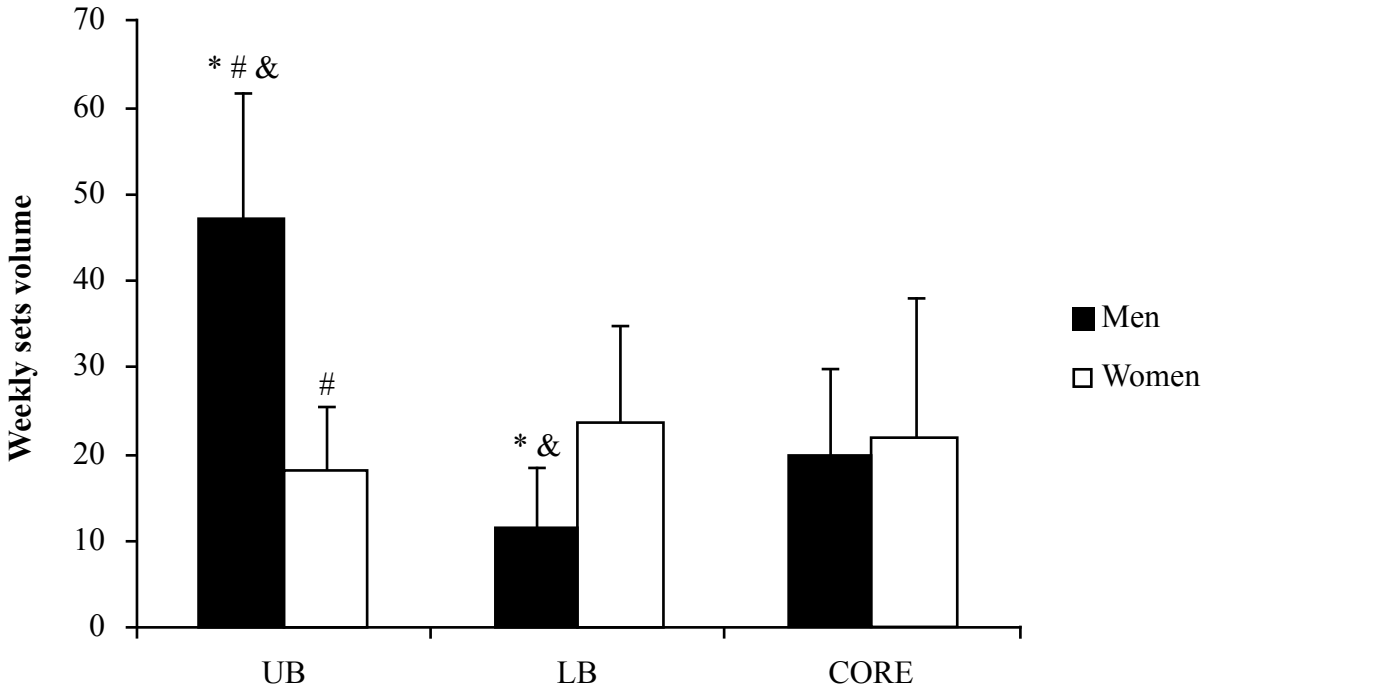

Figure 1. Weekly sets volume per body segment. UB: upper body; LB: lower body; *: P≤0.05 vs. Women; #: P≤0.05 vs. LB; &: P≤0.05 vs. CORE

Table 3. Comparison (P-value) of weekly sets volume between muscle groups in women.

Muscle group	Pec	Lat	Delt	Bic	Tric	Quadr	Ham	TS	Glu	Abd
Pec	-	0.016	<0.001	<0.001	<0.001	<0.001	0.012	0.969	<0.001	<0.001
Lat	0.016	-	<0.001	<0.001	<0.001	<0.001	0.111	0.132	<0.001	<0.001
Delt	<0.001	<0.001	-	<0.001	<0.001	0.892	<0.001	<0.001	<0.001	0.004
Bic	<0.001	<0.001	<0.001	-	0.208	<0.001	<0.001	<0.001	<0.001	0.799
Tric	<0.001	<0.001	<0.001	0.208	-	<0.001	0.003	<0.001	<0.001	0.633
Quadr	<0.001	<0.001	0.892	<0.001	<0.001	-	<0.001	<0.001	<0.001	<0.001
Ham	0.012	0.111	<0.001	<0.001	0.003	<0.001	-	0.005	<0.001	0.004
TS	0.969	0.132	<0.001	<0.001	<0.001	<0.001	0.005	-	<0.001	<0.001
Glu	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	<0.001
Abd	<0.001	<0.001	0.004	0.799	0.633	<0.001	0.004	<0.001	<0.001	-

Med: median; IQ: interquartile ranges; Min: minimal value; Max: maximum value; Var: variations range; Pec: pectoral; Lat: latissimus dorsi; Del: deltoid; Bic: biceps brachii; Tri: triceps brachii; Qua: quadriceps; Ham: hamstrings; TS: triceps surae; Glu: gluteus; Abd: abdominals

Table 4. Comparison (P-value) of weekly sets volume between muscle groups in men

Muscle group	Pec	Lat	Delt	Bic	Tric	Quadr	Ham	TS	Glu	Abd
Pec	-	0.452	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lat	0.452	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Delt	<0.001	<0.001	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bic	<0.001	<0.001	<0.001	-	0.297	<0.001	<0.001	<0.001	<0.001	<0.001
Tric	<0.001	<0.001	<0.001	0.297	-	<0.001	<0.001	<0.001	<0.001	<0.001
Quadr	<0.001	<0.001	<0.001	<0.001	<0.001	-	<0.001	<0.001	<0.001	0.230
Ham	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	0.669	<0.001	<0.001
TS	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.669	-	<0.001	<0.001
Glu	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	<0.001
Abd	<0.001	<0.001	<0.001	<0.001	<0.001	0.230	<0.001	<0.001	<0.001	-

Med: median; IQ: interquartile ranges; Min: minimal value; Max: maximum value; Var: variations range; Pec: pectoral; Lat: latissimus dorsi; Del: deltoid; Bic: biceps brachii; Tri: triceps brachii; Qua: quadriceps; Ham: hamstrings; TS: triceps surae; Glu: gluteus; Abd: abdominals

Discussion

Training volume, as a function of the number of sets performed for each muscle group in training programs designed for muscle hypertrophy, has been the focus of many scientific investigations[4,7]. However, no studies to date have endeavored to compare current recommendations on the topic with what is generally prescribed and practiced in the gym. The present study demonstrated that weekly training volumes are not proportional between different muscle groups in both men and women. These results confirm the supposition that men adopt higher training volumes for the UB muscles, while women perform a greater volume for the LB muscles. Regarding the abdominal muscles, the training volume was not different between the genders.

Although there is no consensus on the ideal number of sets that should be performed for UB and LB muscles, some studies suggest that LB muscles are more responsive to higher training volumes[9,11]. Wernbom, Augustsson and Thomeé[9] demonstrated that higher daily increases in the cross-sectional area of the quadriceps were associated with volumes of 10 or more sets per training session, whereas for the biceps brachii, the volume associated with the best hypertrophic responses was between 4 and 6 sets per training session. In this context, only the women analyzed in the present study seem to follow this observation.

A growing number of studies have attempted to establish the association between the number of sets performed for each muscle group and the consequent neuromuscular adaptation in different populations[4,12]. Recently, Schoenfeld, Ogborn and Krieger[4] demonstrated an increase of ~0.36% in the hypertrophic response for each additional set performed in a training session. Accordingly, some guidelines suggest the performance up to 30 sets per muscle group depending on the level of physical fitness (eg. untrained, trained, bodybuilders), the periodization scheme performed (eg. linear, non-linear) and the purpose of the training program (competition, recreational, health promotion)[10,13,14]. However, multiple sets and/or repeated sessions for the same muscle group can result in the acute reduction of performance[15,16], which may in turn affect chronic neuromuscular adaptations.

The weekly training volume observed in some muscle groups was much higher than currently prescribed recommendations. For example, in men, some muscle groups had median volumes greater than 50 sets per week (maximum of 122 for deltoids), while in women, the gluteals were trained with more than 40 sets per week (maximum of 92). These differences are probably due to cultural factors that tend to overestimate the aesthetics of UB and LB muscles in men and women, respectively. Although recent meta-analyses reveal that a higher number of sets per training session[7] and per week[4] provide greater hypertrophic responses, the weekly number of sets proposed by the authors is lower than that observed in some muscle groups analyzed in the present study. Krieger[7] suggests at least 4 to 6 sets per muscle group per training session, while Schoenfeld, Ogborn and Krieger[4] notes that 10 or more sets per muscle group per week provide the best results. It should be noted that in the meta-analysis of Schoenfeld, Ogborn and Krieger[4], there was insufficient data to determine an upper threshold of volume beyond 10 sets per muscle per week. Thus, it is impossible to conclude if higher volumes (> 10 sets per muscle per week) may lead to greater muscular adaptations or not.

The number of sets performed for a muscle group must consider not only the exercise in which the muscle group is the agonist, but all exercises involving participation in the kinetic chain. For example, when performing 3 sets of the bench press exercise, computations should include 3 sets for pectoral, anterior deltoid and triceps brachii. However, most analyses consider the bench press purely as an exercise for the pectorals, disregarding that movement is carried out in a kinetic muscle chain as opposed to by an isolated muscle[17] and thus ignoring the increased volume performed by the deltoid and triceps brachii. This fact justifies the high training volume performed for the deltoids in men, because although this muscle participates in all the exercises involving shoulder joint movement, many trainers and athletes ignore this participation in some exercises.

An extrapolation of the General Adaptation Principle[18] to resistance training indicates that there is an upper threshold of stress and once this threshold is crossed, adaptations resulting from the program are attenuated or impaired. At present, the literature has not delineated this upper limit with respect to the weekly number of sets performed per muscle group. However, there is some evidence that the increase in the number of exercises and, consequently, of sets per muscle group in a training session may not provide significant additional hypertrophic benefits in both untrained[19] and trained subjects[20,21]. Thus, more studies are needed to clarify the upper threshold of number of sets per muscle per week beyond which additional volume can impair/mitigate results.

Another important point that should be mentioned is the negligence of volume proportionality between different muscle groups in the agonist/antagonist ratio. For example, the weekly training volume observed for the quadriceps and hamstrings was quite disproportional, both in men (16 vs. 8 sets, respectively), and in women (30 vs. 16 sets, respectively). Probably, cultural factors that lead to the aesthetic overestimation of some muscle groups over others (eg, quadriceps over hamstrings, abdominal over low back muscles) may explain these findings. Although it is known that the physiological relationship of strength between agonist and antagonist does not necessarily follow a 1:1 ratio[22], it is still not clear whether this physiological balance should be considered to establish the training volume for each muscle group. Thus, a disproportionate ratio of sets performed between antagonistic muscle groups, such as that observed between quadriceps and hamstrings, may contribute to the development of postural deviations, impairment to dynamic tasks, and increased risk of injury in others activities.

Conclusion

In conclusion, the number of weekly sets performed for some muscle groups was higher than current literature recommendations for muscle hypertrophy. This was particularly true for the deltoids, biceps brachii and triceps brachii in men, and for the

gluteals in women. The results also confirm the hypothesis that men emphasize UB training, while women focus on the LB muscles. Thus, the weekly training volume adopted by subjects of both genders appears disproportional between different muscle groups.

Practical applications

Given the disproportionate training volumes between genders and, on a gender-specific basis, between body segments, fitness professionals should seek to educate trainees on the importance of balancing the number of sets per muscle group in program design. These recommendations can contribute to a better results from the interventions, as well as reduce the risk of injuries in other activities due to muscular imbalances and the possible impairment of adaptations due to excess volume.

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