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ORIGINAL ARTICLE

Resistance training for strength and muscle thickness: Effect of number of sets and muscle group trained

Entraînement en résistance pour le développement de la force et de l'épaisseur du muscle : effets du nombre de séries et des groupements musculaires entraînés

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KEYWORDS
Strength training;
Muscle strength;
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Summary
Objectives. — To investigate the effects of resistance training volume on the adaptations of different muscle groups in untrained young men.
Equipments and methods. — The volunteers were randomly assigned into two groups: (1) three sets of knee extension and a single set of elbow flexion (3K-1E; $n = 11$), or (2) single set of knee extension and three sets of elbow flexion (1K-3E; $n = 13$). Subjects trained two days per week for 12 weeks. Peak torque (PT) was measured at $60^\circ\ s^{-1}$. Muscle thickness (MT) was measured by ultrasound.
Results. — Elbow flexors' MT increased significantly for both groups (7.2% for 3K-1E and 5.9% for 1K-3E), while changes in quadriceps' MT were not significant for either group (2.5% for 3K-1E and 2.9% for 1K-3E). Increases in elbow flexors' PT were 11.2% for 3K-1E and 12.5% for 1K-3E ($P < 0.05$ for both). Changes in knee extensors' PT were significant for 3K-1E (10.9%, $P < 0.05$) but not for 1K-3E (5.1%, $P > 0.05$).
Conclusion. — Single-set training protocols might be sufficient for increasing strength and MT of the elbow flexors and muscle strength of the knee extensors in untrained individuals. On the other hand, neither training stimulus (one set nor three sets) was sufficient to improve the MT of the knee extensors.

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MOTS CLÉS
Force musculaire ;
Volume d'entraînement ;
Hypertrophie musculaire ;
Entraînement en résistance

Résumé
Objectifs. — Étudier les effets du volume d'entraînement en résistance sur les adaptations des différents groupements musculaires chez des jeunes gens non-entraînés.
Équipements et méthodes. — Les volontaires ont été répartis aléatoirement en deux groupes : (1) trois séries d'extension du genou et une unique série de flexion du coude (3G-1C, $n = 11$), ou (2) une unique série d'extension du genou et trois séries de flexion du coude (1G-3C ; $n = 13$). Les volontaires ont été entraînés deux jours par semaine pendant 12 semaines. Le pic du torque (PT) a été mesuré à $60^{\circ}\ s^{-1}$. L'épaisseur musculaire (EM) a été mesurée par échographie.
Résultats. — L'EM des fléchisseurs du coude a augmenté de manière significative pour les deux groupes (7,2 % pour 3G-1C et 5,9 % pour 1G-3C), tandis que les changements dans les EM des quadriceps ne sont pas significatifs pour les deux groupes (2,5 % pour 3G-1C et 2,9 % pour 1G-3C). Les augmentations de PT des fléchisseurs du coude ont été de 11,2 % pour 3G-1C et 12,5 % pour 1G-3C ($p < 0{,}05$ pour les deux). Les changements des PT des extenseurs du genou ont été significatifs pour 3G-1C (10,9 %, $p < 0{,}05$) mais pas pour 1G-3C (5,1 %, $p > 0{,}05$).
Conclusion. — Les protocoles d'entraînement avec des séries simples peuvent être suffisants pour augmenter la force et l'EM des fléchisseurs du coude et la force musculaire des extenseurs du genou chez les personnes non-entraînées. Par ailleurs, aucune des stimulations de l'entraînement (une ou trois séries) n'a été suffisante pour améliorer l'EM des extenseurs du genou.

1. Introduction

Resistance training has been shown to be an effective stimulus for promoting muscle strength and hypertrophy [1,2]. For optimal benefit, resistance training programs should be based on scientific principles that consider training variables such as exercise selection, resistance modality, load, sets, repetitions and rest. Volume (sets × repetitions × load) is probably the training variable that has received the most attention in the last 10 years, with an extensive debate concerning the use of single set versus multiple sets programs [3—5]. According to a meta-analysis by Rhea et al. [6], most studies have reported that resistance training with multiple sets is more effective for increasing strength than training with a single set. Later, Munn et al. [7] reported that three sets of exercise produced twice the strength increase of one set in the early phase of resistance training in untrained subjects. Thus, research has suggested that a training volume greater than one set is recommended to improve strength gains [6]. However, these results might not be valid for different muscle groups [8,9].

Studies involving upper-body muscles reported no differences for strength gains between one and three sets [10—12], while studies involving lower-body muscles reported three sets to be superior to one set [10—14]. McBride et al. [15] compared the effects of single versus multiple sets on strength gains in upper-body versus lower-body muscles and reported that multiple sets produce a greater increase in strength gains in upper-body exercise (biceps curl) when compared to a lower-body exercise (leg press). On the other hand, Paulsen et al. [10] and Ronnestad et al. [12] reported superior strength gains for three sets in lower-body exercises but not in upper-body exercise in untrained subjects.

With regard to muscle hypertrophy, Ronnestad et al. [12] reported that three sets of strength training was superior to one set in leg muscles, while no difference existed between one and three sets in the upper-body muscle mass gains of untrained men. Starkey et al. [16] also reported that one set of high-intensity resistance training was as effective as three sets for increasing the muscle thickness (MT) of the knee extensors in previously untrained adults. On the other hand, Starkey et al. [16] did not investigate the difference in MT changes between upper- and lower-body muscle groups. Thus, due to the controversy between studies on muscle strength gains, and due to the small number of studies that have investigated the effect of training volume on muscle mass changes, the purpose of this study was to determine the effect of one set versus three sets of resistance exercise on the strength and MT gains of different muscle groups in untrained male subjects.

2. Methods

2.1. Experiment overview

Subjects were randomly assigned to one of two groups. One group performed three sets of knee extension exercise and one set of elbow flexion exercise (3K-1E), while the other performed one set of knee extension exercise and three sets of elbow flexion exercise (1K-3E). Training was conducted across 12 weeks, two days a week, with a minimum of 48 h between sessions. Both groups were instructed to perform 8—12 repetitions until volitional fatigue at a speed of 4 s per repetition (2 s for the concentric phase and 2 s for the eccentric phase). The effects on strength gains were tested before and after the 12-week training protocol via isokinetic tests (knee extension and elbow flexion), and the effects on MT were tested through ultrasound images of the elbow flexors and knee extensors.

2.2. Subjects

Thirty young men with no resistance training experience agreed to participate in this study. Eleven college-aged male subjects in the 3K-1E group (22.2 ± 3.2 years; 72.7 ± 13.2 kg; 174.3 ± 6.8 cm) and 13 in the 1K-3E group (23.4 ± 2.6 years; 73.1 ± 13.6 kg; 171.9 ± 8.2 cm) completed the study protocol. Drop-outs were due to lack of time and the performance of other resistance training programs than the study protocol. The inclusion criteria for participation in the study included being older than 18 years and being free of clinical problems that could be aggravated by the protocol. To be included in the statistical analysis, participants were permitted to miss only two training sessions during the 12-week program. Participants were notified of the research procedures, requirements, benefits and risks before providing informed consent. The Institutional Research Ethics Committee granted approval for the study.

2.3. Muscle thickness

Participants were tested before and after the 12-week training period for MT of the elbow flexors and knee extensors of the right limb. All tests were conducted at the same time of the day, and participants were instructed to hydrate normally 24 h before the tests. Measures were taken 3—5 days after the last training session to prevent any swelling from contributing to the MT measurement [17]. During this time, participants were instructed not to participate in any other exercise sessions or intense activity. MT was measured using B-Mode ultrasound (Philips-VMI, Ultra Vision Flip, model BF). A water-soluble transmission gel was applied to the measurement site and a 7.5-MHz ultrasound probe was placed perpendicular to the tissue interface while not depressing the skin. MTs of the rectus femoris muscle (RF) and of the biceps brachii (BIC) were measured according to Abe et al. [18]. Once the technician was satisfied with the quality of the image produced, the image on the monitor was frozen. With the image frozen, a cursor was enabled in order to measure MT, which was taken as the distance from the subcutaneous adipose tissue-muscle interface to muscle-bone interface [18]. A trained technician performed all analyses [19]. The coefficients of variation for BIC and RF MTs were less than 3.0%. Baseline test and retest intraclass correlation coefficient (ICC) for BIC MT was 0.96 (0.93—0.98) and for RF MT was 0.99 (0.98—0.99).

2.4. Peak torque

Unilateral knee extension and elbow flexion peak torque (PT) were tested for both groups, using two sets of four repetitions at $60^\circ\,s^{-1}$, on a Biodex System 3 isokinetic dynamometer (Biodex Medical, Inc., Shirley, NY) with 60 s rest between sets. Calibration of the dynamometer was performed according to the manufacturer's specifications before every testing session. Knee extension strength assessment procedures were as follows: the participants sat upright with the axis of rotation of the dynamometer arm oriented with the lateral femoral condyle of the right knee. Belts were used to secure the thigh, pelvis and trunk to the dynamometer chair to prevent additional body movement. The chair and dynamometer settings were recorded to ensure the same positioning for all tests. The flexor torque produced by the relaxed segment was used for gravity correction. Participants were instructed to fully extend and flex the knee and to work maximally during the test. Elbow flexion strength assessment was as follows: the participants were seated on an arm curl bench with the exercised upper arm supported at 45° of shoulder abduction and their elbow aligned with the axis of rotation of the dynamometer's lever arm. The forearm remained in a supinated position throughout the test session. Verbal encouragement was given throughout the test. The procedures were administered by the same investigator [20]. Baseline test and retest intraclass correlation coefficient and standard error of the mean (S.E.M.) for peak torque were 0.98 and 2.3% for quadriceps, and 0.96 and 2.4% for biceps.

2.5. Training

All training sessions were closely supervised to ensure safety and compliance with the procedures, and because previous research has demonstrated greater gains in supervised versus unsupervised training [21]. Each group was assigned a different volume of the same exercise over the same period of time. Both groups trained with 8—12 RM. If a subject could not perform eight repetitions or could lift the load more than 12 times, he was instructed to adjust the load in order to ensure the completion of the required number of repetitions. Each subject maintained a training log where the number of repetitions performed and the weight used in each set were recorded.

Training was conducted two days a week, with a minimum of 48 h between sessions, for 12 weeks. Twice/week training sessions was chosen because the current physical activity guidelines state that adults should do at least 150 min/week of moderate-intensity physical activity and also two or more days/week of muscle-strengthening activities [22]. One group used a single set of knee extension and three sets of elbow flexion (1K-3E) while the other used three sets knee extension and a single set of elbow flexion (3K-1E). Sets began every 3 min, and the work rest ratio was ~1:3. During training sessions, music tracks with 120 bpm were played in order to facilitate control of movement speed. Before each training session, subjects were instructed to maintain their normal diet over the duration of the study.

2.6. Statistical analyses

Normality of the distribution for outcome measures was tested using the Kolmogorov-Smirnov test. All values are reported as mean ± standard deviation. Paired *t*-tests were used to compare pre- and post-values within groups. To compare differences in PT and MT between groups, final values were compared with ANCOVA, using the initial values as covariates. When groups are assigned at random, ANCOVA is considered an adequate method for comparing changes between groups [23]. Relative percentage change was calculated using the following equation: [(Post-values − Pre-values)/Pre-values × 100]. Statistical significance was set at $P \leq 0.05$. Data were analyzed using the Statistical Package

Table 1A Values of muscle thickness (MT) and peak torque (PT) pre and post 12 weeks of resistance training (means ± standard deviations).

Variable	3K-1E			
	Pre	Post	*P* (pre vs. post)	*P* (1K-3E vs. 3K-1E)
Elbow flexors MT (mm)	27.9(±4.2)	29.9(±3.3)	0.012[a]	0.866
Knee extensors MT (mm)	20.3(±3.7)	20.8(±4.1)	0.208	0.109
Elbow flexors PT (N m)	46.57(±10.56)	51.79(±7.28)	0.013[a]	0.47
Knee extensors PT (N m)	203.31(±33.64)	225.39(±32.22)	0.006[a]	0.901

MT: muscle thickness; PT: peak torque.
[a] $P < 0.05$.

Table 1B Values of muscle thickness (MT) and peak torque (PT) pre and post 12 weeks of resistance training (means ± standard deviations).

Variable	1K-3E			
	Pre	Post	*P* (pre vs. post)	*P* (1K-3E vs. 3K-1E)
Elbow flexors MT (mm)	28.8(±2.8)	30.5 (±4.7)	0.036[a]	0.866
Knee extensors MT (mm)	23.9(±3.6)	23.2(±3.5)	0.114	0.109
Elbow flexors PT (N m)	49.67(±10.47)	55.59(±10.61)	0.003[a]	0.47
Knee extensors PT (N m)	231.16(±31.77)	243.00(±30.56)	0.098	0.901

MT: muscle thickness; PT: peak torque.
[a] $P < 0.05$.

for Social Sciences (SPSS) version 14 software (SPSS Inc., Chicago, IL). Also, the calculation of increases by the effect size in PT (the difference between pretest and posttest scores divided by the pretest standard deviation) and the scale proposed by Rhea [24] were used.

3. Results

Results are shown in Table 1. BIC MT increased significantly for both groups (7.2% for 3K-1E and 5.9% for 1K-3E), while changes in RF MT were not significant for any group (2.5% for 3K-1E and −2.9% for 1K-3E). Increases in elbow flexors PT were 11.2% for 3K-1E and 12.6% for 1K-3E ($P < 0.05$ for both). Besides no significant differences between groups, changes between pre-and post-test in knee extensors PT were significant for 3K-1E (10.9%, $P < 0.05$) but not for 1K-3E (5.1%, $P > 0.05$). Comparisons between groups revealed no difference in the changes of any variable. According to the scale proposed by Rhea [24], the effect size for the change in PT of the knee extensors was small (0.65) for 3K-1E and trivial (0.37) for 1K-3E. The effect size for the change in PT of the elbow flexors was trivial to small for both 3K-1E (0.50) and 1K-3E (0.56) (Table 1).

4. Discussion

The purpose of this study was to verify the effect of one set versus three sets of resistance exercise on the strength and MT gains of different muscle groups. The results suggest that independent of the number of sets (1 or 3) the strength gains are similar for the elbow flexors. Also, no difference was found between one and three sets for knee extensors strength gains. However, the effect size for the knee extensors' PT was higher (0.65) for the three sets compared to the one set group (0.37). Furthermore, the MT of the elbow flexors also improved similar for both groups. However, the training volume used was not sufficient to improve MT of the knee extensors for either training group.

The effects of resistance training volume differences in strength gains between upper- and lower-body muscles have been the subjects of a few studies. Paulsen et al. [10] compared the effects of single set and three sets resistance training protocols in 18 untrained males. Subjects trained three times a week for six weeks. According to the results, the increase in 1 RM load for the leg exercises was significantly greater for the three sets group. However, the relative increase in 1 RM load for the upper-body exercises was similar between groups. More recently, Ronnestad et al. [12] compared the effects of single and multiple-sets resistance training on hypertrophy and strength gains in untrained men after 11 weeks of training, conducted three times a week. According to the results, the increase in 1 RM in the lower-body exercises and knee extension PT was significantly greater for the three sets program, while no difference existed in 1 RM between groups in upper-body exercises. The results of Paulsen et al. [10] and Ronnestad et al. [12] are in agreement with the present study.

Thus, based on our results and previous studies, it can be suggested that upper-body muscles have a lower stimulus threshold for training volume than lower-body muscle groups. Some authors suggest that the difference in the responsiveness of lower-body muscles to increases in training volume are due to the fact that leg muscles are used in daily-life activities to a greater extent than upper-body muscles [10,12]. Therefore, some of their growth potential may have already been reached, making it necessary to use a greater training volume to see favorable muscular strength adaptations.

However, contrary to our results, McBride et al. [15] indicated that, compared to a single set, multiple sets resulted in a significantly greater increase in percentage strength only in the biceps curl exercise (8.5% for single set and 22.8% for multiple sets) and not in the leg press exercise (41.2% for single set and 52.6% for multiple sets). These differences in the results among studies may be due to training volume and training population. McBride et al. [15] divided 25 untrained men ($n = 15$) and women ($n = 13$) into two groups, one group performed one set of leg press and biceps curl exercises, and the other group performed six sets of leg press and a biceps curl exercises. Also, McBride had men and women in both groups. According to Pincivero et al. [25], muscle force-generating ability depends upon many factors, such as muscle mass, muscle fiber type and muscle activation characteristics. This ability has been shown to be significantly higher in males than females, and is considered to be a reflection of greater muscle mass, a higher percentage of fast-twitch muscle fibers and a gender-specific pattern of muscle recruitment. Thus, training volume may lead to different strength gains in men and women.

Regarding muscle mass gains, Ronnestad et al. [12] also assessed the differences in upper- and lower-body training volume on muscle hypertrophy. They reported that thigh cross-sectional area (CSA) increased more in the three sets group than in the one set group. The authors suggested that the strength gains in the three sets group may be due to muscle hypertrophy. Contrary to the suggestion of Ronnestad et al. [12], the increase in muscle mass in the present study may not be the major explanation for the strength gains in the 3K-1E group, since there were no changes in lower-body MT in either group. The cause for the lack of MT gains in the present study may be related to the reduced training volume. In the present study, the 3K-1E group performed only six sets per week of exercises for the knee extensors, while the 1K-3E group performed a total of only two sets weekly. Also, Ronnestad et al. [12] used two knee extensors' exercises (i.e., leg press and knee extension), and our study used only one exercise for the knee extensors.

It is interesting to note, however, that the changes in peak torque obtained in the present study (10.9% and 5.1% for the 3K-1E and 1K-3E, respectively) are similar to those values obtained by Ronnestad et al. [12], who reported increases of 15% and 7% for the protocols involving three sets and one set of exercise, respectively. Therefore, the reduced volume used in the present study compromised more hypertrophy than strength gains. However, we cannot exclude the possibility that our measurement method (ultrasound) may not be as sensitive as magnetic resonance imaging (MRI) in detecting changes in muscle mass.

Regarding upper-body hypertrophy, Ronnestad et al. [12] found that both training groups improved upper trapezius muscle CSA, but there was no difference between groups. These results are in agreement to the present study. However, our results for upper-body muscle mass gains were lower (8.16% for 3K-1E and 5.43% for 1K-3E) than the CSA gains from the Ronnestad et al. [12] study (13.9% for the three sets and 9.7% for the single set). These differences may be due to training frequency (two versus three times/week), muscle group assessed (biceps versus trapezius) and measurement method (ultrasound versus MRI). Furthermore, the higher gains in muscle hypertrophy in the upper-body when compared to lower-body in the present investigation are in agreement with previous studies that observed a greater hypertrophic response to resistance training in upper extremity muscles compared to the lower extremity when the relative intensity and amount of training of the arms and legs were similar [26]. Starkey et al. [16] also determined the effects of different volumes of resistance training on knee extensors' MT assessed by ultrasound. Training was conducted three times per week using one set or three sets of dynamic variable resistance exercise. Similar to the present study they reported no difference for MT between three and one set groups. However, different than our results and those of Ronnestad et al. [12], they found that both training groups improved MT after 14 weeks. Their training frequency was greater than ours (two versus three times/week), which may account for the difference in hypertrophy between studies.

5. Conclusion

In summary, it was concluded that single-set training protocols might be sufficient for increasing strength and MT of the elbow flexors in untrained individuals, while additional sets seem to be necessary for increasing lower body strength. On the other hand, neither training stimulus (one set nor three sets) was sufficient to improve the MT of the knee extensors. These findings have important practical implications for adult fitness and rehabilitation programs in which many individuals have limited time for resistance-type training. Also, our results support the idea that different workout volumes may be used for different muscle groups in untrained individuals.

Conflict of interest statement

None.

References

[1] Kraemer WJ, Adams K, Cafarelli E, Dudley GA, Dooly C, Feigenbaum MS, et al. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. Med Sci Sports Exerc 2002;34:364—80.

[2] ACSM. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. Med Sci Sports Exerc 2009;41:687—708.

[3] Carpinelli RN, Otto RM. Strength training. Single versus multiple sets. Sports Med 1998;26:73—84.

[4] Galvao DA, Taaffe DR. Single- vs. multiple-set resistance training: recent developments in the controversy. J Strength Cond Res 2004;18:660—7.

[5] Rhea MR, Alvar BA, Burkett LN. Single versus multiple sets for strength: a meta-analysis to address the controversy. Res Q Exerc Sport 2002;73:485—8.

[6] Rhea MR, Alvar BA, Burkett LN, Ball SD. A meta-analysis to determine the dose response for strength development. Med Sci Sports Exerc 2003;35:456—64.

[7] Munn J, Herbert RD, Hancock MJ, Gandevia SC. Resistance training for strength: effect of number of sets and contraction speed. Med Sci Sports Exerc 2005;37:1622—6.
[8] Fluck M. Functional, structural and molecular plasticity of mammalian skeletal muscle in response to exercise stimuli. J Exp Biol 2006;209:2239—48.
[9] Thornell LE, Lindstrom M, Renault V, Mouly V, Butler-Browne GS. Satellite cells and training in the elderly. Scand J Med Sci Sports 2003;13:48—55.
[10] Paulsen G, Myklestad D, Raastad T. The influence of volume of exercise on early adaptations to strength training. J Strength Cond Res 2003;17:115—20.
[11] Rhea MR, Alvar BA, Ball SD, Burkett LN. Three sets of weight training superior to 1 set with equal intensity for eliciting strength. J Strength Cond Res 2002;16:525—9.
[12] Ronnestad BR, Egeland W, Kvamme NH, Refsnes PE, Kadi F, Raastad T. Dissimilar effects of one- and three-set strength training on strength and muscle mass gains in upper and lower body in untrained subjects. J Strength Cond Res 2007;21:157—63.
[13] Sanborn K, Boros R, Hruby J, Schilling B, O'Bryant H, Johnson R, et al. Short-term performance effects of weight training with multiple sets not to failure vs. a single set to failure in women. J Strength Cond Res 2000;14:328—31.
[14] Gotshalk LA, Loebel CC, Nindl BC, Putukian M, Sebastianelli WJ, Newton RU, et al. Hormonal responses of multiset versus single-set heavy-resistance exercise protocols. Can J Appl Physiol 1997;22:244—55.
[15] McBride JM, Blaak JB, Triplett-McBride T. Effect of resistance exercise volume and complexity on EMG, strength, and regional body composition. Eur J Appl Physiol 2003;90:626—32.
[16] Starkey DB, Pollock ML, Ishida Y, Welsch MA, Brechue WF, Graves JE, et al. Effect of resistance training volume on strength and muscle thickness. Med Sci Sports Exerc 1996;28:1311—20.
[17] Chilibeck PD, Stride D, Farthing JP, Burke DG. Effect of creatine ingestion after exercise on muscle thickness in males and females. Med Sci Sports Exerc 2004;36:1781—8.
[18] Abe T, DeHoyos DV, Pollock ML, Garzarella L. Time course for strength and muscle thickness changes following upper and lower body resistance training in men and women. Eur J Appl Physiol 2000;81:174—80.
[19] Sanada K, Kearns CF, Midorikawa T, Abe T. Prediction and validation of total and regional skeletal muscle mass by ultrasound in Japanese adults. Eur J Appl Physiol 2006;96:24—31.
[20] Brown LE. Isokinetics in human performance. Champaing: Hum Kinet 2000.
[21] Gentil P, Bottaro M. Influence of supervision ratio on muscle adaptations to resistance training in nontrained subjects. J Strength Cond Res 2010;24:639—43.
[22] USDHHS. 2008 Physical Activity Guidelines for Americans. Washington, DC: ODPHP; 2008.
[23] Jamieson J. Analysis of covariance (ANCOVA) with difference scores. Int J Psychophysiol 2004;52:277—83.
[24] Rhea MR. Determining the magnitude of treatment effects in strength training research through the use of the effect size. J Strength Cond Res 2004;18:918—20.
[25] Pincivero DM, Gandaio CM, Ito Y. Gender-specific knee extensor torque, flexor torque, and muscle fatigue responses during maximal effort contractions. Eur J Appl Physiol 2003;89:134—41.
[26] Cureton KJ, Collins MA, Hill DW, McElhannon FM Jr. Muscle hypertrophy in men and women. Med Sci Sports Exerc 1988;20:338—344.