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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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Training volume

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.