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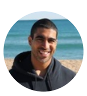
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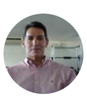
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ARTICLE

Effect of adding single-joint exercises to a multi-joint exercise resistance-training program on strength and hypertrophy in untrained subjects

Paulo Gentil, Saulo Rodrigo Sampaio Soares, Maria Claúdia Pereira, Rafael Rodrigues da Cunha, Saulo Santos Martorelli, André Santos Martorelli, and Martim Bottaro

Abstract: The aim of this study was to examine the effect of adding single-joint (SJ) exercises to a multi-joint (MJ) exercise resistance-training program on upper body muscle size and strength. Twenty-nine untrained young men participated in a 10-week training session. They were randomly divided in 2 groups: the MJ group performed only MJ exercises (lat pulldown and bench press); the MJ+SJ group performed the same MJ exercises plus SJ exercises (lat pulldown, bench press, elbow flexion, and elbow extension). Before and after the training period, the muscle thickness (MT) of the elbow flexors was measured with ultrasound, and peak torque (PT) was measured with an isokinetic dynamometer. There was a significant ($p < 0.05$) increase in MT (6.5% for MJ and 7.04% for MJ+SJ) and PT (10.40% for MJ and 12.85% for MJ+SJ) in both groups, but there were no between-group differences. Therefore, this study showed that the inclusion of SJ exercises in a MJ exercise training program resulted in no additional benefits in terms of muscle size or strength gains in untrained young men.

Key words: muscle hypertrophy, isolation exercise, training volume, exercise selection, training efficiency.

Résumé : Cette étude se propose d'analyser l'effet de l'ajout d'exercices monoarticulaires (« SJ ») à un programme d'exercices polyarticulaires contre résistance sur la grosseur et la force des muscles du haut du corps. Vingt-neuf jeunes hommes non entraînés participent à un programme d'entraînement d'une durée de 10 semaines. Deux groupes sont formés de façon aléatoire; l'un effectue seulement des exercices polyarticulaires (« MJ »: tirage-poitrine et développé couché) et l'autre (MJ+SJ) effectue les mêmes exercices auxquels il ajoute des exercices monoarticulaires (flexion et extension du coude). Avant et après la période d'entraînement, on évalue l'épaisseur des muscles fléchisseurs du coude (« MT ») par échographie et le moment de force de pointe (« PT ») au moyen d'un dynamomètre isocinétique. D'après les observations, les deux groupes présentent des augmentations significatives ($p < 0,05$) de MT (6,5% chez MJ et 7,04% chez MJ+SJ) et de PT (10,40% chez MJ et 12,85% chez MJ+SJ), et ce, sans différences significatives entre les groupes. En conséquence, l'ajout d'exercices monoarticulaires à un programme d'entraînement polyarticulaire n'apporte aucun gain de volume musculaire et de force musculaire chez de jeunes personnes non entraînées. [Traduit par la rédaction]

Mots-clés : hypertrophie musculaire, exercice isolé, volume d'entraînement, choix d'exercices, efficacité de l'entraînement.

Introduction

Optimally designed resistance-training programs are based on scientific principles that ensure correct control of training variables (American College of Sports Medicine (ACSM) 2009). One important variable is exercise selection. Resistance exercises can be classified as single-joint (SJ) or multi-joint (MJ) exercises. MJ (or compound) exercises recruit several muscles or muscle groups at a time, whereas SJ exercises recruit only 1 primary muscle or muscle group. During MJ exercises, some muscles are defined as prime movers (typically major muscle groups) and others are defined as accessories. For example, during the bench press exercise, the pectoralis major is often defined as the prime mover, whereas triceps and deltoids are defined as accessories. The same applies to pull downs, where the latissumus dorsi is often defined as the prime mover and the biceps brachii is often defined as the accessory.

This definition brings about the notion that the prime movers have the major responsibility for the movement, and that the accessory muscle groups have a secondary role and are not completely stimulated during MJ exercises. This results in the notion that if one wants to adequately develop the strength and size of accessory muscles, it is necessary to add isolation exercises to the training program. However, these definitions of prime movers and accessory muscles are controversial. Although some studies have shown that during MJ exercises, large muscles are activated more than smaller muscle groups (Gentil et al. 2007; Brennecke et al. 2009), others have shown that small muscle groups are recruited at an equal or greater extent than the prime movers (Clemons and Aaron 1997; Welsch et al. 2005). Another reason for using SJ exercises is that they are supposedly easier to learn. Rutherford and Jones (1986) and Chilibeck et al. (1998) suggested that muscle hypertrophy occurs earlier when SJ exercises are performed than when MJ exercises are performed because, according to the authors, learning and coordination play a dominant role early in training with MJ exercises. Therefore, many coaches believe that adding SJ exercises to an exercise program might be required for optimum strength and size gains.

However, the advantage of adding SJ assistance exercises was not seen by Rogers et al. (2000). They examined the effect of performing isolated SJ exercises in conjunction with MJ exercises on

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upper arm circumference and upper body strength in 17 national-level baseball players. One group performed only upper body MJ exercises; the other group completed the same MJ exercise program plus biceps curl and triceps extension exercises. Both groups reported the same increases in arm circumference and muscle strength. Therefore, the authors questioned the need for SJ assistance exercises. Because this study was only presented in the form of an abstract during the 2000 National Strength and Conditioning Association Conference, no additional information about the study protocol or results could be obtained. We are unaware of any published studies analyzing the effect of adding supplemental SJ assistance exercise to a MJ exercise session on strength gains and hypertrophy in untrained individuals.

If supplemental SJ exercises are not necessary, it might be possible to design programs that require significantly less time to complete a session. Because lack of time is the most frequently cited barrier to exercise adoption (Eyler et al. 2002; Trost et al. 2002; Schutzer and Graves, 2004; Silliman et al. 2004; Gómez-López et al. 2010), finding exercise programs that are less time consuming could help increase adherence to physical activity. Therefore, the purpose of our study was to evaluate gains in upper body muscle strength and hypertrophy in nonresistance-trained young men after the addition of supplemental SJ exercises. Our hypothesis was that the addition of supplemental SJ exercises would not increase gains in muscle size or strength.

Material and methods

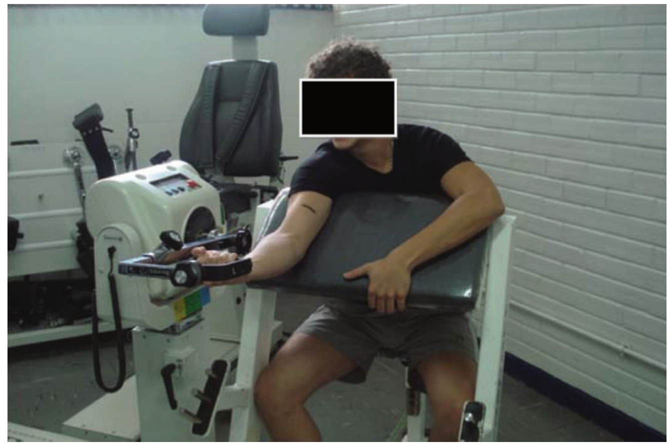
Participants

Fliers distributed around the university campus and word of mouth were used to randomly recruit 34 college-aged men. The criteria for entering the study were being at least 18 years of age, having no resistance-training experience, and being free of clinical problems that could be aggravated by the study procedures. To be included in the analysis, subjects had to attend at least 85% of the training sessions. The participants were instructed to not change their nutritional habits during the study period; if any relevant change was detected (e.g., becoming a vegetarian, restricting calories, taking nutritional supplements or ergogenic aids), the data for that participant were excluded from the analysis. At the end of the study, 29 subjects met the criteria (age, 22.68 ± 2.33 years; height, 175.3 ± 7.0 cm; weight, 72.03 ± 9.46 kg). Exclusions were related to the performance of strength training other than that prescribed in the study protocol, changes in nutritional habits, and (or) poor training attendance. The physical characteristics of the excluded subjects were similar to those of the other subjects. All participants were notified of the research procedures, requirements, and benefits and risks before providing written informed consent. The Institutional Research Ethics Committee granted approval for the study.

Muscle thickness

Participants were tested before and after the 10-week training period for muscle thickness (MT) of the elbow flexors of the right arm. All tests were conducted at the same time of the day, and participants were instructed to hydrate normally 24 h before the tests. Measurements were taken 3–5 days after the last training session so that swelling did not affect the MT measurement (Chilibeck et al. 2004). During this time, participants were instructed to not 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 but did not depress the skin. MTs of the elbow flexors were measured in accordance with the procedure described by Bemben (2002). Once the technician was satisfied with the quality of the image produced, the image on the monitor was frozen. A cursor was then used to measure MT, which was taken as the distance from the subcutaneous adipose tissue–muscle interface to the muscle–bone interface (Abe et al. 2000). A trained technician performed all analyses (Sanada et al. 2006). The coefficients of variation for elbow flexor MTs were less than 3.0%. The baseline test and retest intraclass correlation coefficient for elbow flexor MT was 0.96 (0.93–0.98).

Fig. 1. Illustration of the test performed on a seated Scott Bench.



Flexed arm circumference

Arm circumference was measured on the right side of the body. The arm was raised to a horizontal position in the sagittal (forward) plane, with the elbow at 90 degrees. The subject maximally contracted the elbow flexors, and the largest circumference was measured. The average of 3 measures was used for the analysis.

Peak torque

Unilateral elbow flexion peak torque (PT) was tested with 2 sets of 4 concentric repetitions at 60°s on a Biodex System 3 isokinetic dynamometer (Biodex Medical, Inc., Shirley, N.Y., USA), with 60 s of rest between sets. Calibration of the dynamometer was performed prior to each testing session, in accordance with the manufacturer's specifications. Participants were seated on a Scott Bench with their elbow aligned with the axis of rotation of the dynamometer's lever arm (Fig. 1). The forearm remained in a supinated position throughout the test. Verbal encouragement was given throughout the test. All tests were administered by the same investigator. Baseline test and retest intraclass correlation coefficient for peak torque was 0.96.

Resistance-training intervention

The subjects were divided into 2 groups. The MJ group performed only the bench press and lat pulldown exercises. The MJ+SJ group performed the bench press, lat pulldown, triceps extension, and elbow flexion exercises. Because the purpose of the study was to evaluate the effects of adding supplemental SJ exercises to a MJ exercise program, total training volume between the 2 groups was not equated. All exercises were performed with 3 sets of 8–12 repetitions. Participants were instructed to perform all sets until concentric failure. If necessary, loads were adjusted from set to set to maintain the designated number of repetitions. Training sessions were closely supervised by experienced trainers, because previous research has demonstrated greater gains with supervised training than with unsupervised training (Gentil and Bottaro 2010). Training was conducted 2 days a week, with a minimum of 48 h between sessions. The sets started every 3 min, and were separated by a rest interval of approximately 2 min. Each subject was instructed to record training logs for each workout

Table 1. Characteristics of subjects in the multi-joint training group (MJ) and in the MJ plus single-joint (SJ) training group (MJ+SJ).

Characteristics	MJ (n = 14)	MJ+SJ (n = 15)
Age (y)	22.36±2.1	22.8±2.65
Height (cm)	175.8±5.9	175.2±8.7
Body weight		
Pretraining (kg)	69.25±5.79	72.67±11.05
Post-training (kg)	71.05±6.13	73.93±10.99
Δ (%)	2.60	1.73
Flexed arm circumference		
Pretraining (cm)	30.56±2.61	31.29±2.78
Post-training (cm)	31.82±2.36*	33.35±2.15*
Δ (%)	4.11	6.56
Elbow flexor muscle thickness		
Pretraining (mm)	31.64±3.85	32.78±4.03
Post-training (mm)	33.69±3.52*	35.09±3.55*
Δ (%)	6.46	7.04
Elbow flexor peak torque		
Pretraining (N·m)	49.26±9.49	48.99±11.52
Post-training (N·m)	54.38±10.08*	55.29±10.24*
Δ (%)	10.40	12.85

Note: Values are expressed as means ± standard deviation.
*$p < 0.05$ for post-training vs. pretraining.

day. All training logs for the 10-week period were completed and verified by a researcher-supervisor after each exercise session.

Statistical analyses

All values are reported as mean ± standard deviation. A 2-way mixed-factor 2 × 2 (time × group) ANOVA, with a within-between design, was used to compare means. When necessary, multiple comparisons, with confidence interval adjustment, using the Bonferroni procedure, were used in the post hoc analysis. The intraclass correlation coefficient was applied to assess baseline test and retest reliability for elbow flexor MT and PT. Statistical significance was set at $p \leq 0.05$. Version 16.0 of SPSS (SPSS, Chicago, Ill., USA) was used in the statistical analysis.

Results

Subject characteristics are presented in Table 1. Baseline values of arm circumference, elbow flexor MT, and PT were not different between groups ($p > 0.05$). The ANOVA revealed no group × time interaction for arm circumference, MT, or PT ($p < 0.05$). However, a significant main effect for time was observed for all variables, and both groups showed significant increases in arm circumference, MT, and PT from baseline values ($p < 0.05$).

Discussion

Resistance training is the paramount activity to promote gains in muscle size and strength; however, the design of resistance-training programs is a complex task that involves many variables, including exercise selection. In our study, young men performed upper body resistance training with 2 different protocols. In the MJ group, only MJ exercises were performed; in the MJ+SJ group, SJ exercises were added. We found no difference between groups in gains in elbow flexor muscle size (6.46% for MJ and 7.04% for MJ+SJ) or strength (10.40% for MJ and 12.85% for MJ+SJ), indicating that the addition of isolation exercises might not be necessary to promote optimal results in untrained subjects. Furthermore, the gains in muscle size and strength we found were similar to the gains in elbow flexor MT (5.9%) and PT (12.5%) achieved by subjects training the elbow flexors twice a week with isolation exercises (Bottaro et al. 2011).

It is common to suggest that when MJ exercises are performed, many muscles or muscle groups are recruited, and the assumption that some muscles are more or less stimulated is often based on motor unit recruitment analysis. Although it is often believed that a muscle is better stimulated during isolation exercises, the evidence for this assumption is weak; previous studies have not shown increased motor unit recruitment during SJ exercises (Signorile et al. 1994; Wilk et al. 1996; Gentil et al. 2007). It is important to remember that even if a muscle shows increased motor unit recruitment during a given exercise, quantitative analysis of motor unit recruitment might not reflect the physiological stimuli or stress imposed on the muscles. For example, Prior et al. (2001) and Takahashi et al. (1994) found no relation between muscle activation and muscle damage. In both those studies, the muscles that showed the greatest incidence of muscle damage during the days after the exercise session did not show increased motor unit activation during the performance of the exercise.

Rogers et al. (2000) also investigated the effect of adding SJ exercises to a MJ exercise program on gains in the muscle size and strength of 17 national-level baseball players, and published the results in an abstract. The MJ group performed the bench press, lat pulldown, dumbbell inclined press, and dumbbell 1-arm row. The MJ+SJ group completed the same training program plus biceps curl and triceps extension exercises. They reported no significant differences between groups before or after the training program, which supports our findings. Rogers et al. (2000) reported that upper arm circumference increased in both groups (6.6% for MJ and 6.5% for MJ+SJ), as did the 5-repetition maximum (5RM) bench press (21.4% for MJ and 22.1% for MJ+SJ) and the 5RM lat pulldown (15.7% for MJ and 14.5% for MJ+SJ). We also found that arm circumference increased (4.11% for MJ and 6.56% for MJ+SJ); however, strength gains in our study were somewhat lower (10.40% for MJ and 12.85% for MJ+SJ) than those achieved by Rogers et al (2000). These differences could be related to the training protocol, type of strength assessment, or muscle group measured. The study by Rogers et al. (2000) involved 2 MJ exercises for the same muscle groups (lat pulldown and dumbbell 1-arm row), whereas the present study involved only 1 MJ exercise (lat pulldown). Furthermore, Rogers et al. (2000) assessed 5RM lat pulldown strength and we assessed isokinetic isolated elbow flexor strength (Feiereisen et al. 2010).

One important application of our study is in the design of more time-efficient programs. If the addition of SJ supplemental exercises is not necessary, training programs could be less time consuming and increase adherence to physical activity, because lack of time is the most frequently cited barrier to exercise adoption (Trost et al. 2002; Schutzer and Graves 2004; Silliman et al. 2004; Gómez-López et al. 2010). Furthermore, forgoing the SJ exercises could allow time for more MJ exercises during a training session. This could improve the results of a training program, because the benefits of MJ exercises in terms of hormonal and metabolic responses overshadow those of SJ exercises (ACSM 2009).

In summary, this study showed that the stimuli provided during MJ exercises were sufficient to promote gains in muscle size and strength in previously untrained subjects; no additional benefit was seen with the addition of supplemental SJ exercises over a period of 10 weeks. Thus, coaches and athletes could save time by not including SJ exercises in the training program and still achieve gains in muscle size and strength in the upper body. Future studies should analyze the use of SJ exercises over longer periods of time and in different populations. It would be also interesting to study this concept in lower body muscle groups.

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