Original Research

Journal of Strength and Conditioning Research™

# Single-Joint Exercise Results in Higher Hypertrophy of Elbow Flexors Than Multijoint Exercise

**Pietro Mannarino,[1,2,3] Thiago Matta,[2,3] Jefferson Lima,[3] Roberto Simão,[3] and Belmiro Freitas de Salles[3]**

*[1]Department of Orthopedic Surgery, Clementino Fraga Filho University Hospital, Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro, Brazil; [2]Biomedical Engineering Program, UFRJ, Rio de Janeiro, Brazil; and [3]Physical Education Post-Graduation Program, UFRJ, Rio de Janeiro, Brazil*



**Abstract**

Mannarino, P, Matta, T, Lima, J, Simão, R, and Freitas de Salles, B. Single-Joint Exercise Results in Higher Hypertrophy of Elbow Flexors Than Multijoint Exercise. *J Strength Cond Res* XX(X): 000–000, 2019—Recent data suggest that single-joint exercises are unnecessary to maximize the resistance training (RT) results in novice to advanced individuals. However, the present literature is still inconsistent on this topic and controversy arises. The aim of this study was to compare the effects of the unilateral dumbbell row (DR) (multiple-joint) vs. unilateral biceps curl (BC) (single-joint) exercises on strength and elbow flexors muscle thickness (MT). Ten untrained men were assigned to an 8-week RT program for elbow flexors, one arm performing DR and the other performing BC in a within-subject design. After a familiarization, pretraining MT was measured using an ultrasound (US) technique, and strength was tested using 10 repetition maximum (10RM) tests. After pretesting, 8 weeks of RT (4–6 sets, 8–12 repetitions to concentric failure, 2 sessions per week) was performed. Post-testing was conducted in the same order as pretesting 48 and 72 hours after the last session. Single-joint BC exercise resulted in higher hypertrophy of elbow flexors (11.06%) than the DR (5.16%) multijoint exercise after 8 weeks of RT ($p = 0.009$). The 10RM improvement was higher for DR in DR-trained arm, whereas 10RM for BC was higher in BC-trained arm. The single-joint exercise resulted in higher hypertrophy of the elbow flexors than multijoint exercise after 8 weeks of RT, whereas strength improvements were greater in accordance with specificity of RT exercise. Therefore, in RT prescription for elbow flexors hypertrophy, single-joint exercises such as BC should be emphasized.

**Key Words:** muscle thickness, ultrasound, strength, resistance training

## Introduction

Resistance training (RT) is the most popular and efficient exercise modality to improve muscular strength and promote hypertrophy. However, to achieve and maximize results, it is necessary to adequately prescribe and manipulate RT variables such as load intensity, number of sets, rest interval, training frequency, repetition velocity, exercise order, and selection (1,3,4,11,18,20–23). Exercise selection involves the choice of exercises for an RT program, and several terms have been suggested to classify exercises in different patterns such as primary or assistance, structural or body part, and multiple-joint or single-joint exercises (3).

Both multiple- and single-joint exercises have been shown to be effective to increase muscular strength and hypertrophy (21). Multiple-joint exercises require more coordination and complex neural responses and have generally been considered more effective for increasing overall muscular strength, while single-joint exercises have been used to target specific muscle groups and require reduced levels of skill and techniques (21). Therefore, the American College of Sports Medicine (1,21) recommends that multiple- and single-joint exercises should be included in RT with emphasis on multiple-joint exercises for maximizing overall muscle strength and hypertrophy in novice, intermediate, and advanced individuals.

*Address correspondence to Pietro Mannarino, mannarino.pietro@gmail.com.*

*Journal of Strength and Conditioning Research 00(00)/1–5*



Recent data showed that the addition of a single-joint exercise to a multiple-joint exercise program does not increase muscular strength and hypertrophy of upper-body muscles, suggesting that single-joint exercises are not necessary to maximize the RT results in novice to advanced individuals after 8–10 weeks of RT (1,2,6–9,21). However, only one of these studies actually compared the long-term effects of performing only multiple-joint vs. only single-joint exercises in muscular strength and hypertrophy improvements (8). Gentil et al. (8) showed similar strength and hypertrophy gains of elbow flexors comparing the effects of RT programs including only lat pull down vs. only biceps curl (BC) after 10 weeks. Unfortunately, the study has several major methodological limitations that can impair the authors' conclusions.

Theoretically, in single-joint exercises, the mechanical and chemical stress involved in hypertrophic response are directed to target muscles and limited only by its full loading capacity. In multijoint exercises, however, weaker muscles involved in the kinetic chain can limit early full range of motion. This will limit maximal muscle stress in the target muscle group and consequently the hypertrophic responses. Based on this, the initial hypothesis was that strength improvements would be greater in accordance with the specific RT exercise used while elbow flexors muscle thickness (MT) improvements would be greater in BC-trained arm. Therefore, the aim of this study was to compare the effects of the unilateral dumbbell row (DR) (multiple-joint) vs. BC (single-joint) exercises on strength and elbow flexors MT improvements in untrained men after 8 weeks of RT.

## Methods

### *Experimental Approach to the Problem*

To compare the effects of multiple-joint vs. single-joint exercises, 10 subjects were assigned to an 8-week RT program for the elbow flexors, one arm performing DR and the other performing BC in a within-subject design. All the subjects began undergoing a familiarization period for a 10-repetition maximum (10RM) testing. This was performed before pretesting and the initiation of the RT phase. After this, pretraining MT was measured using a B-mode ultrasound (US) (GE Healthcare, Chicago, IL, USA) technique, and the 10RM tests were performed on 2 nonconsecutive days for both exercises in both arms using a counterbalanced order. After pretesting, 8-week (2 sessions per week) RT was performed. Post-testing was conducted in the same order as pre-testing, and the 10RM and MT tests were performed 48 and 72 hours after the last session, respectively.

### *Subjects*

In this longitudinal study, 10 male volunteers (29.20 ± 3.85 years [range, 24–38 years]; 178.30 ± 7.29 cm; 96.40 ± 17.93 kg; 30.19 ± 4.46 kg·m$^{-2}$) had both arms examined. All subjects were right handed. Age was set between 25 and 40 years to eliminate any variation in hypertrophic responses due to age or sex. None of the subjects had participated in any systematic training or physical activity during the previous 6 months. Any clinical history or report of musculoskeletal pain/injuries, systemic disease, or previous surgery in the upper limbs was considered an exclusion criterion. Written informed consent was obtained from all individual subjects included in the study. In addition, all subjects received nutritional guidance to adopt a high-protein and high-calorie diet and to take a nutritional supplementation provided by the research team before training sessions (Mass Titanium 17500: Carb 132 g, Whey protein 17 g, fat 1 g). The experimental procedures were conducted in accordance with the Declaration of Helsinki. The experimental procedures were approved by the Ethics Committee of the Rio de Janeiro Federal University (registration numbers 570.945 and 519.230).

### *Procedures*

*Ten Repetition Maximum Testing.* Before performing the tests to obtain 10RM loads, all subjects performed 2 sessions to become familiar with the proposed exercises at intervals from 48 to 72 hours. To obtain reliable 10RM loads, data were assessed during 2 nonconsecutive days (48–72 hours). During the 10RM test, each subject performed a maximum of 5 attempts for each exercise with 5-minute rest intervals between attempts. The 10RM loads were accessed for DR and BC exercises in both arms using a counterbalanced order. Both exercises were performed unilaterally with dumbbells in supinated grip, and for DR, the subjects used a hand support for the nonexercised arm. After the 10RM load in a specific exercise was determined, an interval not shorter than 10 minutes was allowed before the 10RM determination of the next exercise. Standard exercise techniques were followed for each exercise to guarantee proper form, and verbal encouragement was provided during all the tests for all subjects. All individuals were instructed to avoid initial momentum. The heaviest load achieved in both days was considered the 10RM load for each exercise in each arm (17). After the 8 weeks of training, the 10RM tests were performed similarly to the pretraining tests to determine the strength gains.

*Muscle Thickness Measures.* The acquisition of US images was performed by the same experienced researcher using B-mode US (GE Healthcare) with a 40-mm linear probe of 8-MHz extended-field-of-view (EFOV) scans was taken longitudinally to elbow flexors according to Nelson et al. (16) recommendations. Each image was obtained at the halfway point of the intermuscular septum to guarantee the echographic images were taken at the same region after coating the transducer with a water-soluble transmission gel. The US probe was centered with respect to each

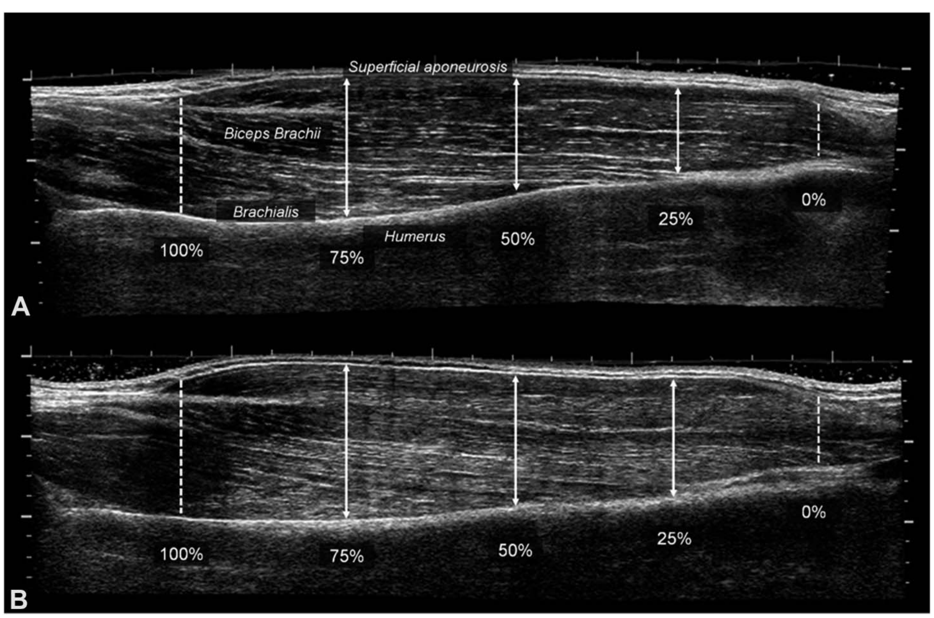


**Figure 1.** Example of subject US image and MT measures at 25, 50, and 75% of elbow flexors length at baseline (A) and after 8 weeks (B). US = ultrasound; MT = muscle thickness.

**Table 1**
**Resistance training protocol.***

| Week | Session/week | Set × repetition |
|---|---|---|
| Familiarization | 2 | |
| 10RM test and retest | 2 | |
| 1–4 | 2 | 4 × 8–12 |
| 5–8 | 2 | 6 × 8–12 |

*10RM = 10 repetition maximum.

location, and the images were recorded with subjects lying supine with arm relaxed and elbow extended. The images were analyzed with public software (ImageJ 1.43u, National Institutes of Health, USA). The MT was considered the perpendicular distance between the superficial aponeurosis and humerus measured at the limits of the US image along 3 muscle lengths (25%—proximal, 50%—middle, and 75% distal) (Figure 1). The MT measure was represented by mean of the 3 muscle-length thickness. All images were performed by the experienced researcher who was blind to the RT protocol performed. After the 8 weeks of training, the MT measures were performed similarly to the pre-training tests to determine the hypertrophy gains.

*Training Procedures.* All the subjects underwent an 8-week RT program for the elbow flexors, one arm using a multijoint exercise (DR) and the other using a single-joint exercise (BC). The arm side was randomly selected to perform multijoint or single-joint RT at baseline with 5 subjects performing the DR with the right arm and 5 performing the BC. The RT protocol was designed based on the American College of Sports Medicine recommendations for healthy individuals and adapted based on previous studies with similar design (21). The 10RM tests were used to set the initial training load. Subjects were instructed to perform both exercises to concentric muscular failure in all sets, and the weighs were continually adjusted session by session to keep the exercises in an 8–12 repetition range with a 2-minute rest interval between sets. The RT program followed a linear periodization with progressive volume, according to the training schedule (Table 1). The RT frequency was 2 sessions per week with at least 72-hour rest between sessions. A total of 16 sessions were performed in the 8-week training period with all the sessions occurring between 8 and 10 AM Verbal encouragement was provided in all training sessions to reach concentric failure. Adherence to the program was superior to 90% in all individuals, and a strength and conditioning professional and a physician supervised all the training sessions.

### Statistical Analyses

Test-retest reliability of 10RM and MT measures was determined in 2 nonconsecutive days for baseline measures, with a minimum 48-hour period between the tests. The intraclass correlation coefficient (ICCr) and 95% confidence interval (95% CI) was calculated interday based on a mean rating ($k = 2$), absolute agreement, and 2-way mixed-effects model (10).

The 10RM and MT data were normalized by the baseline measure. Shapiro-Wilk test was applied to verify the normality of all parameters data on baseline. For the normalized 10RM, Student t test for dependent sample was used to compare multijoint and single-joint arm for DR and BC exercises. For MT%, Wilcoxon nonparametric test was used to compare multijoint and single-joint arm. The significance level was set at $p \leq 0.05$. All analyses were performed using commercial software GraphPad Prism (GraphPad software inc., USA).

## Results

For DR 10 RM, ICCr = 0.978, 95% CI ranged from 0.910 to 0.998 and $p < 0.001$; for BC 10 RM, ICCr = 0.991, 95% CI ranged from 0.964 to 0.986 to 0.998 and $p < 0.001$; and for MT reliability, ICCr = 0.938, 95% CI ranged from 0.725 to 0.986 and $p < 0.001$.

The inference statistics for arm comparisons presented significant differences for 10RM% tests. For DR and BC exercises, 10RM% showed statistical differences between arms (Figures 2 and 3), with significantly higher improvements for multijoint trained arm in DR exercise ($p < 0.001$) (Figure 2) and for single-joint in BC exercise ($p < 0.001$) (Figure 3).

For MT%, the results showed statistical differences between groups ($p = 0.009$), with higher improvements for single-joint group (Figure 4).

## Discussion

Confirming the initial hypothesis, key finding suggest that BC exercise resulted in higher hypertrophy of elbow flexors (11.06%) than the DR (5.16%) after 8 weeks of RT. In addition, 10RM improvements were greater in accordance with specificity of RT protocol. The 10RM improvements were higher for DR in DR-trained arm, while 10RM improvements for BC were higher in BC-trained arm.

Only one previous study compared the chronic effects of performing multiple-joint vs. single-joint exercises in muscular strength and hypertrophy improvements. Gentil et al. (8) compared the effects of RT programs including lat pull down vs. BC on strength and hypertrophy of elbow flexors in untrained young men. Significant increases in MT for multijoint group and single-joint group (6.10 and 5.83%, respectively) were observed. There were also significant increases in peak torque (PT) for multijoint group (10.40%) and single-joint group (11.87%). No significant differences between groups in MT or PT were observed before or after training. The authors concluded that multijoint and single-joint exercises are equally effective to promote increases in upper-body muscle strength and hypertrophy in untrained men and recommend that the selection of exercises should be based on individual and practical aspects such as equipment availability, movement specificity, individual preferences, and time commitment. It is

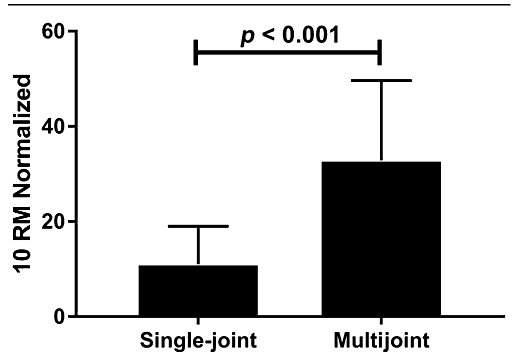


**Figure 2.** Ten repetition maximum (10RM) changes normalized on DR exercise (mean and *SD*) for single-joint and multijoint trained arms. DR = dumbbell row.

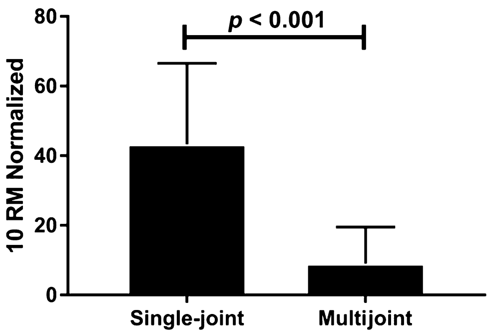


**Figure 3.** Ten repetition maximum (10RM) changes normalized on BC exercise (mean and *SD*) for single-joint and multijoint trained arms.

important to notice that PT was evaluated by an isokinetic dynamometer, which has poor external validity (practical application). Also, MT was analyzed in only one site of elbow flexors what can impair their conclusions. For hypertrophy measure, this study analyzed the mean of 3 different sites of the elbow flexors using EFOV scans. According to Matta et al. (14), the nonhomogeneous hypertrophy of elbow flexors can affect these results.

Previous data showed that the addition of single-joint exercise to a multiple-joint exercise program does not increase muscular strength and hypertrophy of upper-body muscles (2,6,9). Gentil et al. (9) were the first study comparing the effects of performing multijoint exercises vs. multijoint plus single-joint exercises on upper-body strength and hypertrophy in untrained men. The MT increased 6.5% for multijoint group and 7.04% for multijoint plus single-joint group, while PT increased 10.40% for multijoint group and 12.85% for multijoint plus single-joint groups, with no differences between groups. The authors concluded that the addition of single-joint exercises resulted in no additional effect. However, Gentil et al. (9) used the same methodology as Gentil et al. (8) and analyzed MT in only one site and measured strength gains by PT evaluated by an isokinetic dynamometer.

Similarly, França et al. (7) compared the effects of performing multijoint exercises vs. multijoint plus single-joint exercises on upper-body strength and muscle size of trained young men. Both groups significantly increased 1RM for elbow flexion (4.99 and 6.42% for multijoint group and multijoint plus single-joint group, respectively), extension (10.60 and 9.79%, for multijoint group and multijoint plus single-joint group, respectively), flexed arm circumference (1.72 and 1.45%, for multijoint group and multijoint plus single-joint group, respectively), and relaxed arm muscle circumference (1.33 and 3.17%, for multijoint group and multijoint plus single-joint group, respectively), with no differences between groups. Confirming Gentil et al. (9) findings, França et al. (7) also suggest that 8 weeks of RT involving multijoint or multijoint plus single-joint exercises resulted in similar improvements in muscle strength and size in trained subjects, concluding that RT programs involving only multijoint exercises is a time-efficient strategy. However, it is important to highlight that França et al. (7) used poor quality measures to access muscle size (flexed and relaxed arm muscle circumferences) and analyzed the effects of RT after only 8 weeks in trained subjects, what maybe insufficient to result in significant differences between groups in trained subjects.

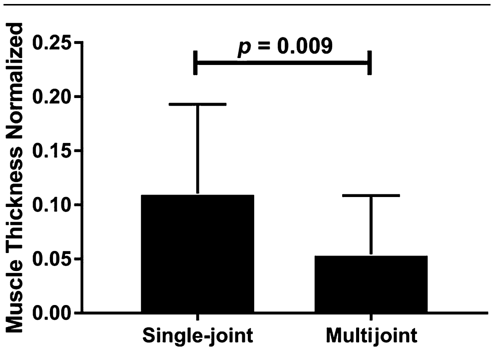


**Figure 4.** Elbow flexors thickness mean changes and *SD* for single-joint and multijoint trained arms.

Recently, Barbalho et al. (3) compared the effects of performing only multijoint exercises vs. performing multijoint plus single-joint exercises on upper- and lower-body strength and anthropometric measures of untrained young women. Both groups significantly decreased biceps and triceps skinfold, with no significant difference between them. Flexed arm circumference significantly increased in both groups; however, increases in multijoint plus single-joint group (4.39%) were significantly greater than multijoint group (3.50%). Increases in 10RM load in elbow extension, elbow flexion, and knee extension were all significant and not different between groups. Even with the results showing significant higher flexed arm circumference improvements in the group where single-joint exercises were added, the authors concluded that adding single-joint exercises to a multijoint RT program resulted in no benefits in muscle performance or anthropometric changes in untrained women.

The same authors of previous mentioned studies suggested in a recent review that single-joint exercises are not necessary to maximize the RT results in novice to advanced individuals (7). Because of these limitations, the previous mentioned studies are not strong evidence to support Gentil et al. (8) review conclusions. This study tried to answer if a single-joint exercise (BC) would be more effective to promote muscle strength gains and hypertrophy than a multijoint exercise (DR). We assumed that in DR weaker muscles involved in the kinetic chain could limit maximal elbow flexors stress, and consequently hypertrophy. Therefore, the initial hypothesis was that BC would promote greater muscle stress and consequently hypertrophic adaptations. In fact, greater elbow flexors hypertrophy was observed in the BC group. The 10RM% increases were significantly different between groups, observing a specificity for the exercise used during the RT protocol as previously reported in the reviewed literature for neural adaptation for strength gains (5). The 10RM% improvements were higher for BC in the BC group and DR in the DR group.

This study has important strengths when compared with previous research in the field. First, the study design where individuals performed different exercises between sides guaranteed the "ideal controls" as the subjects acted as controls for themselves. This eliminated the possibility of different distribution of responders and noresponders between groups (16). Second, the muscle hypertrophy evaluation using US in 3 different points can be considered superior to anthropometric measurements and even superior to US in a single point, where inhomogeneous hypertrophic responses inside the elbow flexors muscles can result in heterogeneous results (12). Finally, volunteers received strict supervision during all the RT protocol and nutritional guidance to maximize hypertrophic responses what is usually overlooked in most RT papers (13).

This study presents some limitations. First, the work focused in untrained healthy young males. Extrapolation of these results to trained subjects, female subjects or other age ranges should be seen carefully. Second, the exercises were selected trying to guarantee that the biceps muscle would be recruited in the same forearm position and during the complete range of motion. However, it is necessary to recognize that biomechanics and force application on elbow flexors are inherently different between both exercises. This implies different levels of muscle activity as reported by Signorille et al. (21) in multijoint exercise and Oliveira et al. (17) in single-joint exercises. Finally, the study was restricted to the elbow flexors muscle (i.e., biceps and brachialis), which have specific architectural characteristics. Using these results to infer hypertrophic responses in other muscles, especially in pennate or single-joint muscles, can jeopardize conclusions (12).

## Practical Applications

The present results suggest that single-joint exercise resulted in higher hypertrophy of elbow flexors than multijoint exercise after 8 weeks of RT. In addition, strength improvements were greater in accordance to specificity of RT exercise. Therefore, in RT prescription for elbow flexors hypertrophy in untrained men, single-joint exercises such as BC should be emphasized. Conversely, in RT prescription for strength development, the exercise choice should be in accordance with the specific movements or techniques in which strength improvements are necessary.

## Acknowledgments

Dr. Roberto Simão thank the Brazilian National Board for Scientific and Technological Development (CNPq) and Research and Development Foundation of Rio de Janeiro State (FAPERJ). The authors acknowledge Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Financiadora de Estudos e Projetos (FINEP), and Fundação de Amparo à Pesquisa do Estado do Rio de Janeiro (FAPERJ).

## References

1. Adams K, Cafarelli E, Dudley GA, et al. Progression models in resistance training for healthy adults. *Med Sci Sports Exerc* 34: 364–380, 2002.
2. American College of Sports Medicine. ACSM position stand. Progression models in resistance training for healthy adults. *Med Sci Sports Exerc* 41: 687–708, 2009.
3. Barbalho M, Gentil P, Raiol R, et al. Influence of adding single-joint exercise to a multijoint resistance training program in untrained young women. *J Strength Cond Res* 2018. Epub ahead of print.
4. Bird SP, Tarpenning KM, Marino FE. Designing resistance training programmes to enhance muscular fitness: A review of the acute programme variables. *Sports Med* 35: 841–851, 2005.
5. Figueiredo VC, de Salles BF, Trajano GS. Volume for muscle hypertrophy and health outcomes: The most effective variable in resistance training. *Sports Med* 48: 499–505, 2018.
6. Folland JP, Williams AG. The adaptations to strength training. *Sport Med* 37: 145–168, 2007.
7. de França HS, Branco PAN, Guedes Junior DP, et al. The effects of adding single-joint exercises to a multi-joint exercise resistance training program on upper body muscle strength and size in trained men. *Appl Physiol Nutr Metab* 40: 822–826, 2015.
8. Gentil P, Fisher J, Steele J. A review of the acute effects and long-term adaptations of single- and multi-joint exercises during resistance training. *Sport Med* 47: 843–855, 2017.
9. Gentil P, Soares S, Bottaro M. Single vs. multi-joint resistance exercises: Effects on muscle strength and hypertrophy. *Asian J Sports Med* 6: 1–5, 2015.
10. Gentil P, Soares SRS, Pereira MC, et al. Effect of adding single-joint exercises to a multi-joint exercise resistance-training program on strength and hypertrophy in untrained subjects. *Appl Physiol Nutr Metab* 38: 341–344, 2013.
11. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J Chiropr Med* 15: 155–163, 2016.
12. Kraemer WJ, Adams K, Cafarelli E, et al. Progression models in resistance training for healthy adults. *Med Sci Sports Exerc* 36: 674–688, 2009.
13. Kraemer WJ, Ratamess NA. Fundamentals of resistance training: Progression and exercise prescription. *Med Sci Sports Exerc* 36: 674–688, 2004.
14. Matta T, Simão R, De Salles BF, Spineti J, Oliveira LF. Strength training's chronic effects on muscle architecture parameters of different arm sites. *J Strength Cond Res* 25: 1711–1717, 2011.
15. Morton RW, McGlory C, Phillips SM. Nutritional interventions to augment resistance training-induced skeletal muscle hypertrophy. *Front Physiol* 6: 245, 2015.
16. Nelson CM, Dewald JPA, Murray WM. In vivo measurements of biceps brachii and triceps brachii fascicle lengths using extended field-of-view ultrasound. *J Biomech* 49: 1948–1952, 2016.
17. Oliveira LF, Matta TT, Alves DS, Garcia MAC, Vieira TMM. Effect of the shoulder position on the biceps brachii EMG in different dumbbell curls. *J Sport Sci Med* 8: 24–29, 2009.
18. Roberts MD, Haun CT, Mobley CB, et al. Physiological differences between low versus high skeletal muscle hypertrophic responders to resistance exercise training: Current perspectives and future research directions. *Front Physiol* 9: 834, 2018.
19. De Salles BF, Maior AS, Polito M, et al. Influence of rest interval lengths on hypotensive response after strength training sessions performed by older men. *J Strength Cond Res* 24: 3049–3054, 2010.
20. de Salles BF, Simão R, Miranda F, Novaes JdaS, Lemos A, Willardson JM. Rest interval between sets in strength training. *Sports Med* 39: 765–777, 2009.
21. Signorile JF, Zink AJ, Szwed SP. A comparative electromyographical investigation of muscle utilization patterns using various hand positions during the lat pull-down. *J Strength Cond Res* 16: 539–546, 2002.
22. Simão R, de Salles BF, Figueiredo T, Dias I, Willardson JM. Exercise order in resistance training. *Sports Med* 42: 251–265, 2012.
23. Williams TD, Tolusso DV, Fedewa MV, Esco MR. Comparison of periodized and non-periodized resistance training on maximal strength: A meta-analysis. *Sports Med* 47: 2083–2100, 2017.