Does the addition of single joint exercises to a resistance training program improve changes in performance and anthropometric measures in untrained men?

Matheus Barbalho (1,2), Victor Silveira Coswig (3), Rodolfo Raiol (4), James Steele (5,6), James P Fisher (5), Antonio Paoli (7), Antonino Bianco (8), Paulo Gentil (2)

(1) Centro de Ciências Biológicas e da Saúde. Universidade da Amazônia, Belém, Pará, Brasil; (2) Faculdade de Educação Física e Dança, Universidade Federal de Goiás, Goiânia, Brasil; (3) Faculdade de Educação Física. Universidade Federal do Pará, Castanhal, Pará, Brasil; (4) Centro de Ciências Biológicas e da Saúde. Centro Universitário do Estado do Pará, Belém, Pará, Brasil; (5) Center for Health, Exercise and Sport Science, Southampton Solent University, Southampton, United Kingdom; (6) ukactive Research Institute, London, United Kingdom; (7) Department of Biomedical Sciences, University of Padova, Padova, Italy; (8) Sport and Exercise Sciences Research Unit, University of Palermo, Palermo, Italy

Abstract

The present study compared changes in muscle performance and anthropometric measures in young men performing resistance training (RT) programs composed of only multi joint (MJ) exercises, or with the addition of single joint (SJ) exercises (MJ+SJ). Twenty untrained men were randomized to MJ or MJ+SJ groups for 8 weeks. Both groups performed the same MJ exercises. The difference was that the MJ+SJ group added SJ exercises for upper and lower limbs. Participants were tested for 10 repetitions maximum (10RM), flexed arm circumference, and biceps and triceps skinfolds. Both groups significantly increased 10RM load for the bench press (MJ 38.5%, MJ+SJ 40.1%), elbow extension (MJ 28.7%, MJ+SJ 31.9%), pull down (MJ 34.0% MJ+SJ 38.5%), elbow flexion (MJ 38.2%, MJ+SJ 45.3%), leg press (MJ 40.8%, MJ+SJ 46.8%) and knee extension (MJ 26.9%, MJ+SJ 32.9%), with no significant difference between them. The decreases in biceps (MJ -3.6%, MJ+SJ –3.9%) and triceps (MJ –3.4%, MJ+SJ -3.3%) skinfolds were significant for both groups, with no difference between them. However, the flexed arm circumference increased significantly more for MJ+SJ (5.2%), than for MJ (4.0%). The use of SJ exercises as a complement to a RT program containing MJ exercises brings no additional benefit to untrained men in terms of muscle performance and skinfold reduction, though it promoted higher increases in arm circumference.

Key Words: strength training, muscle hypertrophy, training volume, exercise selection, isolation exercise

Eur J Transl Myol 28 (4): xx1-xx8, 2018

The American College of Sports Medicine recommends in their guidelines the inclusion of multiple and single joint exercises during progressive resistance training (RT) to effectively increase muscle strength in healthy adults.[1] However, these guidelines do not specify the effects of these exercises when applied together or independently in an RT program. It has been discussed that optimization of results produced from a RT program are dependent on the manipulation of a number of variables including but not limited to: exercise order, rest interval, number of exercises performed, and exercise selection.[2,3] Resistance exercises can be classified as single-joint (SJ) or multi-joint (MJ) exercises.[4] MJ exercises involve more than one joint and recruit several muscles or muscle groups at a time, whereas SJ exercises recruit a primary muscle or muscle group. During MJ exercises, some muscles are defined as prime movers and others are defined as accessories. For example, during the bench press exercises, the pectoralis major is often defined as the prime mover and triceps is considered secondary.[5] That suggests the prime movers have the major responsibility for the movement, and that the accessory muscle groups have a secondary role and may experience less stimulation during MJ exercises.

Therefore, based on this assumption, the general belief is that if one wants to adequately develop the strength and size of accessory muscles, the addition of SJ exercise would be necessary.

In agreement with this, most popular recommendations postulate that RT sessions should involve both SJ and MJ exercises,[1] being supported by previous reports that experienced individuals (i.e. bodybuilders) combine MJ and SJ exercises in their routines.[6–9] However, the notion that a muscle would be better stimulated when trained during SJ has been challenged by studies that reported no difference in muscle size and strength changes between RT programs involving only SJ or MJ[10] and also by studies that showed higher results for MJ in terms of muscle strength and cardiorespiratory fitness.[11] There is also evidence that the addition of SJ exercises to a MJ exercise RT program does not increase muscle size and strength gains in untrained,[12] or trained men.[13] This being so even in spite of the fact that the last approach also meant performance of a greater volume of exercise. In light of this, the inclusion of SJ exercises has been questioned due to an unnecessary time commitment that may ultimately impair exercise adherence,[4] since lack of time is a common barrier to exercise adoption.[14,15] Notwithstanding, a recent study in untrained women partially challenged that recommendation, since the addition of SJ exercise resulted to increased gains in arm circumference.[16] The reasons for the divergence regarding the results reported by Gentil et al.[12] and Barbalho et al.[16] are not obvious, since both used similar training volumes and exercises. The only notable differences was that Barbalho et al.[16] used linear periodization in women, while the RT program in the study of Gentil et al.[12] wasn’t periodized and involved men. Another possible confounding factor was that Gentil et al.[12] used ultrasound to analyze only elbow flexors, while the analysis of arm circumference performed by Barbalho et al.[16] might include other muscles, as elbow extensors, which showed different regional adaptations to SJ and MJ.[17,18] Considering results apparent divergence, it would be interesting to replicate the protocol of Barbalho et al.[16] in young men to verify if the results would replicate or not the results in the in group of women. Moreover, the only known study to compare MJ vs. MJ+SJ in untrained men was performed by Gentil et al.[12] which warrants further investigations to add to the body of literature. Therefore, the purpose of the present study was to evaluate the effects of adding SJ exercises to a MJ exercise RT program in the gains of upper and lower body muscle strength and anthropometry in untrained young men.

Material and Methods

Experimental overview

Two initial weeks involved familiarization with RT exercises and tests for muscle performance and anthropometric measures. Muscle performance was tested using 10 repetitions maximum (10RM) tests in both MJ (bench press, pull down and leg press) and SJ exercises (elbow extension, elbow flexion, and knee extension). Anthropometric changes were evaluated by measures of flexed arm circumference (FAC), and biceps and triceps skinfolds. All measures were taken before the beginning of the experiment and 5-7 days after the last training session. Training volume was not equated, because the difference was intended to be inherent to the protocols and to reflect the addition of SJ exercises to typical MJ exercise RT programs. After two initial weeks of evaluation, participants were randomly assigned to two groups by block randomization: a) a group that performed only MJ exercises (MJ group, n=12); and b) a group performed a program involving both MJ and SJ exercises (MJ+SJ group, n=12). Training was performed for eight weeks following a linear periodization model.

Participants

After being informed of the experimental procedures, its risks and benefits, the participants (20 young heathy male) signed an informed consent form. The study was approved by the local Ethics Committee of under the number CAAE 69724617.7\.0000.5169. A priori sample size tests (G*Power 3.0.10) revealed that a total of 20 participants would be required to detect an effect size of 0.8 with a statistical power of 0.90 and a alfa of 0.05. Therefore, 24 volunteers were recruited to prevent critical data loss due to attrition. The invitation was performed through fliers distributed over the university campus, by social media and by word-of-mouth. The inclusion criteria were being at least 18 years old, having no previous RT experience and being free of clinical problems that could be aggravated by the study procedures. Minimum attendance was set at 80% based on previous findings,[19] which lead to the exclusion of four participants from the analysis, two in each group. Thus the final group numbers were: MJ group, n=10; MJ+SJ group, n=10. Whilst there was no control of the participants’ diets, they were instructed to maintain their habitual diets and were regularly questioned to check if any drastic changes occurred, such as the use of ergogenic aids and the adoption of different nutrient selection (i.e. increasing protein intake, decreasing carbohydrate intake, becoming vegetarian, etc.).

Assessments

Anthropometric measures

The measurements were performed on the right side of the body in the first visit and 5 to 7 days after the last training session. The biceps and triceps skinfolds were measured using calipers at the meso-humeral point, while the arm was in the anatomical position, hanging down the side of the body and relaxed (Adip Plicometer Scientific Cescorf®, Porto Alegre, Rio Grande do Sul, Brazil). Three measurements were taken and mean values were used during the analysis. For flexed arm circumference, the arm was lifted to a horizontal position in the sagittal plane, with the elbow at 90 degrees. The subject contracted maximally the flexors of the elbow, and the largest circumference was measured. The intraclass correlation coefficients (ICC) of these procedures were determined in our laboratory prior to conducting the study, in two identical test sessions with a one-week interval. Values ranged from 0.96 to 0.97 for skinfolds and 0.96 for FAC. In these analysis, the standard error of measurement (SEM) were 0.12 and 0.16 mm for triceps and biceps skinfolds, respectively, and 0.19 cm for the FAC.

Ten repetitions maximum test (10RM)

Participants performed 10RM tests on bench press, elbow extension, pull down, elbow flexion, leg press and knee extension (Physicus, Pró, Auriflama, São Paulo, Brazil). We chose 10RM instead of 1RM because, when participants are training in high repetition ranges, it seems more appropriate to evaluate performance through multiple repetition tests.[20,21] The tests were performed over 3 consecutive days. On the first day, participants were tested for bench press and elbow flexion; the second involved pull down and knee extension; leg press and elbow extension were tested on the third day. The warm-up consisted of 10 repetitions with a comfortable self-selected load followed by 5 minutes of rest. Then, the initial load was estimated based on the participants' height, weight and muscularity. If the volunteer failed to perform 10 repetitions or performed more than 10, the load was adjusted by a minimum of 1 kg. Rest between attempts was established in 5 minutes and no participant needed more than three attempts to reach 10RM. The ICC of thse procedures ranged from 0.93 to 0.98. In this analysis SEM was generally less than 3%.

Training Protocol

Training was performed 4 times a week, divided into 2 different muscle groups, as shown in Table 1. Therefore, each muscle group was trained twice a week with at least 72 hours between sessions. All sessions were supervised with a ratio of at least one supervisor to five trainees.[22]

Table 1. *Training Protocols*

Session A (Monday/Thursday)	Session B (Tuesday/Friday)
Barbell bench press	45º leg press
Military press	Seated knee flexion
Lat pull down	Calf raises
Seated cable row	*Knee extension
Cable triceps*	
Barbell biceps curl*	

*Used only by the MJ+SJ group

Both groups performed the same MJ exercises, using the same number of sets per exercise (three), repetition ranges, set endpoints, and rest intervals. The difference was only the inclusion of SJ exercises for the MJ+SJ group. The protocol was based on linear periodization. During weeks 1 and 2, participants used loads permitting 12-15 repetitions before reaching momentary failure with 30-60 seconds of rest between sets. During weeks 3 and 4, loads permitting 10-12 repetitions before reaching momentary failure were used with 1-2 minutes of rest between sets. During weeks 5 and 6 loads permitting 6-8 repetitions before reaching momentary failure were used with 2-3 minutes of rest between sets. During weeks 7 and 8, participants used loads permitting 4-6 repetitions before reaching momentary failure with inter-set intervals of 3-4 minutes. Participants were instructed to perform every set to momentary failure as previously defined by Steele et al.[23] and when they were able to perform more repetitions than suggested, the load was increased (1 to 5 kg) in alignment with the desired repetition range for the next training session. The volunteers were instructed to perform the concentric and eccentric phases in 2 seconds each, without pausing between contractions.

Statistical analysis

All values are reported by means ± standard deviation. Assumptions of normality of distribution were examined using Shapiro-Wilk's test. The independent variable was the group (MJ or MJ+SJ) and the dependent variables were the absolute change in the outcome variables (post-minus pre-test scores). Analysis of covariance (ANCOVA) was used to compare absolute change in each outcome variable between groups with pre-test scores used as a covariate. Further, 95% confidence intervals (CI) were examined for within group changes. Significant within group change was considered to have occurred if the 95%CIs for changes did not cross zero. Statistical analysis was performed using JASP (version 0.8.1.2; University of Amsterdam, Netherlands), with alpha for significance accepted at <0.05.

Results

Table 2 shows participant baseline demographic characteristics and Table 3 shows the variables analyzed before and after the intervention program.

Muscle Performance Outcomes (10RM)

Between-groups comparisons using ANCOVA revealed no significant differences for changes in any muscle performance outcome (table 4). The 95%CIs also suggested that both groups significantly increased in the 10RM load in the bench press (38.5% for MJ and 40.1% for MJ+SJ), elbow extension (28.7% for MJ and 31.9% for MJ+SJ), pull down (34% for MJ and 38.5% for MJ+SJ), elbow flexion (38.2% for MJ and 45.3% for MJ+SJ), leg press (40.8% for MJ and 46.8% for MJ+SJ) and knee extension (26.9% for MJ and 32.9% for

Table 2. *Characteristics of the participants (mean ± standard deviation).*

	MJ (n=10)		MJ+SJ (n=10)	
	Mean	SD	Mean	SD
Age (yrs)	20.2	1.47	21.5	1.90
Height (m)	175.5	5.10	175.2	4.58
Body Mass (kg)	75	7.98	73	6.21

MJ+SJ). Change for each muscle performance outcome in addition to the 95%CIs for the changes are shown in Table 4.

Anthropometric measures (FAC, and Biceps and Triceps Skinfolds)

Between groups comparisons using ANCOVA revealed no significant differences for changes for biceps and triceps skinfolds (table 4). The 95%CIs also suggested that both groups significant decreased both biceps skinfold (-3.6% for MJ and -3.9% for MJ+SJ) and triceps skinfold (-3.4% for MJ and -3.3% for MJ+SJ). Between group comparisons using ANCOVA did reveal a significant difference for change in FAC favoring the MJ+SJ group. The 95% CIs suggested both groups significantly increased FAC yet the change in the MJ+SJ group was significantly greater than that in the MJ only group (4.0% for MJ+SJ and 5.2% for MJ).

Discussion

The present study compared two groups performing RT programs composed of only MJ exercises or MJ with the addition of SJ exercises in muscle performance and anthropometric changes in untrained men. According to our results, the addition of SJ exercises did not result in

Table 3. *Characteristics of the participant's pre and post the training period (mean±standard deviation)*

	MJ group			MJ+SJ group		
	Pre	Post	p	Pre	Post	P
Bench press 10RM (kg)	28.0±5.4	38.8±4.3	<0.001	28.4±4.1	39.0±4.3	<0.001
Triceps 10RM (kg)	14.2±4.8	18.4±5.3	<0.001	15.2±3.2	19.4±3.4	<0.001
Pull down 10RM (kg)	22.6±5.8	30.8±5.5	<0.001	23.8±3.3	31.8±3.5	<0.001
Biceps 10RM (kg)	14.2±5.9	19.6±5.3	<0.001	15.2±3.7	20.8±4.1	<0.001
Leg press 10RM (kg)	25.4±7.3	36.6±7.7	<0.001	26.8±5.3	37.2±5.1	<0.001
Knee extension (10RM)	20.8±6.2	27.0±6.1	<0.001	22.0±3.2	27.6±3.3	<0.001
Biceps skinfold (mm)	12.8±0.4	12.3±0.4	<0.001	12.9±0.5	12.4±0.5	<0.001
Triceps skinfold (mm)	13.7±0.5	13.2±0.5	<0.001	13.8±0.4	13.4±0.4	<0.001
Flexed arm circumference (cm)	30.4±0.6	31.6±0.6	<0.001	30.6±0.5	32.2±0.6	<0.001

Legends: MJ – multi-joint group; MJ+SJ – multi and single joint group.

Table 4. *Change in outcomes over the training period in addition to 95% CIs. (marginal mean±standard error)*

	MJ group		MJ+SJ group			
	Change	95%CIs	Change	95% CIs	F	p
Bench press 10RM (kg)	10.8±0.4	9.7 to 11.8	10.6±0.9	8.3 to 12.8	0.019	0.892
Triceps 10RM (kg)	4.2±0.2	3.7 to 4.6	4.2±0.2	3.7 to 4.5	0.068	0.797
Pull down 10RM (kg)	8.2±0.2	7.7 to 8.6	8±0.2	7.3 to 8.6	0.219	0.646
Biceps 10RM (kg)	5.4±0.3	4.7 to 6.9	5.6±0.9	4.9 to 6.2	0.418	0.526
Leg press 10RM (kg)	11.2±0.6	9.8 to 12.5	10.4±0.9	8.1 to 12.6	0.380	0.546
Knee extension (10RM)	6.2±0.6	5.7 to 6.6	5.6±0.4	4.7 to 6.5	1.511	0.236
Biceps skinfold (mm)	-0.5±0.02	-0.5 to -0.4	-0.4±0.03	-0.5 to -0.4	0.780	0.390
Triceps skinfold (mm)	-0.4±0.03	-0.5 to -0.3	-0.5±0.02	-0.5 to -0.4	0.042	0.840
Flexed arm circumference (cm)	1.2±0.1	1.1 to 1.3	1.6±0.1	1.4 to 1.7	16.418	0.001

Legends: MJ – multi-joint group; MJ+SJ – multi and single joint group

greater changes in muscle strength nor reductions in skinfold thickness compared to MJ alone. Regarding FAC, the between groups difference was statistically significant, with greater increases for the MJ+SJ.

The muscle strength results of the present study are in agreement with previous studies in untrained and trained subjects.[12,13] The study by Gentil et al.[12] investigated the performance of only MJ exercises (bench press and lat pulldown) compared to the same exercises with addition of triceps extension and elbow flexion in peak torque, with no difference between groups. The study by França et al.[13] compared changes in upper body strength in trained men after 8 weeks performing RT with MJ+SJ exercises or only MJ exercises and found no difference in strength gains between groups. Similarly, Barbalho et al.[16] investigated the same design presented here in untrained women and the results suggested no difference between groups for strength gains in the bench press, triceps extension, biceps curls, leg press and knee extension. An important aspect of our findings was that the MJ group had increases similar to the MJ+SJ group in elbow flexion, elbow extension, and knee extension, although they did not perform these exercises, which is similar to results which have been previously reported.[13,16] It seems possible that performing SJ exercises did not bring greater specific performance gains to the 10RM test because, compared with MJ exercises, SJ exercises involve simple tasks that do not heavily depend on motor learning.[24] Therefore, the performance of specific SJ may not be necessary when the task tested involves SJ movements. As for the anthropometric measures, our results conflict with Gentil et al.[12] who found no difference in elbow flexor muscles thickness between MJ and MJ+SJ. However, similar to the present study, Barbalho et al.[16] found significant difference in FAC between groups. One important difference between the studies is that Gentil et al.[12] analyzed only the elbow flexors using ultrasound, while the analysis of FAC, which was performed by Barbalho et al.[16] and in the present study, also involves elbow extensors. In this regard, a previous study showed that elbow flexors' muscle thickness increase similarly after SJ and MJ exercises.[10] However, it has been shown that the elbow extensors may experience different patterns of regional muscle hypertrophy between SJ and MJ exercises.[17,18] The analysis of triceps hypertrophy in MJ,[18] and SJ exercises,[17] were performed in different studies, which prevents direct comparisons. However, it might be possible that elbow extensors respond differently than flexors to SJ and MJ exercises. As such, for this specific muscle group, performance of either MJ or SJ alone may result in similar whole muscle increases in size due to differential regional hypertrophy, yet both combined may optimize whole muscle hypertrophy at least in untrained men. The results of the present study are however in contrast with França et al.[13] who also used a periodized RT program and reported no differences for the changes in FAC between MJ and MJ+SJ in trained men. There are many possibilities for this apparent divergence. The first is that trained men experience reduced increases in muscle size when compared to untrained;[25] therefore, the changes observed in trained individuals might have been too small to be detected. It might also be possible that both MJ and MJ+SJ would experience a ceiling effect over the long term, but based upon our results it may be that MJ+SJ will reach that point earlier due to the more rapid initial increase. Therefore, while the short terms results favor MJ+SJ, there may be no long-term differences. Ogasawara et al.,[26] reported that the time course of muscle hypertrophy differs between pectoralis and triceps after performing chest press supporting that the addition of isolated triceps exercises might have accelerated the gains in muscle size at this initial training phase. Another possible explanation is that experienced individuals have a higher ability to employ effort and previous studies showed that fatigue might alter muscle fiber recruitment, with a greater participation of muscles that were not involved to a large extent in the beginning of the exercise.[10,27] This might increase the participation of arm muscles during MJ exercises. Moreover, trained subjects might be able to recruit more muscle fibers in the muscles involved in an exercise. Taken together, these might explain why adding SJ did not result in significant benefits for experienced individuals. The increased training volume might also be used to explain the advantage of MJ+SJ over MJ for muscle hypertrophy. However, it is important to note that the benefits of training volume for muscle hypertrophy is debated heavily,[28,29] and there is both evidence suggesting additional volume from SJ exercises is not influential,[12,13] as well as to the contrary.[16] An alternative explanation is that SJ would be necessary because the physiological stress in arm muscles is reduced during upper body MJ exercises.[30] Some important limitations of the present study are the lack of anthropometric measures for lower body and the absence of a more precise method for analyzing increases in muscle size. However, it is important to note that measures of arm circumference are a popular and reliable method for estimating changes in muscle size during RT.[31–33] Another important limitation is training duration, which leaves many open questions. Considering that gains in muscle size are more evident in the beginning of the training period,[34–38] it would be important to know if the difference in arm circumference would persist over long term, or if this will diminish over time. Furthermore, considering that gains in muscle size are diminished over long-term, the differences between MJ and MJ+SJ might progressively decrease until becoming negligible, as previously reported in trained men.[13] Future studies are needed to test these hypotheses. Taking together all our present observations, we may conclude that the stimuli provided during MJ exercises were sufficient to promote gains in muscle strength in untrained men and no additional benefit was obtained by the inclusion of supplemental SJ exercises over a period of eight weeks. However, the addition of SJ exercise resulted in additional gains in arm circumference. In light of this, we suggest that the use of RT programs containing only MJ exercises might be recommended with the purpose to provide a time efficient approach, which might help to increase exercise adherence due to a reduction in time commitment. However, the addition of SJ exercises might be considered for anthropometric changes, at least in the initial training period. It must be questioned, however, if the differences in FAC would compensate for the increase in time commitment, since maximum gains in muscle size might not be the main purpose of many people involved with resistance training. Moreover, the fact that the MJ group showed significant changes in anthropometric measures and performance challenges the common belief that arms SJ exercises are essential for muscle size and strength.

List of acronyms

FAC - flexed arm circumference
ICC - intraclass correlation coefficients
MJ - multi-joint
RT - resistance training
SEM - standard error of measurement
SJ - single-joint
10RM - 10 repetitions maximum

Author's contributions

Each author contributed in equal part to the manuscript.

Acknowledgments

We would like to thank all the participants of the study and their coaches for consenting to provide the data. ***Funding***: None.

Conflict of Interest

The authors declare no conflicts of interests.

Ethical Publication Statement

We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

Corresponding Author

Paulo Gentil, Faculdade de Educação Física e Dança, Universidade Federal de Goiás – Avenida Esperança s/n, Campus Samambaia – Goiânia, 74690-900, Brazil.
Phone: +59 62 35211085
E-mail: paulogentil@hotmail.com

E-mail of co-authors

Matheus Barbalho: matheussmbarbalho@gmail.com
Victor Silveira Coswig: vcoswig@gmail.com
Rodolfo Raiol: rodolforaiol@gmail.com
James Steele james.steele@solent.ac.uk
James P Fisher: james.fisher@solent.ac.uk
Antonio Paoli: antonio.paoli@unipd.it
Antonino Bianco: antonino.bianco@unipa.it

References

1. ACSM. Progression Models in Resistance Training for Healthy Adults. Med Sci Sport Exerc 2009;3:687–708.
2. Jimenez-Pavon D, Lavie CJ. High-intensity intermittent training versus moderate-intensity intermittent training: Is it a matter of intensity or intermittent efforts? Br J Sports Med 2017;51:1319–20.
3. Paoli A. Resistance training: the multifaceted side of exercise. AJP Endocrinol Metab 2012;302:E387–E387.
4. 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 [Internet]. Sport Med 2017;47:843-55. doi:10.1007/s40279-016-0627-5.
5. Rocha Júnior V de A, Gentil P, Oliveira E, Do Carmo J. Comparison among the EMG activity of the pectoralis major, anterior deltoidis and triceps brachii during the bench press and peck deck exercises. Rev Bras Med Esporte 2007;13:43–6.
6. de Souza D, Santos J, de Jesus D, Gentil P. Biochemical Profile and Body Composition Alteration of Amateur Bodybuilders during the Pre-Contest Period. J Funct Morphol Kinesiol 2018;3:26.
7. Gentil P, Barbosa de Lira CA, Paoli A, et al. Nutrition, pharmacological and training strategies adopted by six bodybuilders: case report and critical review. Eur J Transl Myol 2017;27:51–66.
8. Hackett DA, Johnson NA, Chow CM. Training practices and ergogenic aids used by male bodybuilders. J Strength Cond Res 2013;27:1609–17.
9. Viana R, Gentil P, Brasileiro E, et al. High Resistance Training Volume and Low Caloric and Protein Intake Are Associated with Detrimental Alterations in Body Composition of an Amateur Bodybuilder Using Anabolic Steroids: A Case Report. J Funct Morphol Kinesiol 2017;2:37.
10. Gentil P, Soares S, Bottaro M. Single vs. Multi-Joint Resistance Exercises: Effects on Muscle Strength and Hypertrophy. Asian J Sport Med 2015;6:e24057.
11. Paoli A, Gentil P, Moro T, et al. Resistance training with single vs. multi-joint exercises at equal total load volume: Effects on body composition, cardiorespiratory fitness, and muscle strength. Front Physiol 2017;8:1–6.
12. Gentil P, Rodrigo S, Soares S, et al. Effects of adding single-joint exercises to a multi-joit exercise resistance-training program on strength and hypertrophy in untrained subjects. Appl Physiol Nutr Metab 2013;344:341–4.
13. de Franca HS, Branco PA, 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 2015;40:822–6.
14. Gómez-López M, Gallegos AG, Extremera AB. Perceived barriers by university students in the practice of physical activities. J Sport Sci Med 2010;9:374–81.
15. Kimm SYS, Glynn NW, Mcmahon RP, et al. Self-perceived barriers to activity participation among sedentary adolescent girls. Med Sci Sports Exerc 2006;38:534–40.
16. Barbalho M, Gentil P, Raiol R, et al. Influence of Adding Single-Joint Exercise to a Multijoint Resistance Training Program in Untrained Young Women. 2018;(May):1 [ePub ahead of print].
17. Wakahara T, Miyamoto N, Sugisaki N, et al. Association between regional differences in muscle activation in one session of resistance exercise and in muscle hypertrophy after resistance training. Eur J Appl Physiol 2012;112:1569–76.
18. Wakahara T, Fukutani A, Kawakami Y, Yanai T. Nonuniform muscle hypertrophy: Its relation to muscle activation in training session. Med Sci Sports Exerc 2013;45:2158–65.
19. Gentil P, Bottaro M. Effects of Training Attendance on Muscle Strength of Young Men after 11 Weeks of Resistance Training [Internet]. Asian J Sport Med 2013;4:101-6.
20. Buckner SL, Jessee MB, Mattocks KT, et al. Determining Strength: A Case for Multiple Methods of Measurement. Sport Med 2017;47:193–5.
21. Fisher J, Steele J, Smith D. High- and Low-Load Resistance Training: Interpretation and Practical Application of Current Research Findings. Sport Med 2017;47:393–400.
22. 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.
23. Steele J, Fisher J, Giessing J, Gentil P. Clarity in reporting terminology and definitions of set endpoints in resistance training [Internet]. Muscle and Nerve 2017; doi:10.1002/mus.25557.

24. Gentil P, Del Vecchio FB, Paoli A, et al. Isokinetic Dynamometry and 1RM Tests Produce Conflicting Results for Assessing Alterations in Muscle Strength. J Hum Kinet 2017;56(1):19–27.
25. Ahtiainen JP, Pakarinen A, Alen M et al. Muscle hypertrophy, hormonal adaptations and strength development during strength training in strength-trained and untrained men. Eur J Appl Physiol 2003;89:555–63.
26. Ogasawara R, Thiebaud RS, Loenneke JP, et al. Time course for arm and chest muscle thickness changes following bench press training. Interv Med Appl Sci 2012;4:217–20.
27. Akima H, Foley JM, Prior BM, et al. Vastus lateralis fatigue alters recruitment of musculus quadriceps femoris in humans. J Appl Physiol 2002;92:679–84.
28. Arruda A, Souza D, Steele J, et al. Reliability of meta-analyses to evaluate resistance training programmes. J Sports Sci 2017;35:1982–4.
29. Schoenfeld BJ, Ogborn D, Krieger JW. Dose-response relationship between weekly resistance training volume and increases in muscle mass: A systematic review and meta-analysis. J Sports Sci 2017;35:1073–82.
30. Ferreira DV, Gentil P, Soares SRS, Bottaro M. Recovery of pectoralis major and triceps brachii after bench press exercise. Muscle and Nerve 2017;56:963–7.
31. Argus CK, Gill N, Keogh J, et al. Effects of a short-term pre-season training programme on the body composition and anaerobic performance of professional rugby union players. J Sports Sci 2010;(June 2015):37–41.
32. Cureton KJ, Collins MA, Hill DW, McElhannon FM. Muscle hypertrophy in men and women. Med Sci Sports Exer. 1988;20:338–44.
33. Yamanaka T, Farley RS, Caputo JL. Occlusion training increases muscular strength in division IA football players. J Strength Cond Res 2012;26:2523–9.
34. Williams MJ, Gibson NV, Sorbie GG, et al. Activation of the Gluteus Maximus During Performance of the Back Squat, Split Squat, and Barbell Hip Thrust and the Relationship With Maximal Sprinting. J Strength Cond Res 2018;(May):1 [Epub ahead of print].
35. Baroni BM, Geremia JM, Rodrigues R, et al.. Muscle architecture adaptations to knee extensor eccentric training: Rectus femoris vs. Vastus lateralis. Muscle Nerve. 2013;48:498–506.
36. Farup J, de Paoli F, Bjerg K, Riis S, Ringgard S, Vissing K. Blood flow restricted and traditional resistance training performed to fatigue produce equal muscle hypertrophy. Scand J Med Sci Sport 2015;25:754–63.
37. Moritani T, deVries HA. Neural factors versus hypertrophy in the time course of muscle strength gain. Am J Phys Med 1979;58:115–30.
38. Seynnes OR, Boer M De, Narici MV, et al. Hormonal responses and adaptations to resistance exercise and training. Sports Med 2007;35:572–84.