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ORIGINAL ARTICLE

Single joint exercises do not provide benefits in performance and anthropometric changes in recreational bodybuilders

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Abstract
The purpose of the present study was to compare the changes in anthropometric measures and muscle performance in users and non-users of androgenic anabolic steroids (AAS) performing resistance training (RT) programmes involving only multiple joint (MJ) exercises or a combination of MJ and single joint (SJ) exercises. Thirty recreational bodybuilders were divided into 4 groups: non-AAS users performing only MJ exercises (MJ), non-AAS users performing MJ + SJ (MJ + SJ), AAS users performing only MJ exercises (AAS – MJ) and AAS users performing MJ + SJ exercises (AAS – MJ + SJ). Before and after 8 weeks of training, the participants were tested for 10 repetition maximum (10RM) in different RT exercises. Flexed arm circumference (FAC), biceps and triceps skinfolds were measured. No interactions were found between time and the performance of SJ exercise in any variable ($p > .05$). However, there was a significant interaction between AAS use and time ($p < .001$), such that AAS users showed greater 10RM gains in all exercises, skinfold decreases and increases in FAC than non-users. In conclusion, our study shows that the addition of SJ exercises to MJ exercises brings no additional benefit in terms of muscle performance and anthropometric changes in trained men, either if they were using AAS or not. These results suggest that trained men can save time not including SJ in their routines and still achieve optimal results. Moreover, our results show that AAS use is associated with greater increases in muscle strength and FAC and greater reductions in biceps and triceps skinfold thickness.

Keywords: *Muscle hypertrophy, muscle definition, resistance exercise, exercise selection, muscle strength*

Highlights
- The addition of single exercises to multi joint exercises brings no additional benefit in terms of muscle performance and anthropometric changes in trained men, irrespective of anabolic steroid use.
- Anabolic steroid use is associated with greater increases in muscle strength and flexed arm circumference and greater reductions in biceps and triceps skinfold thickness.
- Trained men can save time not including single joint in their routines and still achieve optimal results.

Introduction

Resistance training (RT) has become a popular exercise modality, usually performed to promote changes in anthropometric measures, body composition and performance (Hass, Feigenbaum, & Franklin, 2001). RT can be performed with multiple (MJ) and single joint (SJ) exercises (Gentil, Fisher, & Steele, 2017) and most popular recommendations suggest that RT programmes should involve both MJ and SJ (ACSM, 2009). The suggestion that the addition of SJ exercises might be necessary to provide optimal stimulation and thus adaptations, especially to the arm muscles, is partially supported by the current literature. In this regard, acute (Ferreira et al., 2017; Soares et al., 2015) and chronic (Ogasawara, Thiebaud, Loenneke, Loftin, & Abe, 2012) studies suggest that arm muscles are not adequately stimulated during MJ exercises. Taken together, these suggest that MJ exercise might promote a suboptimal stimulus for some muscles

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and, therefore, the addition of SJ exercises might improve muscle adaptations (Gentil, Fisher, et al., 2017).

However, this hypothesis is challenged by studies showing that SJ and MJ exercises promote similar increases in muscle size and strength in young men (Gentil, Soares, & Bottaro, 2015) and studies showing that the addition of SJ exercises brings no additional increases in muscle hypertrophy and strength gains when compared to a programme involving only MJ exercises in untrained (Gentil et al., 2013) and trained men (de Franca et al., 2015) and women (Barbalho, Coswig, Raiol, Steele, Fisher, Paoli, & Gentil, 2018). However, contradictory results were reported by Barbalho et al. who found greater increases in flexed arm circumference (FAC) in untrained young women (Barbalho, Gentil, et al., 2018) and men (Barbalho, Coswig, Raiol, Steele, Fisher, Paoli, Bianco, et al., 2018) performing a combination of MJ and SJ exercises when compared to a group that performed only MJ exercises.

Notwithstanding the conflict in scientific literature, much of those who advocate for the inclusion of SJ exercises allude to the observation of bodybuilding practices as an argument. Indeed, bodybuilders, who present impressive amounts of muscle mass, usually include high volumes of SJ exercises in their routines (de Souza, Santos, de Jesus, & Gentil, 2018; Gentil, Lira, et al., 2017; Hackett, Johnson, & Chow, 2013; Viana et al., 2017). However, anecdotal evidence collected from bodybuilding might be confounded by other factors, like the use of androgenic anabolic steroids (AAS), which has been shown to increase muscle mass in response to RT (Bhasin et al., 1996) and to alter body composition in healthy young men even in the absence of RT (Bhasin et al., 1996, 2012). Therefore, it is not possible to isolate the influence of training strategies from the use of AAS. On the other hand, it might be suggested that, for people using AAS, the small difference that would eventually occur with the addition of SJ exercise might be potentialized, such as to justify the addition of SJ exercise to that specific group.

However, the interaction between the addition of SJ exercise and the use of AAS has not been tested, which leaves the topic open for speculation. If the use of SJ exercises would not be necessary, even for AAS users, many people might benefit by reducing their training volumes, as previously suggested (de Souza et al., 2018; Gentil, 2015; Gentil, Lira, et al., 2017; Viana et al., 2017). However, if SJ exercises bring additional benefits, its use might be justified when the objective is to obtain maximal increases in muscle size (Gentil, Lira, et al., 2017). Therefore, the purpose of the present study was to compare the effects on anthropometric measures and muscle performance in users and non-users of AAS performing RT programmes involving only MJ or MJ + SJ exercises. Our hypothesis is there will be no difference between the use of MJ or MJ + SJ; the use of AAS will result in higher increases in muscle strength and changes in body composition; there will be no interaction between AAS use and the performance of SJ exercises.

Materials and methods

Experimental overview

Thirty recreational bodybuilders with at least 3 years of previous RT experience were divided into current AAS users and non-AAS users before being randomized further into groups performing only MJ exercises (AAS – MJ and MJ groups), or performing MJ + SJ exercises (AAS – MJ + SJ and MJ + SJ groups). Group allocation was counterbalanced according to the initial FAC. Training followed a non-linear periodization model for 8 weeks. Before and after the training period, the participants were tested for 10 repetition maximum (10RM) in the bench press, elbow extensors, lat pulldown, elbow flexors, leg press, and knee extension exercises. FAC, biceps and triceps skinfolds were also measured to evaluate anthropometric changes. Training volume was not equated, since the difference was inherent to the protocols and reflected the addition of SJ exercises.

Participants

A priori sample analysis revealed that a total sample of 24 participants would be necessary to detect an effect size of 0.40, which was calculated based on a partial η^2 of 0.14 to reach large effects, at an alpha level of 0.05 and a power of 0.8 (G*Power, Dusseldorf, Germany). Therefore, 30 participants were recruited to account for eventual attrition. To participate in the study, volunteers had to be at least 18 years old and to not have any clinical conditions that would limit their participation or could be aggravated by the study protocol. Participants also had to have performed RT uninterruptedly during the previous 3 years, at a frequency of at least 4 sessions per week. Potential participants were screened in a fitness centre commonly frequented by recreational bodybuilders and the ones that met the inclusion criteria were invited to participate in the study. Minimum attendance was set at 80% based on previous findings (Gentil & Bottaro, 2013), but no participant was excluded. After being informed of the experimental procedures, its risks and benefits, the participants signed an informed consent form. The study was approved by the local Ethics Committee and the experiment followed the recommendations of the Declaration of Helsinki.

All the participants trained in the same facility, which facilitated the control of their routines. The information about their diets and AAS were obtained directly from them and their coaches. The group that reported to use AAS reported the use of 600 mg of testosterone enanthate and 200 mg of stanozolol per week during the whole training period. The researchers were not involved in the AAS prescription. All participants followed a meal plan containing 4–5 g/kg of carbohydrates, 2.5–3 g/kg of protein and 1 g/kg of fat. Whilst the diet was not controlled by the researchers, all participants declared to adherence to the plan.

Assessments

Ten repetitions maximum test (10RM). Before and after the intervention, participants performed 10RM tests in the bench press, elbow extension, lat pulldown, elbow flexion, leg press, and knee extension exercises (Physicus, Pró; Auriflama, São Paulo, Brazil). Tests were divided in 3 consecutive days. In the first day, participants were tested for bench press and knee extension; the second involved lat pulldown and elbow flexion; and the third involved leg press and elbow extension. We chose 10 RM instead of 1RM because it seems more suitable to evaluate performance when training at higher repetition ranges (Fisher, Steele, & Smith, 2017).

During the tests, participants warmed up with 10 repetitions at a comfortable self-selected load and then rested for 5 min. After warming up the estimated 10RM load was set based on the participants' training history. If the volunteer was not able to perform 10 repetitions or performed more than 10 repetitions, the load was adjusted starting at 1 kg. Rest between attempts was set at 5 min and no more than three attempts were needed in any case. The test–retest intraclass correlation coefficient (ICC) of this procedure was determined in our lab prior to conducting the study by performing two identical test sessions one week apart, the values ranged between 0.95 and 0.98 ICC, with a CV of 2.8–4.7% for bench press, 6.8–8.6% for elbow extension, 1.4–4.8% for lat pull down, 3.6–5.7% for elbow flexion, 1.2–2.6% for leg press and 4.2–7.0% for knee extension.

Anthropometric measures. FAC, biceps and triceps skinfold were measured on the right side of the body during the first day of 10RM testing. The participants were instructed to avoid RT for at least 3 days before the tests. For FAC, the arm was raised to a horizontal position in the sagittal plane, with the elbow at 90 degrees. The subject maximally contracted the elbow flexors, and the largest circumference was measured. Biceps and triceps skinfold were measured 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 measures were taken and the average of the values was used during the analysis.

Training protocol. Training was performed 6 times a week, divided in three different routines, as shown in Table I. All participants were supervised and monitored in all exercises, with a supervision ratio of at least 1 supervisor to 5 trainees. The training programme was intended to not differ much from the participants' regular schedules yet permit the researchers to have control over the training routines. All groups performed the same MJ exercises, loads, repetition ranges, set endpoints, and rest intervals, differing only in the exclusion of some SJ exercises for the MJ groups. Specific exercises were included for plantar flexors and hamstrings to avoid potential muscle imbalances, since they are not highly involved in the MJ exercises used (Gentil, Lira, et al., 2017). The protocol was based on a nonlinear periodization model as shown in Table I. Participants were instructed to perform every set to momentary failure as previously defined by Steele, Fisher, Giessing, and Gentil (2017). When they were able to perform more repetitions than suggested, the load was increased for the next training session. The volunteers were instructed to maintain the cadence of two seconds for both the concentric and eccentric phases, without pausing between contractions.

Statistical analysis

Normality of the data was confirmed by the Kolmogorov–Smirnov test. All values are reported by means ± standard deviation. The mean values were compared using factorial ANOVA [exercise selection (MJ vs. MJ + SJ) × AAS use (user vs. non-users) × time (pre vs. post)]. When necessary, multiple comparisons using the Bonferroni procedure were used for post hoc comparisons. Statistical significance was established as $p < .05$. Statistical analysis was performed using SPSS version 20 (SPSS Inc, Chicago, IL).

Table I. Training programmes and periodization.

Monday/Thursday	Thursday/Friday	Wednesday/Saturday
Barbell bench press	Lat pulldown	45° leg press
Inclined barbell bench press	Seated row	Barbell squat
Military press	Upright barbell row	Knee extension*
Pulley elbow extension*	Barbell elbow flexion*	Calf raise
		Knee flexion
Weeks	Repetitions	Rest intervals
1 and 5	12–15 RM	30–60 s
2 and 6	4–6 RM	3–4 min
3 and 7	10–12 RM	1–2 min
4 and 8	6–8 RM	2–3 min

*Performed only by the MJ + SJ and AAS – MJ + SJ group.

Results

Characteristics of the participants are shown in Table II. There were no differences in any variable between groups at baseline. There was a significant increase in body mass for all groups (from 81.1 ± 3.3 to 83.2 ± 3.2 for MJ, from 83 ± 5.3 to 4.6 ± 5.2 for MJ + SJ, from 88.7 ± 3.7 to 93.2 ± 4.1 for AAS – MJ and from 85.7 ± 2.8 to 91.2 ± 3.1 kg for AAS – MJ + SJ). The mean total training load throughout the period is presented as Supplementary file. The MJ group showed significantly lower values of total training load than other groups for sessions A, B and C, while the training load of AAS – MJ was lower than MJ + SJ and AAS – MJ + SJ, but only for sessions C (Supplementary file 1.)

No interactions were found between time and the performance of SJ in any variable (Table III). However, there was a significant interaction between AAS use and time ($p < .001$), such that AAS users showed greater 10RM gains in all exercises, as well as, greater skinfold decreases and increases in FAC than non-users.

The reduction in biceps (from 5 ± 0.6 to 4.6 ± 0.7 for MJ, 5.3 ± 0.7 to 4.8 ± 0.7 for MJ + SJ, from 5.3 ± 0.4 to 4.3 ± 0.4 for AAS – MJ and from 5.2 ± 0.5 to 4.2 ± 0.4 for AAS – MJ + SJ) and triceps (from 6 ± 0.9 to 5.5 ± 0.8 for MJ, from 6.3 ± 0.9 to 5.8 ± 0.9 for MJ + SJ, 6.3 ± 0.5 to 5.2 ± 0.6 for AAS – MJ and from 6.1 ± 0.6 to 5.1 ± 0.6 for AAS – MJ + SJ) skinfolds and the increases in FAC (from 38.4 ± 0.6 to –38.9 ± 0.6 for MJ, from 38.6 ± 0.6 to 39.1 ± 0.6 for MJ + SJ, from 38.3 ± 0.7 to 39.4 ± 0.6 for AAS – MJ and from 38.5 ± 0.4 to 39.8 ± 0.4 for AAS – MJ + SJ) were significant for all groups and the results for AAS – MJ and AAS – MJ + SJ were higher than for both MJ and MJ + SJ (Figure 1).

Discussion

The present study compared muscle performance and anthropometric changes in recreational bodybuilders, both users and non-users of AAS that performed RT programmes composed of only MJ or MJ + SJ exercises. The results showed that the performance of SJ exercises did not influence any of the variables measured. However, the increases in muscle performance and FAC, as well as, the decreases in skinfold thickness were greater for the AAS users, independent of the performance of SJ exercises.

Our results are in agreement with those previously reported by (de Franca et al., 2015), who compared changes in upper limb muscle strength and size in 22 trained men performing RT programmes involving MJ or MJ + SJ exercises. The study lasted 8 weeks and each muscle was trained twice a week. The changes in FAC for MJ and MJ + SJ were similar to those found in the present study and were not significantly different between groups (1.72% and 1.45% for the MJ and MJ + SJ, respectively). In

Table II. Characteristics of the participants.

	Non-users		AAS users	
	MJ ($n = 8$)	MJ + SJ ($n = 8$)	MJ ($n = 7$)	MJ + SJ ($n = 7$)
Age (yrs)	23.1 ± 1.8	22.7 ± 1.4	22.8 ± 0.8	23.1 ± 1.3
Height (m)	178 ± 4.2	179.3 ± 5.3	181.2 ± 4.8	180.4 ± 3.2
Body Mass (kg)	81.1 ± 3.3	83 ± 5.3	88.7 ± 3.7	85.7 ± 2.8
Training Experience (yrs)	3.5 ± 0.8	3.5 ± 0.7	3.4 ± 0.8	3.5 ± 0.8

Table III. Anthropometric measures and performance tests.

		Non-users		AAS users		*P* values		
		MJ ($n = 8$)	MJ + SJ ($n = 8$)	MJ ($n = 7$)	MJ + SJ ($n = 7$)	AAS × time	Exercise × time	AAS × exercise × time
10 RM Bench Press (kg)	Pre	93.5 ± 3.3	94.5 ± 2.5	95.4 ± 4.5	93.7 ± 2.6	<.001	.823	.823
	Post	100.2 ± 3.7*	101.0 ± 2.8*	120.2 ± 3.9*†	118.5 ± 3.2*†			
10RM Elbow extensors (kg)	Pre	41.2 ± 2.8	43.0 ± 3.7	42.2 ± 3.1	40.8 ± 3.4	<.001	.862	.862
	Post	44.7 ± 3.1*	46.6 ± 4.0*	48.5 ± 3.4*†	47.1 ± 3.0*†			
10RM Lat pull down (kg)	Pre	70.5 ± 2.5	72.5 ± 3.4	73.1 ± 1.0	72.5 ± 2.2	<.001	.352	.352
	Post	76.5 ± 3.1*	77.0 ± 3.8*	85.4 ± 1.9*†	84.8 ± 1.9*†			
10RM Elbow flexors (kg)	Pre	52.7 ± 2.3	54.5 ± 3.1	53.1 ± 1.9	51.7 ± 2.4	<.001	.495	.495
	Post	55.5 ± 2.9*	57.7 ± 3.1*	61.7 ± 3.3*†	60.2 ± 3.5*†			
10RM Leg Press (kg)	Pre	171.2 ± 2.8	172.7 ± 4.5	173.4 ± 2.2	172.8 ± 2.7	<.001	.136	.678
	Post	187.0 ± 2.8*	186.7 ± 4.7*	206.5 ± 3.5*†	205.0 ± 5.3*†			
10RM Knee Extension (kg)	Pre	55.2 ± 2.3	55.0 ± 3.8	58.0 ± 2.8	56.2 ± 2.9	<.001	.145	.921
	Post	59.0 ± 2.1*	58.2 ± 4.3*	66.5 ± 2.9*†	64.2 ± 3.9*†			
Arm circumference (cm)	Pre	38.42 ± 0.65	38.61 ± 0.61	38.38 ± 0.71	38.58 ± 0.47	<.001	.157	.432
	Post	38.96 ± 0.62*	39.18 ± 0.61*	39.47 ± 0.66*†	39.80 ± 0.48*†			
Triceps skinfold (mm)	Pre	6.05 ± 0.90	6.36 ± 0.91	6.31 ± 0.58	6.15 ± 0.61	<.001	.373	.143
	Post	5.57 ± 0.86*	5.86 ± 0.92*	5.22 ± 0.65*†	5.17 ± 0.68*†			
Biceps skinfold (mm)	Pre	5.05 ± 0.69	5.31 ± 0.72	5.34 ± 0.48	5.24 ± 0.50	<.001	.918	.45
	Post	4.62 ± 0.71*	4.85 ± 0.70*	4.30 ± 0.44*†	4.22 ± 0.44*†			

* Statistically different from the correspondent pre value ($p < .05$).
† Statistically different from non-AAS users in the same moment ($p < .05$).

addition, both groups showed similar increases in 1RM for elbow flexion (4.99% and 6.42% for groups MJ and MJ + SJ, respectively) and extension (10.60% and 9.79% for MJ and MJ + SJ, respectively). The present study brings new findings for trained men, since lower body performance was

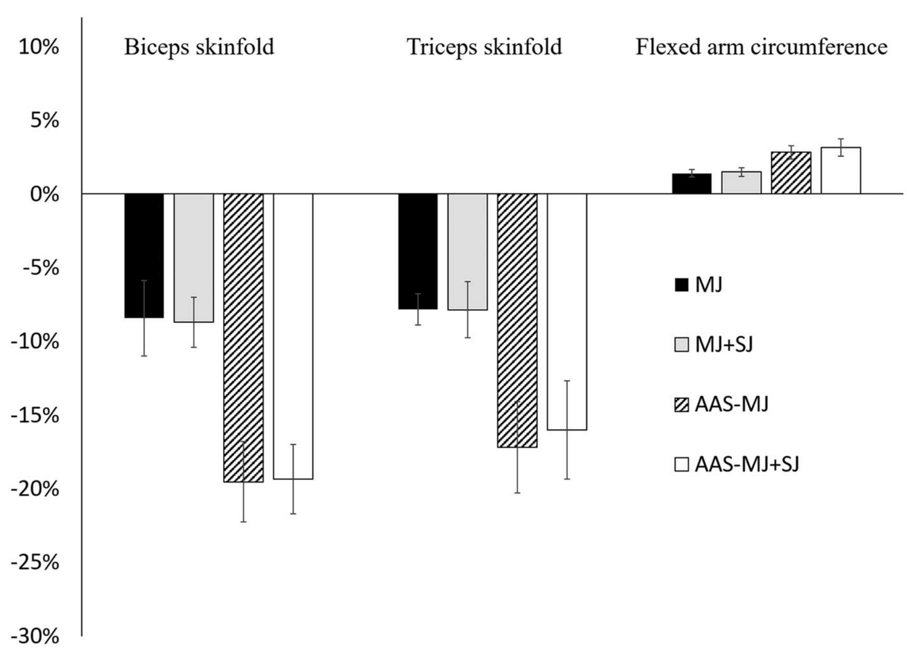

Figure 1. Changes in flexed arm circumference, biceps and triceps skinfolds (means and standard deviations). Note: MJ – Non-androgen anabolic steroids users performing only multiple joint exercises. MJ + SJ – Non-androgen anabolic steroids users performing multiple and single joint exercises. AAS – MJ – Androgen anabolic steroids users performing only multiple joint exercises. AAS – MJ + SJ – Androgen anabolic steroids users performing multiple and single joint exercises.

also examined. Our data showed that the addition of SJ did not bring benefit in muscle performance for leg press and knee extension 10RM, which is similar to previously reported in untrained women (Barbalho, Gentil, et al., 2018).

Our results confirm previous findings that the addition of SJ exercises to a MJ training programme did not promote additional benefits in performance even when the tests involved SJ movements (Barbalho, Gentil, et al., 2018; de Franca et al., 2015; Gentil et al., 2015, 2013; Paoli, Gentil, Moro, Marcolin, & Bianco, 2017). This might occur because SJ movements are relatively simple tasks that do not have a high reliance on motor learning; therefore, the performance of specific SJ exercises to optimize their performance may be unnecessary. Although the use of 10RM test, instead of 1RM or isokinetic tests, might have affected the results, it is important to note that previous studies using 1RM tests (de Franca et al., 2015) and isokinetic dynamometry (Gentil et al., 2013) did not find differences between MJ and MJ + SJ.

The higher gains in muscle performance, FAC, and decreases in skinfold thickness seen in AAS users are in agreement with previous literature. Regarding the reduction in skinfold thickness, previous studies have shown that endogenous testosterone is associated with fat loss in response to RT (Kvorning, Andersen, Brixen, & Madsen, 2006), while others reported body fat reductions with supraphysiological doses of AAS healthy people whether they performed RT (Hartgens et al., 2001) or not (Bhasin et al., 2012). The increases in FAC due to AAS might be associated with its anabolic effects, as commonly reported in the literature (Bhasin et al., 1996, 2012). While the increases in muscle performance might be associated with muscle hypertrophy (Storer et al., 2003), there is also evidence that AAS might increase strength by other mechanisms, like changes in muscle architecture (Blazevich & Giorgi, 2001).

Another point of view for the higher gains in AAS users is based on the improved performance and recovery (Cheung & Grossmann, 2018), which would allow them to train more frequently and at higher volumes. Interestingly, in our study AAS users performed higher total training volumes than non-users. Whilst the association between increases in training volume and increases in muscle strength are controversial (Steele, Fisher, Assunção, Bottaro, & Gentil, 2017), the higher performance due to AAS use might help to explain our results.

Whilst a detailed analysis of the side effects caused by AAS abuse is beyond the scope of the present study, it is important to highlight that AAS has been associated with many important health risks. For example, AAS is associated with increased risk of myocardial infarctions, alterations in serum lipids (decreased HDL and increased LDL), elevation in blood pressure and increased risk of thrombosis (Hoffman & Ratamess, 2006). Previous studies reported that bodybuilders using AAS showed resting systolic blood pressure values higher than optimal (Gentil, Lira, et al., 2017) and markers of liver damage (de Souza et al., 2018). Certainly, not all users will experience all side effects, and many effects might not be obvious. Indeed, the lack of long term controlled trials examining AAS renders it difficult to know with confidence the adverse event rates. However, it is important to emphasize that an attitude of invulnerability to the AAS risks is perhaps misguided, and despite the relatively clear benefits to certain aspects of body composition and performance, the precautionary principle should perhaps be emphasized in the absence of evidence.

An important limitation of the present study was the use of anthropometric measures. Previous studies have suggested that SJ and MJ exercises resulted in different patterns of muscle hypertrophy (Wakahara et al., 2012; Wakahara, Fukutani, Kawakami, & Yanai, 2013). Therefore, it might be possible that our results are limited to the region analysed and not necessarily representative of the response of the whole muscle. It is important to note that measures of arm girth are popular and reliable methods for estimating changes in muscle size during RT (Cureton, Collins, Hill, & McElhannon Jr., 1988; de Franca et al., 2015) and, whilst one may argue that more sensitive methods would show different results, the practical relevance of such difference is questionable.

Conclusion

In conclusion, our study shows that the addition of SJ exercises to an RT programme that already contains MJ exercises brings no additional benefit in terms of muscle performance and anthropometric changes in trained men, whether they were using AAS or not. These results might help to design more time-efficient RT programmes, since it suggests that trained men can save time not including SJ in their routines and still achieve optimal results. For those interested in bodybuilding recreationally who, unlike professionals, may be unable to dedicate considerable time to the pursuit these findings are potentially valuable. Moreover, our results show that AAS use is associated with greater increases in muscle strength and FAC, as well as, greater reductions in biceps and triceps skinfold thickness. Therefore, caution is urged before using anecdotal evidence and/or reproducing the practices of people using

AAS, since their results may not necessarily be due solely to the use of SJ exercises, but rather to the use of AAS.

Disclosure statement

No potential conflict of interest was reported by the authors.

Supplemental data

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