Effects of isotonic resistance training at two movement velocities on strength gains

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ABSTRACT

Considering the need to adequately prescribe training, the aim of this study was to compare the effect of isotonic resistance training at 0.44 and 1.75 $rad \cdot s^{-1}$ on gains in muscular strength. Fourteen healthy volunteers were stratified into slow (SG: 0.44 $rad \cdot s^{-1}$; n = 8; 26 ± 7 yr; 66 ± 12 kg) and fast (FG: 1.75 $rad \cdot s^{-1}$; n = 6; 28 ± 7 yr; 55 ± 9 kg) groups exercising squat and bench press (1 set, 8-10 RM, 3 x/wk, 12 weeks). Six of these subjects took part in a comparison group (CG: 25 ± 6 yr; 59 ± 13 kg), and did not train during a control period of 12 weeks preceding training. Paired t-test showed no differences in the measured variables for CG. Repeated measures 2 x 2 ANOVA showed significant ($P < .05$) gains for both training groups and exercises in 1 RM (SG: 27.6 ± 16.8% and 16.8 ± 11.8%; FG: 21.4 ± 12.6% and 16.2 ± 14.1%, squat and bench press, respectively) and 8-10 RM tested at 0.44 $rad \cdot s^{-1}$ (SG: 36.0 ± 22.4% and 14.7 ± 9.2%; FG: 31.1 ± 19.2% and 18.8 ± 8.7%) and 1.75 $rad \cdot s^{-1}$ (SG: 27.2 ± 11.1% and 15.2 ± 11.4%; FG: 23.6 ± 19.2% and 20.9 ± 9.8%), with no significant differences between groups. Results of this study did not support velocity specificity in training with isotonic equipment.

Keywords: Repetitions maximum. Strength training. Squat. Bench press. Specificity.

INTRODUCTION

It has already been demonstrated that resistance training is an important tool in the prevention and maintenance of health-related life quality. Moreover, the recommendations suggest that it should be part of an exercise program for young adults and older individuals[1]. The recommendations include number of exercises, sets, repetitions and weekly frequency. The movement velocity has only been vaguely mentioned until the last positioning of the American College of Sports Medicine about resistance training[1], which suggests velocity's specificity. There is evidence that movement velocity strongly influences performance, once the load from 8-10RM to 1.75 $rad \cdot s^{-1}$ was significantly higher than that from 8-10RM to 0.44 $rad \cdot s^{-1}$[2].

According to what was mentioned in a recent review[3], the studies which investigated training with different velocities did not lead to a common conclusion. Some indicated that training with low velocities (0.35 to 1.68 $rad \cdot s^{-1}$) would lead to gains in the whole range of tested velocities (different in each study and varying from isometric contractions until 5.24 $rad \cdot s^{-1}$), while others indicated that the gains occurred only close to the training velocity. The same occurred with training at fast velocities (1.75 to 5.24 $rad \cdot s^{-1}$). The majority of these studies used isokinetic[4-6] or hydraulic equipment[7-9], while only a few used isotonic equipments[10-13], more commonly available for the ordinary population. One may observe that results obtained with isokinetic training may not be transferred for the isotonic one, and vice-versa, due to possible differences in the recruiting pattern of muscle fibers. A complete review can be found in the article by Pereira and Gomes[3].

Results of isotonic studies have shown a trend for no difference in the training velocities gains when the tests are performed in isotonic equipment; however, specificity may be observed when it is tested in another way. Behm[10] trained development at 3.4 $rad \cdot s^{-1}$ and found significant gains in 1RM as well as gains in training velocity and below it when isocinetically tested. Young and Bilby[13] found significant gains in 1RM for both squat slow and fast training velocities (the velocities were only verbally specified and controlled) and significant gains in isometric strength for both groups, with higher gains in strength for the slow group and in strength development rate for the fast group. Weir *et al.*[12] found gains in all tested velocities after training squat and knee extension at approximately 1.41-1.50 $rad \cdot s^{-1}$. The study by Morrissey *et al.*[11] trained squats in two groups, one at 0.87 $rad \cdot s^{-1}$ and another at 1.75 $rad \cdot s^{-1}$. Significant gains were observed in the 1RM test (performed in the two different velocities) in both experimental groups. However, gains in the isokinetic work were not significant for the slow group (although being higher for slow velocities) and were significant in all its tested velocities range in the fast group (although the gains have been higher in faster velocities).

Due to contradictory results of the training effects with a specific velocity and to the need to better prescribe training, the aim of the present study was to investigate the effects of two movement velocities – 0.44 and 1.75 $rad \cdot s^{-1}$ – in the strength gains in lower limbs exercises (squat) as well as upper limbs and trunk (bench press). These exercises were chosen for being common in resistance training and also for allowing comparison of possible adaptation differences between upper and lower limbs, both multi-articular exercises. They also allow the comparison of results with the available literature which in its majority used the squat exercise. The tested hypothesis was that there would not be significant differences in strength gains as training results with slow and fast velocities.

METHODS

The study consisted of a 12-week control period, during which the subjects were instructed to keep their regular leisure activities as well as a 12-week training period. The dependent variables were tested before and after each one of these periods. The squat and bench press exercises were used for the experimental treatment, with controlled movement velocities, while six other exercises, namely front row, hip adduction, hip abduction, elbow flexion, plantar flexion and abdominals (none of which involved the primary used muscle group in squat or bench press), were performed with free movement velocity, chosen by the subject. These supplemen-

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tary exercises were included to complete training for the main muscle groups and hence they will not be further mentioned in this review.

Subjects

Fourteen healthy volunteers from both sexes, age between 18 and 37 years, participated in the study after having received detailed verbal explanation about the study's procedures and signed a written consent form, according to the institutional rules and the Helsinki Declaration. Eleven of these subjects were physically inactive (one had previous experience in resistance training) and three were physically active (all with previous resistance training experience). During the experimental period, all subjects limited their activities to their systematic physical activities prescribed in this study.

Prior to the training period, six of the 14 subjects were submitted to the 12 weeks of the control period (table 1). After this period and immediately before training, all subjects were ranked according to bench press 1RM (determined in the pre-training tests) and later distributed in two groups in the ABBA way. Sixteen subjects were initially distributed in the training groups; however, since two have left the study due to reasons not related to the experimental procedures, eight subjects (three males) were placed in the slow group (SG, trained at 0.44 rad·s^{-1}) and six (one male) in the fast group (FG, trained at 1.75 rad·s^{-1}). The t-independent test showed that the two groups were initially equivalent in all the selected variables (pre-training values in table 2).

TABLE 1
Characteristics (mean ± SD) of the pre and post control comparison group

Variable		Comparison group (n = 6)	
		Pre	Post
Age (years)		25.3 ± 6.2	–
Height (cm)		165.7 ± 7.3	–
Body fat (%)		20.9 ± 5.0	19.5 ± 3.8
Body weight (kg)		59.0 ± 12.8	59.9 ± 12.7
1 RM (kg)	squat	124.0 ± 47.8	115.3 ± 39.5
	bench press	53.7 ± 26.6	53.8 ± 26.5
1RM/Body weight	squat	2.1 ± 0.4	1.9 ± 0.3
	bench press	0.9 ± 0.3	0.9 ± 0.3
8-10 RM to 0.44 rad·s^{-1} (kg)	squat	93.2 ± 31.0	85.4 ± 29.9
	bench press	36.2 ± 17.0	35.5 ± 15.9
8-10 RM to 1.75 rad·s^{-1} (kg)	squat	105.6 ± 42.7	98.1 ± 35.5
	bench press	42.0 ± 21.6	40.4 ± 18.5

Velocities and exercises

The velocities were controlled by the rhythm marked by electronic beating at 132 bpm. The fast velocity used four beats for the complete movement (~1.8 s – two beats per phase) and the slow one, 16 beats (~7.3 s – eight beats per phase). Assuming a ~1,57 rad breadth for squat and bench press, two beats in 132 bpm represent an angular velocity of 1.75 rad·s^{-1}, while eight beats represent 0.44 rad·s^{-1}.

Squat was performed starting from a standing position and going until 1.57 rad in the hip and knee articulations and later returning to the initial position. Bench press was performed starting from a position with elbows extended and going until the arms were parallel to the ground (1.57 rad in the elbow articulation), later returning to initial position. Both exercises were performed in a *Smith Machine* (Buick, Ramas Metalúrgica, Ltda., RJ, Brazil) and two technicians provided safety conditions. The subjects were verbally instructed to correct the movement when they were not in the correct rhythm or breadth.

Test procedures

All tests were performed in the same equipment used for the training. Prior to the test visit, the subjects participated in one to four familiarization sessions, determined according to the performance observed by the main technician. In the first test visit, the subjects were submitted to an anthropometric protocol (females – body weight, height and triceps, suprailiac and thigh skinfolds; males – body weight, height and chest, abdomen and thigh skinfolds) and to the 1RM test performed at free velocity In the two following visits, the subjects were randomly submitted to the 8-10RM tests, performed with controlled velocities of 0.44 and 1.75 rad·s^{-1}.

Prior to the tests, the subjects would perform stretching exercises (one 10 s set of static stretching) for the main muscle groups and a set of 10 repetitions of squat and bench press with load of 60% of 1RM and free velocity. This load was previously estimated based on the subject's and technician's experience. The same stretching exercises were performed after the tests. The load was initially estimated and immediately after, it was added or subtracted until the load in which the subject could correctly perform only the pre-set number of repetitions with the correct velocity was reached. The rest interval between trials was between two and five minutes. A maximum of six trials was allowed in a test day (mean of 3 trials were necessary for 1RM and 2 trials for 8-10RM). A new visit was scheduled whenever necessary (which occurred in only 7 of a total of 204 tests). The participants were verbally encoraged to perform their best. The 1RM and 8-10RM tests' trustworthiness using the same procedures and sample with similar characteristics was determined in a pilot study (CCI > 0.99)[14].

TABLE 2
Characteristics (mean ± SD) of the pre and post slow and fast groups

Variable		Slow group (n = 8)		Fast group (n = 6)	
		Pre	Post	Pre	Post
Age (years)		26.1 ± 6.6	–	27.8 ± 6.6	–
Height (cm)		168.6 ± 8.7	–	161.8 ± 5.7	–
Body fat (%)		21.4 ± 9.0	21.5 ± 9.6	21.4 ± 3.9	21.7 ± 4.1
Body weight (kg)		65.5 ± 12.4	65.8 ± 12.5	55.3 ± 8.8	55.3 ± 8.4
1 RM (kg)	squat*	100.9 ± 37.6	124.6 ± 35.8	98.4 ± 26.0	118.1 ± 26.5
	bench press*	53.2 ± 25.2	60.6 ± 25.8	40.1 ± 17.4	46.4 ± 19.3
1RM/Body weight	squat*	1.6 ± 0.5	1.9 ± 0.5	1.8 ± 0.3	2.1 ± 0.2
	bench press*	0.8 ± 0.3	0.9 ± 0.3	0.7 ± 0.2	0.8 ± 0.2
8-10 RM to 0.44 rad·s^{-1} (kg)	squat*	76.0 ± 32.2	99.3 ± 33.0	68.9 ± 14.0	90.1 ± 21.0
	bench press*	36.1 ± 15.0	41.1 ± 16.6	27.6 ± 11.4	32.6 ± 12.5
8-10 RM to 1.75 rad·s^{-1} (kg)	squat*	85.6 ± 33.7	106.3 ± 33.4	85.4 ± 22.9	104.2 ± 25.2
	bench press*	41.9 ± 18.6	47.7 ± 20.2	31.1 ± 14.6	37.0 ± 15.2

* main time effect (pre and post) significant ($p < 0.001$).

Training procedures

The training had a 12-week duration and frequency of three weekly times. Each training session consisted of a set of eight exercises: squat and bench press performed in one of the pre-set velocities, and six other exercises in free, non-controlled velocity. The exercises were performed in this order and in isotonic equipment, eight to ten maximal repetitions each, with approximately one minute recovery interval between exercises. Prior to the training session, the subjects performed stretching exercises (a 10 s static stretching set) for the main muscle groups, and a set of 10 squat and bench press repetitions with load of 75% from that which would be used for training, at free velocity. The same stretching exercises were performed after training. Load increases were added in the following session when the subject was able to perform 10 correct repetitions in the pre-set velocity for two consecutive sessions. The frequency and amount of increases varied among subjects and were in average from 1.2 kg and 0.4 kg per week for squat and bench press, respectively. A graphic representation of the used loads during training can be seen in figure 1.

Statistical analysis

A t-test for dependent samples was used for the analysis of the differences between pre and post control period. A 2 x 2 ANOVA with repeated measurements was used for the determination of differences between experimental and pre and post training groups. A significance level of 0.05 was used in all statistical analyses.

The ANOVA premises test showed that two variables did not satisfy the variances homogeneity (8-10RM at 0.44 rad·s^{-1} and 1RM concerning body weight, both only for squat), although the higher variance did not exceed the lower two times. Although ANOVA is a robust test, the violation of its limits becomes critical when the sample size is small, as in the present study. Therefore, in order to avoid type I error, a more conservative value of p (0.01) was used when analyzing these variables.

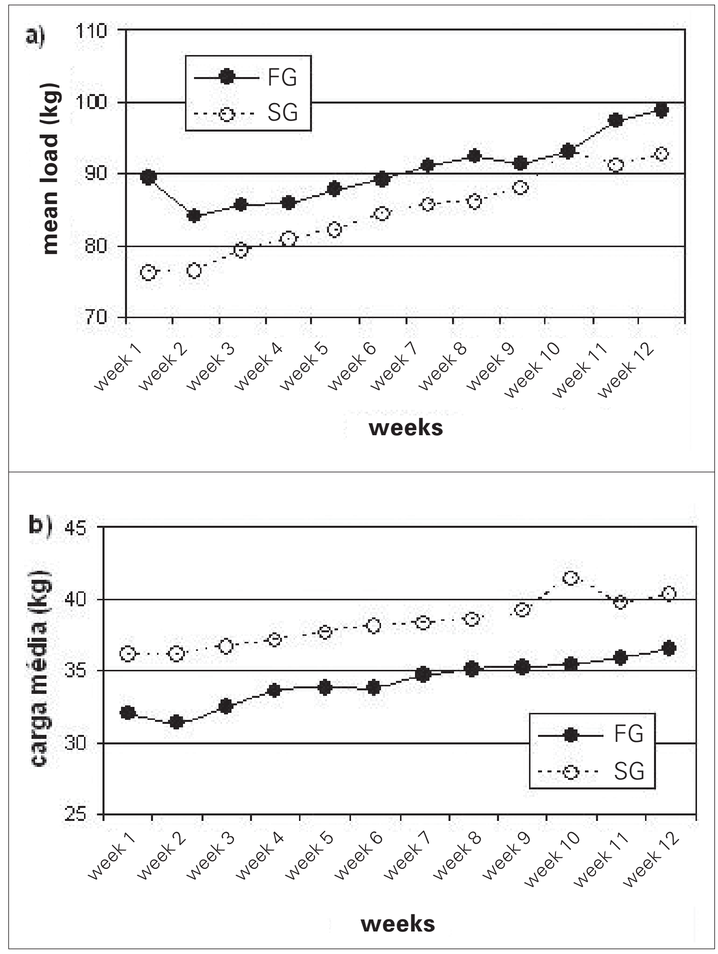

Figure 1 *– Mean weekly load (mean ± SD) during 12 weeks of training at different velocities (FG – fast group; SG – Slow group): a) squat; b) bench press.*

RESULTS

The t-test for dependent samples results did not show significant differences between the pre and post control periods (table 1). Concerning the training commitment, significant differences were not found in the mean weekly frequency between SG (average ± SD: 2.8 ± 0.2) and FG (2.7 ± 0.4), with a total of 33.5 ± 2.2 and 32.8 ± 4.6 sessions, respectively. The training resulted in non-significant alterations in the body composition (body fat and total body weight) (table 2).

ANOVA results showed non-significant group x time interaction, both for the 1RM tests (absolute and concerning body weight) and for the 8-10RM ones at 0.44 rad·s^{-1} and at 1.75 rad·s^{-1}, in both exercises. Pre and post-training significant differences were observed ($p < 0.001$) (table 3). Although ANOVA did not show significant differences between groups, the gains in 1RM and 8-10RM in the two velocities for squat were higher in SG than in FG (figure 2). The gains for bench press were similar between groups for 1RM, higher in FG for the 8-10RM tests, though.

DISCUSSION

Considering the few studies which investigated training with different velocities using isotonic equipment and the need to bet-

TABLE 3
2 x 2 ANOVA with repeated measurements results for differences between pre and post-training experimental groups

Variable		Main time effect *F*	Main time effect Sig.	Time x group interaction *F*	Time x group interaction Sig.
Body fat (%)		0.1057	0.7507	0.0454	0.8349
Body weight (kg)		0.1236	0.7313	0.1236	0.7313
1 RM (kg)	squat	90.0213	0.0000	0.7595	0.4006
	bench press	31.2825	0.0001	0.1887	0.6717
1RM/Body weight	squat	61.9806	0.0000	0.0205	0.8886
	bench press	22.2486	0.0005	0.4541	0.5132
8-10 RM to 0.44 rad·s^{-1} (kg)	squat	54.9246	0.0000	0.1279	0.7268
	bench press	49.4646	0.0000	0.0008	0.9773
8-10 RM to 1.75 rad·s^{-1} (kg)	squat	62.2478	0.0000	0.1388	0.7160
	bench press	32.0503	0.0001	0.0037	0.9527

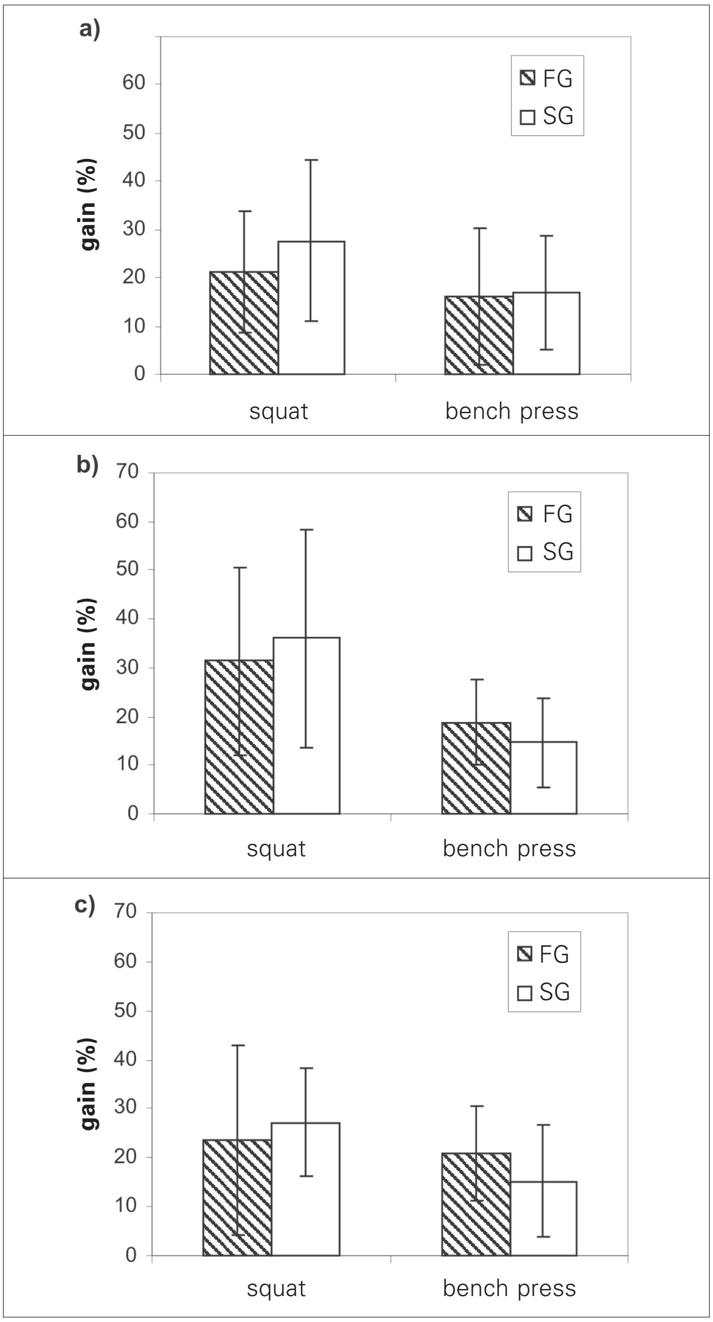

***Figure 2** – Percentage gains in load (mean ± SD) with training at different velocities (FG – fast group; SG – slow group): a) 1RM test; b) 8-10RM to 0.44 rad·s^{-1} tests; c) 8-10RM to 1.75 rad·s^{-1} test.*

ter understand and prescribe resistance exercise programs, the aim of this study was to investigate the effects of lower and upper limbs exercise training using isotonic equipment and different movement velocities. This study is unique since no other study mentioned above has observed the two body segments trained with different velocities and measured in the same equipment and velocities used for training.

The results of this study showed similar gains in maximal strength (tested in isotonic equipment) between velocities. These findings are according to those by others[11,13], where gains in 1RM for squat were significant, but similar for groups of fast and slow isotonic training. Studies which performed training in isokinetic equipment found differences between groups (tested in 1RM in the leg press), as the ones by Pipes and Wilmore[15], where the fast training groups showed gains significantly higher than the ones in the slow group, and by Smith and Melton[16], where the slow group obtained higher gains than the fast one.

The gains in 1RM of squat are according to other studies about isotonic training with controlled movement velocity, where fast training groups obtained gains between 21.0 and 31.0% and the slow training ones between 22.5 and 30.0%[11,13]; however, higher than the ones reported for training in isokinetic equipment, which varied from 6.7 to 21.2% for the fast groups and from 9.8 to 17.7% for the slow ones. All these studies had duration shorter than the present one, varying from 6 to 8 weeks. It is worth mentioning that Young and Bilby[13] submitted the subjects to subjectively determined velocities, namely slow and fast, while Morrissey *et al.*[11] used controlled velocities of 0.87 and 1.75 rad·s^{-1}.

The gains in bench press 1RM of this study were lower than the ones found by other authors after training with no velocity control, with three sets of 6-8RM, where gains of 20.2%[17] and 18.9% were reported[18]. On the other hand, the study by Mayhew *et al.*[19] found lower gains (9.1%) after a 12-week program with a varied combination of sets and repetitions in a group of male adults.

Possible explanations for the strength gains after resistance training are muscle hypertrophy, metabolic alterations and neuromuscular adaptations[10]. There is evidence for muscle hypertrophy after resistance training with movement velocity control, although differences between groups of different velocities have not been found[9-10,13]. The literature is scarce and controversial concerning hypertrophy of specific types of fibers after training with velocity control. Coyle *et al.*[4] found significant increases in the site of type II fibers only for the fast training group (5.24 rad·s^{-1}),while Ewing *et al.*[5] found increases in sites of type I and IIa fibers for both groups (1.05 and 4.19 rad·s^{-1}), with no increases in the site of the type IIb fibers.

Concerning metabolic alterations, there are no studies which have specifically compared training with different velocities and investigated enzymatic alterations. However, there is some evidence that the results may be contradictory. Bell *et al.*[7] found increases in the ATPase activity with training at 3.14 rad·s^{-1}, while Tesch *et al.*[20] found decreases in the ATPase activity after training with no velocity control.

The muscle activation (breadth and frequency of mean power obtained by electromyography, EMG) during isokinetic tests was steady from 0.57 to 3.14 rad·s^{-1}[21] and, after training with different movement velocities, no differences in the EMG measurements were observed in the vastus lateralis at 0.44; 0.87; 1.75 and 2.18 rad·s^{-1}[11]. Moreover, Barnes[22] did not find difference in fatigue (torque decrease relative to the peak torque) between the 1.05 and 5.24 rad·s^{-1} velocities, suggesting hence that there is no difference in the recruiting of motor units, once it would be expected that phasic motor units would fast fatigue, while the tonic ones would be more resistant. It is important to note that Morrissey *et al.*[11] observed higher quadriceps activation during the vertical jump test after training with fast velocity alone. It may suggest that the training specificity with controlled velocity may be relevant to the performance of sport modalities which strongly depend on muscular power.

In the present study, the lack of significant difference in the strength gains between the two training groups does not justify the differences in the adaptation processes, according to the findings mentioned above which did not identify differences in muscular hypertrophy and activation after training with different velocities. In addition to that, even with higher gains (non-significant) in one of the groups, such gains pointed to different directions for squat and bench press, which makes it impossible to conclude whether one velocity is better than the other for strength gains.

A possible explanation for higher gains, despite not being significant, of FG in the bench press may be the fact that this group had only one male, and therefore, the obtained gains by the females (traditionally with lower upper limbs and chest development and thus, greater gain potential) became more evident in the group as a whole. Conversely, the SG had three males, which could have diluted the gains in the upper limbs for this group. The higher gains (non-significant) of SG in squat could not be justified this way. Further studies with a larger sample to verify whether training at slow velocity would be generally favorable to strength gain are needed.

CONCLUSIONS

The results of this study showed that the differences between groups were not significant, both for squat and bench press, which may have been a consequence of the small sample number or due to the short duration of the study. One may suggest that squats should be performed at a slower velocity, based on higher gains (non-significant) found in this study as well as the possibility to reduce injury risks in the crossed ligaments, associated with faster velocities[23]. Nevertheless, it has not been clear yet whether this or any other movement velocity should be recommended for the remaining resistance exercises.

Therefore, based on the results of the present study as well as in the available literature, whenever the resistance training for young adults objective is strength, the movement velocity should not be a concern. This fact seems to be true in the training for health and life quality scenario. Once new research has not been conducted, the prescription of resistance training with 0.44 or 1.75 $rad \cdot s^{-1}$ velocities for this population seems to be a good recommendation.

Considering the limitations in this study, such as the sample's heterogeneity, only two multi-articular exercises with velocity control and training program with relatively short duration, some issues can be raised. Training experience and gender differences may be intervenient variables; adaptations to the uni-articular movement may be different from those of the multi-articular one; and, the discreet trend observed in this study may be exacerbated or suppressed with a longer training period. Thus, suggestions for future studies include: groups with similar resistance training experience; distinct male and female groups; longer training period and training of other muscle groups which includes uni-articular movements.

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