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Effects of Different Number of Sets of Resistance Training on Flexibility

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ABSTRACT

International Journal of Exercise Science 10(3): 354-364, 2017. The aim of this study was to investigate the effects of six months of training with three different number of sets of resistance training on flexibility in young men. Forty-seven men (mean ± SD age = 24 ± 1yrs; body mass = 79.39 ± 9.12 kg; height = 174.5 ± 5.6 cm) were randomly divided into three training groups performing either one set (G1S), three sets (G3S), or five sets (G5S) of all exercises in a resistance training session or a control group (CG). All groups were assessed pre- and post-training for Sit-and-Reach test and range of motion of 10 joints using goniometry. The training protocol included three weekly sessions and was composed of nine exercises performed at a moderate intensity (eight to 12RM). The results demonstrated significant differences pre- to post-training for the Sit-and-Reach test for all training groups; however, only the G5S showed significant differences when compared to the CG (31.04 ± 5.94cm vs. 23.56 ± 6.76cm, respectively; $p < 0.05$). Of the ten joint movements measured, there were range of motion increases only to shoulder flexion (G1S), shoulder extension (G3S), elbow flexion (G3S), and knee flexion (G3S) when comparing pre- to post-training ($p < 0.05$). In conclusion, different resistance training volumes improved flexibility for some joints of young men. These findings indicate that performing only resistance training can result in increases in flexibility.

KEY WORDS: Performance, resistance exercises, stretching, strength

INTRODUCTION

Flexibility and strength are considered part of the five basic components of health-related fitness and, adequate levels of both are required to ensure quality of life, postural stability, balance, and sports performance (1,2,3). Sex, physical aptitude, age, and training specificity can affect flexibility. Increased flexibility has been shown with isolated resistance training in healthy young adult women (8,15,17), middle-aged (mean age 37 years) (9) and elderly women (mean age 68.9 years) (4) and has also been shown in groups composed of both men and women due to performing only resistance training (10,11), in healthy adult men (5,16,18), as well as elderly men (mean age approximately 70 years) (6,7). All of the above studies ranged in training duration from 4 to 16 weeks, except for one study examining flexibility increases in elderly men due to six months of resistance training (6). Additionally, the longest duration study (16 weeks) examining flexibility changes in healthy young women measured flexibility only by sit-and-reach test (17). The longest duration study examining flexibility increases with tests other than the sit-and-reach test in healthy young women is eight weeks (14) and 11 weeks for healthy young men (18). Thus, there is a lack of studies examining flexibility increases in healthy young adults during long-term resistance training.

The training programs of the majority of studies showing increases in flexibility when performing only resistance training utilized multiple sets of each exercise. Untrained young women (8,14,17), middle-aged women (9), and elderly women (4), all showed increases in flexibility when performing three sets of each exercise in a training session. Increases in flexibility have also been shown in training groups composed of both adult men and women performing three sets (11) and four sets (10) and, adult men performing three sets (5,16,18) of each exercise in a training session. While in elderly men in which training began with one set for four weeks progressing to two sets for four weeks, three sets for four weeks, and four sets for four weeks of each exercise, flexibility increases were shown over six months of training (6). Similarly, in elderly men, increases in flexibility were shown with training beginning with 2 sets progressing to 3 sets over 16 weeks of training (7). The studies training elderly men were not designed to determine whether different numbers of sets affected flexibility.

Whether or not different training volumes, such as different numbers of sets, affect flexibility is unclear. However, one study (6) does report that in elderly men, six months of resistance training with either 40, 60 or 80% of one repetition maximum does increase flexibility in an intensity dependent manner, so flexibility increased at various joints, ranging from 3-12, 6-22 and 8-28%, respectively. Exercise order, another variable, may also affect changes in flexibility. Agonist/antagonist training and an alternated upper and lower body exercise order, both, result in significant increases in flexibility (14). However, the effect size changes shown by the alternated order generally were large while the effect size changes shown by the agonist/antagonist training were moderate. The above two studies indicate resistance training variables can affect changes in flexibility.

Simão *et al.* (16) investigated the effects of 10 weeks of resistance training with one or three sets on flexibility in young men. Flexibility was measured using Sit-and-Reach test. Both, one and three sets per exercise, significantly increased range of motion at Sit-and–Reach test. However, no significant difference was shown between one and three sets per exercise and, only the three set training group showed a significantly greater increase in Sit-and-Reach flexibility compared to the control group, indicating flexibility changes may be affected by the number of sets performed.

The aforementioned studies demonstrated resistance training alone can increase range of motion or flexibility. These same studies also indicate training intensity and exercise order may affect changes in range of motion when performing only resistance training. So, we are aware of only one study (16) comparing the effects of different resistance training volumes (i.e., number of sets per exercise) might have on flexibility. Thus, there is a lack of studies examining the possible effects of different resistance training volumes, such as different numbers of sets, on flexibility over long training periods (greater than 10 weeks). Therefore, the purpose of this study was to investigate the effects of six months of resistance training with different number of sets per exercise (one, three, and five sets) on flexibility in men. The main hypothesis was resistance training would increase flexibility at some joints, but not at others and there would be a significant difference in flexibility changes between the number of sets per exercise performed.

METHODS

Participants

Forty-seven men (mean ± SD: age = 24 ± 1yrs; body mass = 79.39 ± 9.12 kg; height = 174.5 ± 5.6 cm) from the Brazilian Navy School of Lieutenants were volunteered for this study. Exclusion criteria were: a) the performance of another type of regular physical activity during the study; b) functional limitations to perform resistance training or the tests included in the study; c) medical limitation that could affect the training program; and, d) the use of nutritional or ergogenic supplementation. Subjects were experienced in traditional military training involving body weight exercises, such as push-ups, pull-ups, and abdominal exercises. The participants were not experienced resistance trainers and had not been performing flexibility training prior to the start of the study. Before data collection, all subjects answered the PAR-Q questionnaire (15) and read and signed an informed consent form. The study was approved by the Ethics Committee of the University.

Protocol

On the first day, all anthropometric and flexibility measurements were made. On the second day, all flexibility tests were repeated to determine test-retest reliability. The tests were performed on two non-consecutive days prior to training with at least 48 hours between test days. This procedure allowed determination of test-retest reliability. The same flexibility tests were performed post-training using the same time line as pre-testing, by the same investigator, using identical procedures. All pre-training and post-training flexibility testing was conducted at approximately the same time of day (between 07:00 and 08:00 am). To prevent information bias during the measurements, the data collected during the first pre-training assessment and the data from the first and the second pre-training assessment were not available to the examiner in subsequent assessments. The Sit-and-Reach test was performed according to the procedures of American College of Sports Medicine (ACSM) (2). Before the test, a light warm up of two sets of four static stretching exercises was performed for the muscle groups involved in the test (hamstrings, hip flexor, quadriceps, and calf) with each set being 10 seconds in duration and a 10-second rest period between the sets and exercises. Immediately after the static stretches, Sit-and-Reach test was performed. The score used for statistical analysis was the best of three trials with 10-second rest periods between each trial (2). Immediately after the sit-and-reach test, flexibility was assessed by goniometry on 10 joint movements: shoulder flexion, extension, abduction and horizontal adduction, elbow flexion, hip flexion and extension, knee flexion, and trunk flexion and extension (12). To assess flexibility, the investigator adjusted the subject's body to the point of mild discomfort or anatomical limitation. The measurements were taken using a Lafayette Goniometer (Sammons Preston Rolyan #7514, Bolingbrook, IL), following the procedures described by Norkin and White (12).

After pre-testing, subjects were randomly assigned into one of three training groups: one set (G1S; n=12; 24±1years; 79.7±9.4 kg; 177.9±5.2cm) three-sets (G3S; n=13; 24±1years; 76.2±8.1kg; 174.9±3.4cm) or five-sets (G5S; n=13; 24±1years; 82.2±10.7kg; 172.9±7.3cm), or into the control group (CG; n=09; 24±1years; 79.3±8.2kg; 173.2±3.4cm). Prior to each training session, the subjects performed a specific warm-up, consisting of 10 repetitions with approximately 50% of the load used in the first exercise of the training session. The exercise order for all training groups was: bench press (BP), leg press (LEG), latpulldown (LAT), leg extension (LE), shoulder press (SP), leg curl (LC), biceps curl (BC), abdominal crunch lying on the floor (ABD), and triceps extension (TE). The control group (CG) did not participate in the training program. Resistance training sessions were performed three days per week with 48 to 72 hours of rest between sessions (totaling 72 training sessions). All sets of each exercise were performed with 8-12 repetition maximum resistances until volitional failure, with a rest interval of 90 to 120 seconds between sets and exercises. Load was increased when more than 12 repetitions could be performed. Adherence to the training was at least 95% of all sessions, for all participants. If an individual performed less than 95% of the sessions, their test results were not used in the statistical analysis. All training sessions were monitored by an experienced investigator and the subjects were not allowed to perform aerobic or flexibility exercises during the training period.

Statistical Analysis

Intraclass Correlation Coefficients (ICC) model ICC3,1, standard error of measurement (SEM), and minimal differences (MD) were used to assess flexibility reliability (19). The Shapiro-Wilk normality test and the homoscedasticity test (Bartlett criterion) were performed to evaluate data distribution. All variables showed normal distribution and homoscedasticity. Two-way analysis of variance (ANOVA) (time [pre vs. post] × group [G1S vs. G3S vs. G5S vs. CG]) were used to analyze differences among the groups for changes in flexibility (Sit-and-Reach and goniometry tests) pre- to post-training. When appropriate, follow-up analyses were performed using Tukey post-hoc tests. An alpha level of $p < 0.05$ was considered statistically significant for all comparisons. Statistica 7.0 *(Statsoft, Inc., Tulsa, OK, USA)* statistical software was used for all statistical analyses. The calculation of the effect size (ES) and the scale proposed by Rhea (13) were used to examine the magnitude of any treatment effect.

RESULTS

All flexibility assessments demonstrated high reliability. For the Sit-and-Reach test, ICC, SEM, and MD were 0.96, 1.46 and 4.04, respectively; 0.98, 2.07, and 5.73 for shoulder flexion, 0.92, 3.43, and 9.51 for shoulder extension, 0.92, 3.35, and 9.29 for shoulder abduction, 0.94, 1.86, and 5.16 for shoulder horizontal adduction, 0.96, 1.29, and 3.58 for elbow flexion, 0.98, 1.19, and 3.30 for hip flexion, 0.98, 0.56, and 1.56 for hip extension, 0.96, 1.33, and 3.69 for knee flexion, 0.96, 0.37, and 1.03 for trunk flexion, and 0.98, 0.22, and 0.60 for trunk extension, respectively.

The between group comparison demonstrated that only G5S compared to the CG ($p < 0.05$) was statistically significant (Figure 1). There were statistically significant differences for the sit-and-reach test when comparing pre-to post-training for all training groups ($p < 0.05$). However, ES data revealed moderate improvements for G1S (ES = 0.96; Δ%= 24.5%) and small improvements for G3S (ES= 0.48; Δ%= 13.2%), G5S (ES = 0.52; Δ%= 17%), and CG (ES= 0.47; Δ%= 17.2%).

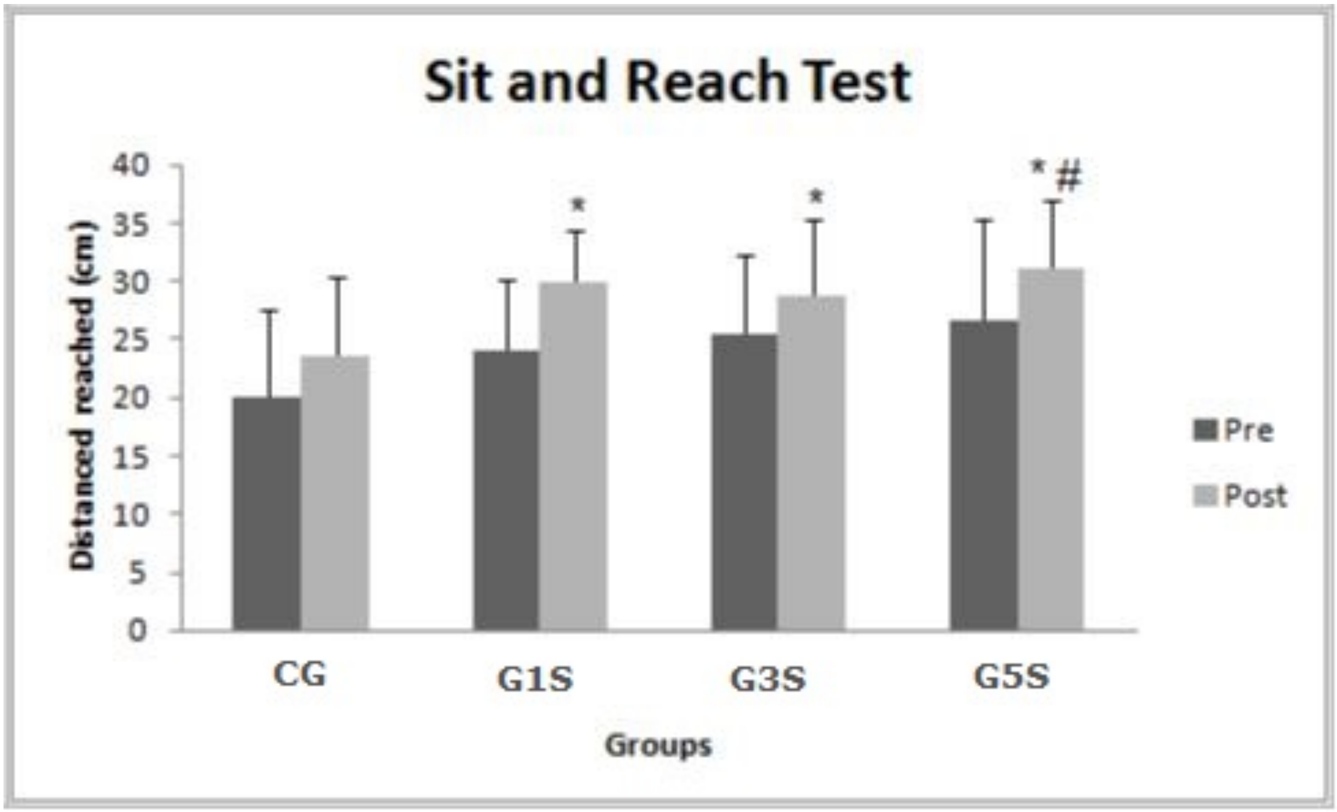

Figure 1. Sit-and- Reach Test results (mean ± standard deviation (SD)). CG – control group; G1S – one set group; G3S – three set group; G5S – five set group. * = significant difference from pre-training ($p < 0.05$). # = significant difference from CG post-training ($p < 0.05$).

For the goniometry assessments, the flexibility test-retest reliability showed high ICC pre- and post-training, with values ranging between 0.92 and 0.98 of the ten joint movements measured. There were increased levels of flexibility when comparing pre- to post-training for shoulder flexion (G1S) and shoulder extension, elbow flexion and knee flexion (G3S) ($p < 0.05$). The between group comparison did not present significant differences ($p > 0.05$) (Figures 2, 3 and 4). ES data demonstrated trivial flexibility improvements in shoulder flexion (G5S: ES= 0.28; Δ%= 3.4%) and moderate in elbow flexion (G1S:ES= 0.83; Δ%= 4.1% and G3S: ES= 1.01; Δ%=

5.1%), knee flexion and trunk flexion (G3S: ES= 1.37; Δ%= 6.6%, and ES= 0.98; Δ%= 30.8%, respectively).

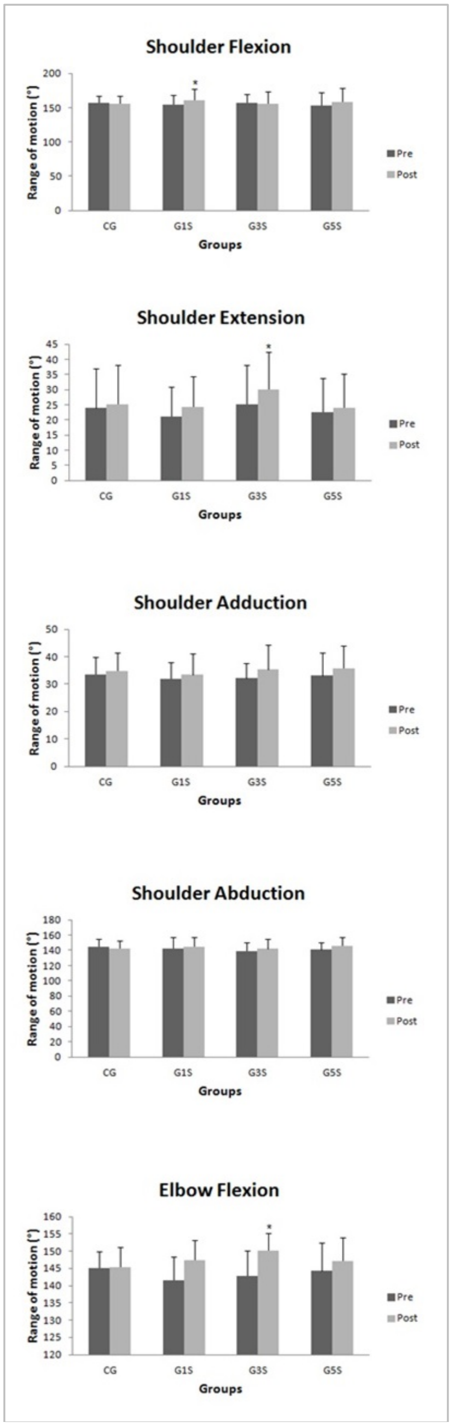

Figure 2. Goniometry results of upper body (mean ± standard deviation (SD)). CG – control group; G1S – one set group; G3S – three set group; G5S – five set group. * = significant difference from pre-training (p < 0.05).

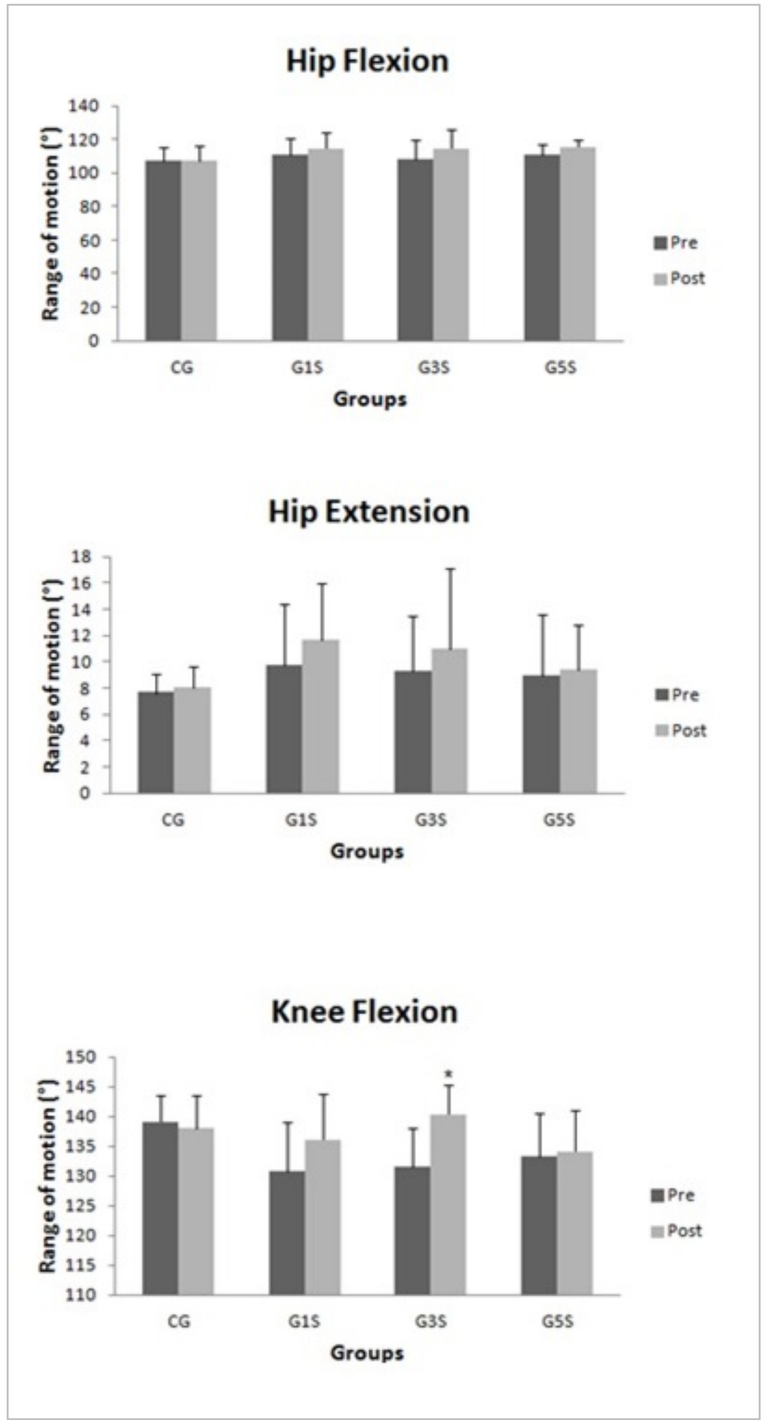

Figure 3. Goniometry results of lower body (mean ± standard deviation (SD)). CG – control group; G1S – one set group; G3S – three set group; G5S – five set group. * = significant difference from pre-training (p < 0.05).

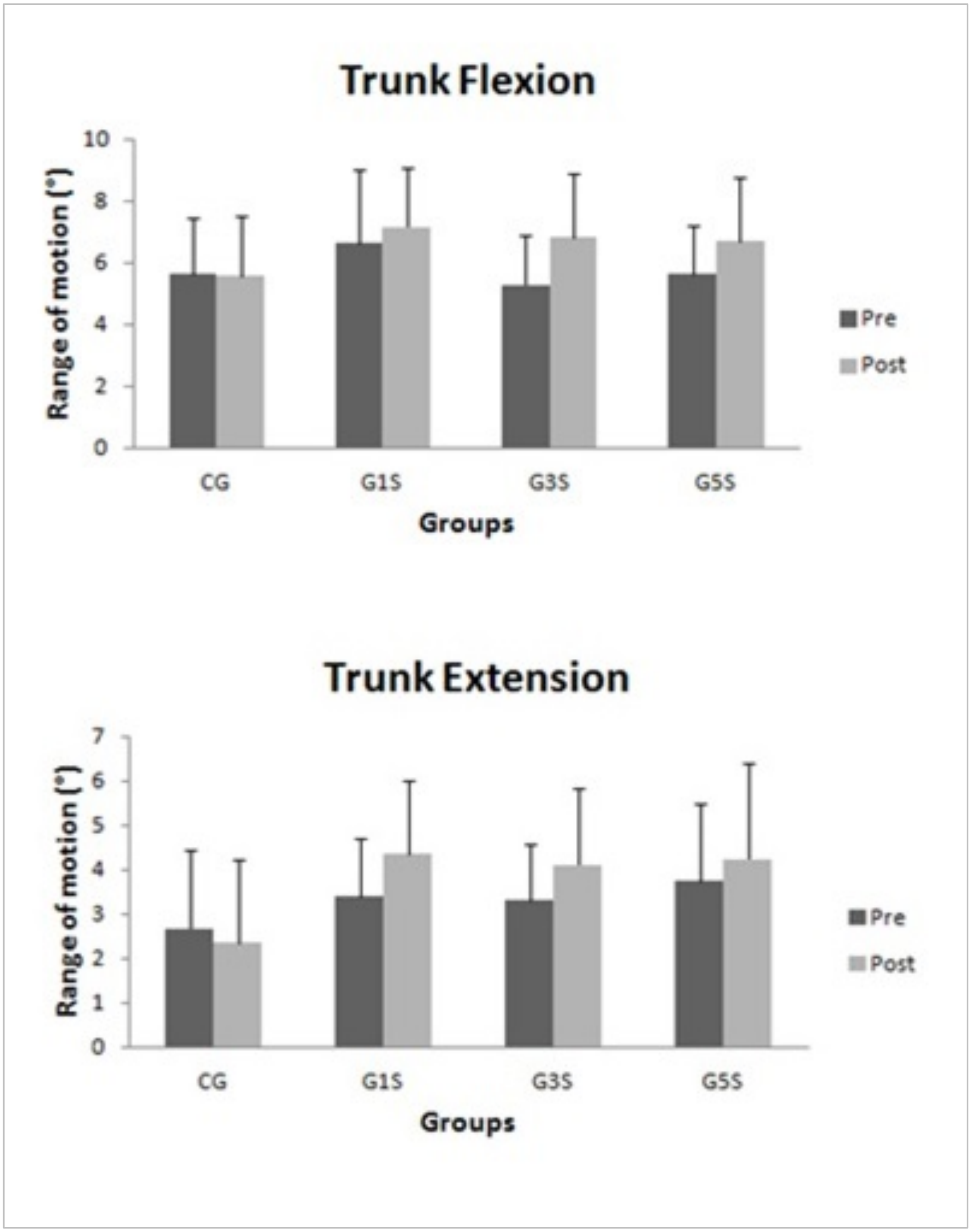

Figure 4. Goniometry results of trunk (mean ± standard deviation (SD)). CG – control group; G1S – one set group; G3S – three set group; G5S – five set group. * = significant difference from pre-training ($p < 0.05$).

DISCUSSION

The major finding of this study was that performing resistance training with no flexibility training increased flexibility results on sit-and-reach test and other goniometry measures. In addition, there were no significant differences in flexibility changes due to the number of sets per exercise performed. For the sit-and-reach test, all training groups increased in flexibility with no significant difference between the number of sets per exercise performed. However, only G5S demonstrated significant differences when compared to the CG. Effect size showed moderate improvements for G1S and small improvements for G3S and G5S in the sit-and-reach test. For goniometry, the different volumes of resistance training increased flexibility when compared to pre-training for shoulder flexion (G1S) and shoulder extension, elbow flexion and knee flexion (G3S) ($p < 0.05$). Effect size data demonstrated moderate increases in elbow flexion (G1S and G3S), knee flexion and trunk flexion (G3S). In the other assessed movements (shoulder flexion and extension, shoulder adduction and abduction, hip flexion and extension, and truck extension) effect sizes indicated small or trivial changes. The CG showed no significant change in any of the flexibility tests and effect sizes indicated trivial increases or small decreases in flexibility.

The increase in flexibility shown in some, but not all movements examined in the present study can be due to limitations in our study, such as the use of machine-based exercises, since free weight exercises can train different range of motions and could show us different flexibility adaptations. The machine-based program was chosen because it was considered safer and it is common at training facilities. Our findings are in agreement with previous investigations showing increases in flexibility due to performing resistance training with no flexibility training (4,5,8-11,14,16-18) However, only four previous studies assessed the effects of manipulating resistance training variables on flexibility (6,8,14,16). In a study comparing the effects of three different resistance training intensities on flexibility, Fatouros *et al.* (6) examined sedentary elderly men with a mean age of approximately 70 years during 6 months of training and 6 months of detraining. The results indicated flexibility changes are intensity dependent for training and detraining. Greater increases in flexibility were shown with training performed with higher intensities as well as flexibility increases were better maintained during detraining to whom performed higher intensities. Training with 40, 60 and 80% of one repetition maximum increased flexibility at various joints, ranging from 3-12%, 6-22% and 8-28%, respectively. After detraining, the flexibility of the groups that trained at intensities of 60 and 80% of 1RM was generally significantly greater than pre-training, while the flexibility of the group that trained with 40% of 1RM generally had decreased to pre-training values after detraining.

Santos *et al*. (14) assessed the effects of training with either an alternated upper/lower body exercise order or an alternated agonist/antagonist exercise order in young sedentary women. After eight weeks of training, both training groups increased strength and flexibility significantly from baseline and when compared to the control group. Recently, Kim *et al*. (8) examined the effects of traditional resistance training (two second concentric and eccentric repetition phases) and "SuperSlow" resistance training (10 second concentric and eccentric repetition phases) during four weeks of training on flexibility. Pre-training to post-training comparisons showed both groups increased Sit-and-Reach range of motion significantly (traditional resistance training = 11%, super slow training = 14.7%), but there was no significant difference between the two training groups. Thus some training variables may affect (i.e. intensity) while other training variables (i.e., exercise order and repetition velocity) may not affect flexibility increases.

Simão *et al*. (16) is the only study that investigated the effects of different number of sets (one vs. three) on flexibility. Both training groups, composed of young men showed significant increases in flexibility by the sit-and-reach test compared to pre-training, but only the group that performed three sets showed a significant difference compared to the control group post-training. The results of the present study agree with Simão *et al.* (16) in that all training groups increased flexibility by the sit-and-reach test, with no significant difference between training groups, the difference of the present study was that the five set group, was the only one group that showed a significant difference to the control group post-training in flexibility by the sit-and-reach test. Hence, the present study's results disagree with Simão *et al*. (16) in that greater training volume (number of sets performed) did not affect sit-and-reach flexibility increases. In the other 10 joint specific tests of flexibility no significant difference between training groups was shown.

Studies utilizing circuit weight training agree with the current study and those reviewed above in that resistance training increases or has no negative effect on flexibility (5,9). In both of these circuit weight training studies training lasted 10 weeks and, after training, flexibility increased significantly in some (5 of 10 movements), but not in all the joint movements assessed.

The authors are aware of three studies comparing the effects of resistance training alone or in combination with another type of training on flexibility (7,11,17). Fatouros *et al.* (7) compared aerobic training, resistance training and the combination of both on flexibility in older adults; where the resistance training alone and the combined training showed significant increases in flexibility in seven of the ten joint movements measured. In contrast, Nóbrega *et al.* (11) compared the effects of 12 weeks of resistance training, flexibility training and the combination of both types of training on the flexibility of young adults, using the flexitest, and concluded that significant increases in flexibility were found only in the groups that trained flexibility alone or in combination with resistance training. Simão *et al.* (17) investigated the effects of resistance training alone, flexibility training alone and the combination of both performed for 16 weeks, on strength and flexibility gains. All training groups demonstrated increases in flexibility measured by sit-and-reach test when compared to pre-training and control group. In addition, effect sizes showed a large improvement in flexibility for all three training groups.
There are methodological differences, such as age of the subjects, training duration and different methods determining flexibility between the current study and the studies referenced. However, all of these studies are in agreement that resistance training alone either increased flexibility or showed no significant negative effect on flexibility. Additionally, increases in flexibility due to performing resistance training or flexibility in combination with resistance training also do not negatively affect strength increases due to training.

The use of machine-based exercises can be considered limitations of the present study because free weight exercises can work at different ranges of motion, possibly leading to different flexibility adaptations. Thus, not all exercises used were optimal for the joints that were studied.

As practical applications we can conclude that resistance training results in no negative effects on flexibility, while demonstrating some increases in flexibility in some joints. Performing one, three, or five sets of each exercise in a resistance training program increased flexibility although it has no significant effects between groups on changes in goniometry assessment. Strength and conditioning coaches and other allied health professionals can expect increases in flexibility when resistance training is performed even without accompanying flexibility training.

REFERENCES

1. American College of Sports Medicine. ACSM Position Stand: Quantity and Quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med Sci Sports Exerc 43(7): 1334-1359, 2011.

2. American College of Sports Medicine. ACSM´S Guidelines for Exercise Testing and Prescription (6th Ed.). Lippincott: Williams & Wilkins, 2000.

3. American College of Sports Medicine. ACSM Position Stand: the recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. Med Sci Sports Exerc 30(6): 975-991, 1998.

4. Barbosa AR, Santarém JM, Filho WJ, Marucci MF. Effects of resistance training on the sit-and-reach test in elderly women. J Strength Cond Res 16(1): 14-18, 2002.

5. Cyrino ES, Oliveira AR, Leite JC, Porto DB, Dias RMR, Segantin AQ, Mattanó RS, Santos VA. Comportamento da flexibilidade após 10 semanas de treinamento com pesos. Rev Bras Med Esporte 10(4): 233-237, 2004.

6. Fatouros IG, Kambas A, Katrabasas I, Leontsini D, Chatzinikolaou A, Jamurtas AZ, Douroudos I, Aggelousis N, Taxildaris K. Resistance training and detraining effects on flexibility performance in the elderly are intensity-dependent. J Strength Cond Res 20(3): 634-642, 2006.

7. Fatouros IG, Taxildaris K, Tokmakidis SP, Kalapotharakos V, Aggelousis N, Athanasopoulos S, Zeeris I, Katrabasas I. The effects of strength training, cardiovascular training and their combination on flexibility of inactive older adults. Int J Sports Med 23(2): 112-119, 2002.

8. Kim E, Dear A, Ferguson SL, Seo D, Bemben MG. Effects of 4 weeks of traditional resistance training vs. superslow strength training on early phase adaptations in strength, flexibility, and aerobic capacity in college-aged women. J Strength Cond Res 25(11): 3006-3013, 2011.

9. Monteiro WD, Simão R, Polito MD, Santana CA, Chaves RB, Bezerra E, Fleck SJ.Influence of strength training on adults women's flexibility. J Strength Cond Res 22(3): 672-677, 2008.

10. Morton SK, Whitehead JR, Brinkert RH, Caine DJ. Resistance training vs. Static stretching: effects on flexibility and strength. J Strength Cond Res 25(12): 3391-3398, 2011.

11. Nóbrega AC, Paula KC, Carvalho AC. Interaction between resistance training and flexibility training in healthy young adults. J Strength Cond Res 19(4): 842-846, 2005.

12. Norkin CC, White DJ. Measurement of Joint Motion: A Guide to Goniometry. Philadelphia, PA: F.A. Davis Company, 1985.

13. Rhea MR. Determining the magnitude of treatment effects in strength training research through the use of the effect size. J Strength Cond Res 18(4): 918-920, 2004.

14. Santos E, Rhea MR, Simão R, Dias I, de Salles BF, Novaes J, Leite T, Blair JC, Bunker DJ. Influence of Moderately Intense Strength Training on Flexibility in Sedentary Young Women. J Strength Cond Res 24(11): 3144-3149, 2010.

15. Shephard RJ. PAR-Q, Canadian home fitness test and exercise screening alternatives. Sports Med 5(3):185-195, 1988.

16. Simão R, Leite T, Reis VM. Influence of the number of sets at a strength training in the flexibility gains. J Human Kinetics 29A: 47-52, 2011.

17. Simão R, Lemos A, Salles B, Leite T, Oliveira E, RheaM, Reis VM. The Influence of Strength, Flexibility, and Simultaneous Training on Flexibility and Strength Gains. J Strength Cond Res 25(5): 1333-1338, 2011.

18. Thrash K, Kelly B. Research notes: Flexibility and Strength Training. J Appl Sport Sci Res 1(4): 74-75, 1987.

19. Weir JP. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. J Strength Cond Res 19(1): 231-240, 2005.