"Effects of Volume Training on Strength and Endurance of Back Muscles: A Randomized Controlled Trial" by Shigaki L et al.
Journal of Sport Rehabilitation

Section: Original Research Report

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Running Head: Training volumes of back muscles

Journal: *Journal of Sport Rehabilitation*

Acceptance Date: April 26, 2017

DOI: https://doi.org/10.1123/jsr.2016-0253

Title: Effects of volume training on strength and endurance of back muscles: A randomized controlled trial

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Abstract

Context: Strength/resistance training volume has historically been supported in the American College of Sports Medicine recommendations. However, for the back muscles, exercise prescription related to the number of sets, such as single vs. multiple, is not well established in the literature. **Objective:** The purpose of this study was to compare the effects of two training volumes on strength and endurance of back extensor muscles in untrained young participants, with regard to a repeated measures design. **Design:** Randomized controlled trial. **Setting:** Laboratory of functional evaluation and human motor performance. **Participants:** Forty-four untrained young participants (mean age= 21 yrs) were randomized into three groups: single set (SSG, n= 14), multiple sets (MSG, n= 15), and untrained control (CG, n= 15). **Intervention:** The SSG and MSG underwent a 10-wk progressive resistance training program (2 $\text{days}\cdot\text{week}^{-1}$) using a 45° Roman chair. **Main Outcome Measures:** Back maximal strength (dynamometer) and isometric and dynamic endurance (time-limit, trunk extension-flexion cycles, and electromyography muscle fatigue estimates). **Results:** The results showed differences between the MSG and control group for isometric endurance time (mean 19.8 seconds, 95% CI 44.1 to 4.8), but without time intervention significance. Significant improvement after training (P <0.05) was found predominantly during dynamic endurance (number of repetitions) for both the MSG (+61%) and SSG (+26%) compared to pre-intervention, while the control group reported no benefit. There was no significant (P > 0.05) difference in either strength or electromyography estimates after training. **Conclusions:** Both multiple and single volume training were efficient in promoting better back endurance during dynamic performance based on mechanical variables (time and number of repetitions).

Key words: Exercises, Back pain, Rehabilitation, Training.

Introduction

Chronic low back pain (CLBP) is a common condition and a public health problem, with a high prevalence worldwide, leading to major socio-economic consequences. Poor back muscle endurance is a predictor of a first episode of low back pain as well as long-term back-related disability and CLBP[1,2]. The excessive fatigue of back muscles in subjects with CLBP may be associated with a shift in muscle fiber proportion toward type II fibers and reciprocal atrophy of lumbar muscles (multifidus, iliocostalis)[3,4]. Trunk muscle fatigue may increase neuromuscular deficits, resulting in brief uncontrolled movements, subsequent tissue strain injury, and low back pain[5]. Thus, exercises for back muscles have been beneficial in restoring the function of these impaired muscles in strategies for both prevention and intervention of CLBP disorders[6].

Overall, back muscle specific training suggests isolating the recruitment of the lumbar back muscles, while minimizing hip extensor muscle contribution during the exercise[7]. The specificity and progressive overload of the lumbar extensor muscles are apparently needed to achieve the optimal therapeutic results during back rehabilitation programs[7]. Different types of exercises (e.g., machines, benches, and/or Roman chair) can provide enough stimuli to improve strength and/or endurance of lumbar extensor muscles, which in return promote better stability and protect the lumbar spine[8]. However, the optimal training volume with regard to back strength and endurance gains remains unknown for the lumbar muscles. Strength/resistance training volume has historically been supported by the American College of Sports Medicine (ACSM) recommendations[9], which also take into consideration the back muscles with regard to CLBP disorder prevention.

To date, there is no consensus in relation to determining the best volume of training depending on the muscle group targeted. Some studies[10–13] have supported the use of multiple set protocols, while others indicate that the use of single set protocols is also sufficient for strength/endurance gains in the upper and lower-limb muscles[14,15]. Apparently, no difference between single and multiple sets[16–18] was reported for either upper or lower-limb muscles during different types of training. However, these studies did not generalize their results for the lumbar extensor muscles, which have a greater impact for individuals with CLBP. In a recent study designed specifically to assess the back muscles, Steele et al.[19] showed similar results comparing single vs. multiple sets only for the strength variable after a 6-week training program in recreationally trained males. Unfortunately, these authors did not evaluate back endurance by time limit and/or electromyography variables, which are important clinical outcomes for exercise training programs in individuals with CLBP[1,2].

The main purpose of the present study was to compare the effects of two volumes of training on strength and endurance variables of back extensor muscles during a 10-wk specific training program in untrained young participants. We hypothesized that the multiple set protocol would promote greater improvement in endurance than the single set protocol for lumbar muscles, since the nature of endurance training is in accordance with the ACSM position[9].

Methods

Design

This study was a randomized controlled trial conducted in the Center for Health Science Research, at the Laboratory of functional evaluation and human motor performance (LAFUP) – UNOPAR, Londrina-PR, Brazil. The study was conducted according to Resolution 466/2012 of the National Health Council (local Ethics committee: #846.393) and registered on www.ClinicalTrials.gov (ID: NCT02326792). All participants were informed of the procedures, risks and benefits of the investigation and signed an informed consent document that was approved by the Institutional Review Board of the University.

Participants

Forty-four young participants, paired by sex (50% females and 50% males), were recruited. The sample size was calculated from the mean and standard deviation (SD) of a previous study[20]. The significance level was 0.05 with the power of the sample estimated at 80%. The estimated sample size using the differences in the endurance time variable between the pre and post-training values, corrected by standard deviation (SD), was applied: intervention experimental group (Δ = 30 seconds) versus control group (Δ = 8 seconds). Thus, the sample estimated for the present study was a minimum of 13 participants in each group.

The inclusion criteria were: (1) aged between 18 and 30 years; (2) not having low back pain with or without pain irradiation to the lower limbs; (3) not involved in the practice of systematic physical activity (i.e., 2 days per week as reported by the ACSM) in the 6 months prior to the start of the study; (4) not having ingested any nutritional supplement or anabolic steroid; (5) not having medical restrictions for physical exercise. The exclusion criteria were: (1) mental or physical illnesses that influenced the exercise protocol; (2) any type of surgery on the locomotor system or spine in the previous 24 months; (3) upper body mass, including trunk, head and upper limbs, greater than 50% of the total trunk extensor muscle strength in a horizontal position related to the Sorensen test; (4) Body mass index (BMI) over 30 kg/m^2.

Participants were blindly randomized into one of three groups: (1) control group (CG, n = 15), (2) single set group (SSG, n = 14), or (3) multiple set group (MSG, n = 15). Figure 1 illustrates a flow diagram of the study from the invitation and recruitment of participants, criteria selection, to the final analysis.

Procedures

Participants answered a form with demographic data such as name, date of birth and gender. Anthropometric measurements were also evaluated (weight, height, body mass index). To measure upper body mass, the participant was positioned on the 45º Roman chair while the upper body rested on the same equipment, used to measure maximal back strength. When the participant was completely relaxed, upper body mass was recorded using a load cell. The same investigator performed the procedure for all participants to eliminate inter-tester measurement error. In the first week of testing, the participants were familiarized with all experimental tasks and exercises used for training, to minimize learning effects. A trained and blinded evaluator performed the assessments for this study.

To evaluate the upper body mass (trunk weight) and maximal strength of the back extensor muscles, a 45° Roman chair (Nakagym, Ltd., SP) was used (Figure 2 (A)). A load cell (SF01, EMG system of Brazil Ltda.), with a capacity of 0-200 kgf, was attached to the Roman chair with a chain and to a nylon torso harness, equipped with a ring at the mid-sternal region to measure the maximum strength of the back extensors (in Newtons: N)[21]. The participants performed three maximal voluntary isometric contractions (MVIC) of the back extensors in a horizontal position (Figure 2 (A)), with a three minute rest between trials. The peak across MVICs was retained for subsequent analyses[7,22]. We performed a pilot study with 10 young participants which showed that the test-retest for these measures (trunk weight and back MVIC) were excellent (ICC>0.90).

After the MVIC, the participants rested for 10 minutes to minimize the effects of residual fatigue, and then performed a modified Sorensen test using a 45º Roman chair (Figure 2 (B)). The modified Sorensen test is the most widely used test in the literature for evaluating the isometric endurance of back extensor muscles[23]. During the test, participants maintain the trunk horizontally without any support until exhaustion (maximum fatigue). For this test, the load was determined at 50% maximal strength of the back extensor muscles from MVIC (endurance intensity = upper body mass + MVIC + equipment weight × 50%)[21]. Endurance time in seconds was recorded to determine mechanical muscle fatigue. Only during the modified Sorensen test were the back muscle electromyography (EMG) measurements computed as detailed below, to determine physiological fatigue with respect to EMG signal stationarity (section: EMG measurement).

After 48 hours, the participants performed a dynamic back endurance test in a 45º Roman chair with their trunk unsupported. The participants started the exercise in a trunk extension position. They were then encouraged to perform flexion-extension trunk cycles according to an indicator bar positioned to achieve a range of motion of approximately 45º. Each flexion–extension cycle lasted 4 s (2 s of flexion and 2 s of extension), paced with a metronome (Dolphin digital metronome, UK, using 30/bpm). Verbal feedback was provided by the evaluator during the test. The participants were instructed to perform trunk flexion-extension cycles up to the maximal number of repetitions possible until exhaustion (Figure 2 (C))[24]. This test was performed at 50% MVIC of the back extensor muscles as in isometric conditions.

EMG signals were collected from 8 pre-amplified (gain: 1000) active surface electrodes with a Bagnoli-8 EMG System (Delsys Inc., Wellesley, MA, USA). All EMG signals were subsequently bandpass filtered (20 and 450 Hz; 8th order zero-lag Butterworth IRR filter) to remove high frequency noise as well as low-frequency movement and electrocardiography (ECG) artifacts. ECG is dominant in torso EMG signals, which made necessary the use of a high-pass cut-off frequency (at least 20 Hz; as pointed out by Redfern et al.[25], which is above that recommended (10 Hz) to remove movement artefacts (JEK standards for reporting EMG data)).

After the skin at the electrode sites had been shaved and abraded with alcohol, the electrodes were positioned bilaterally on the multifidus at the L5 level (MU-L5-Left and MU-L5-Right), and on the iliocostalis lumborum at the L3 level (IL-L3-L and IL-L3-R), following the recommendations of Defoa et al.[26] with regard to muscle fiber direction [see details in Da Silva et al. [22]]. A reference (ground) silver-silver chloride electrode was positioned over the T8 spinous process. To secure the placement of electrodes for the pre- and post-intervention assessments, a template was produced during the baseline measure (pre- session) by copying electrode locations as well as natural skin blemishes on an acetate.

In the present study, only the median frequency (MF) estimate as the best and most reliable fatigue index was used to assess back muscle fatigue from the stationarity of the EMG signal during the modified Sorensen test[27]. The magnitude of the electromyographic spectral content was evaluated by the MF value of the power spectra (Short-fast Fourier transform, Hanning window processing). MF was calculated in successive time windows (50% overlapped) of 250ms for the total of the 60-second contraction in each fatigue protocol condition. A least squares linear regression analysis was then applied to the MF time series to calculate the rate of decline in MF over time (MF/time slope). The slope from this relationship was then divided by the corresponding intercept value (obtained from linear regression analysis) and multiplied by 100 to yield the normalized EMG index of muscle fatigue (NMFslp); this accounted for subcutaneous tissue thickness differences between participants.

No between-side back muscle differences were observed (t-test results not reported here) across groups and thus NMFslp scores were averaged bilaterally to reduce the data to two back muscles and increase their reliability[27]. All EMG data processing was performed using both EMG work analysis from the Delsys system (Version 4.0, Delsys, MA, USA) and MATLAB subroutines (Version 8.0; The MathWorks Inc., Natick, MA, USA, release 14).

The participants in the SSG and MSG carried out resistance training of the back muscles twice a week for a total of 10 weeks. The training sessions were separated by at least 48 hours. Both groups (SSG and MSG) performed trunk flexion-extension cycles on a 45º Roman chair machine. The SSG performed only a single set, while the MSG performed 3 sets of exercises, with a 1 minute rest interval between each set as recommended for local muscular endurance by the ACSM[9]. In both training groups, participants performed the exercise with hands on opposite shoulders, while working with a range of motion of 45° as for the dynamic endurance test. The training with 15-20 repetitions was according to the ACSM endurance gains[9]. The trunk movement (flexion-extension) was controlled in all repetitions by a metronome and by verbal encouragement feedback.

A trained professional who was blinded to the evaluation measures conducted the resistance training in both groups. The initial load on the first day of training was 50% of the load in the first tests. The participants were encouraged to perform as many repetitions as possible, up to 20 repetitions on the day of training. In both groups (SSG and MSG), as soon as 20 repetitions were reached, intensity was increased by 5%, through external washers crossing the trunk, for the next training session for the single group and the next set for the MSG group. The progression continued as long as the training was executed, up to 10 weeks, after which a new assessment was performed in the laboratory. If participants of both groups were unable to perform a minimum of 15 repetitions, then the load was decreased by 5%. This intervention protocol was based on a previous study reported by Mayer et al.[8].

All participants were instructed to maintain their habitual daily diet during the period of the study. The CG was instructed to maintain their daily activities and habits during the 10 weeks of intervention. After 20 sessions of training, a total of 10 weeks, all participants were invited to return to the laboratory, one week after the final training, to perform the same tests as in the first evaluation.

Statistical analyses

All statistical analyses were performed with SPSS® statistical software (version 20.0 for Windows) with an alpha level of 0.05. All variables were normally distributed based on the Shapiro-Wilk test, further supported by Levene’s Test of Equality of Error Variances.

Two-way ANOVA with repeated measures was used to assess differences between the groups (control, SSG, MSG) and times (pre- and post-intervention), and the effects of interactions (Groups × Times) on the dependent variables: maximal back strength (MVIC), isometric endurance (time-limit and EMG fatigue estimates), and dynamic endurance (number of repetitions). When necessary, a post-hoc Tukey test was used to locate differences between the groups. The Effect Size (ES) using Cohen’s *d*[28] for main outcomes was also computed when significant differences were reported, with the 95% Confidence Interval (CI). The ES magnitude was established as 0.20-0.49 for small, 0.50-0.79 for medium, and ≥ 0.80 for large.

The intention to treat analysis was considered in the study and performed in order to maintain participants in the group where they were initially allocated after randomization.

Results

The anthropometric characteristics of the three homogeneous groups are presented in table 1. The adherence of participants to the training presented a mean of 87.8% for the SSG group, and 88.0% for the MSG group (with no significant difference between them).

The mean descriptive values and ANOVA results for mechanical variables such as strength, and isometric and dynamic endurance are presented in Table 2, while the physiological measures are reported in Table 3. Firstly, there was no significant ($P > 0.05$) differences in either strength (Table 2; with illustration in Figure 3A) or electromyography estimates (Table 3) after the interventions with single set and multiple set training.

For the isometric endurance test, the only significant differences between groups without time differences were reported in the time-limit from the ANOVA results. The *Post hoc* test revealed a significant ($P < 0.01$) difference in favor of the MSG versus the control group, as illustrated in Figure 3B (mean 19.8 s; 95% CI = - 44.1 to 4.8; ES $d = 1.13$). Interestingly, no significant differences were reported between the single and multiple set protocols for any comparison.

The main results of the study were in the dynamic endurance test. Significant effects of time sessions (pre- and post-intervention) and interaction effects ($P < 0.05$) were found for the variable number of repetitions (Table 2 and Figure 3C). Both the MSG (pre = 12.7 vs. post = 20.5; ES $d = 1.11$) and SSG groups (pre = 13.2 vs. post = 16.5; ES $d = 0.87$) demonstrated efficiency in back mechanical endurance gains during dynamic performance after training. These results are further illustrated in Figure 3C.

Discussion

This study compared the effects of two volumes of training on strength and endurance variables of back extensor muscles, during a 10-wk specific training program in untrained young participants. Our hypothesis was not supported, that the multiple set protocols would promote greater improvement in endurance in the lumbar muscles compared to a single set. This hypothesis was established due to the nature of the endurance training, based on the ACSM position[9].

The present study revealed that both methods of training were efficient for the back muscles, especially for mechanical endurance gains. Similar results between methods were found, mainly for the dynamic endurance variable. There were no differences in either strength or electromyography estimates after the interventions. The originality of the present study over past research is comparing for the first time the two training volumes on the main outcome for prevention of CLBP disorders; namely back endurance (mechanical and physiological variables). These results have many implications for clinical decision making, including exercise prescription during back rehabilitation and training.

The ACSM recommends the use of multiple sets for endurance muscular gains. Two systematic reviews, including a meta-analyses, supported multiple sets rather than a single set for resistance training of different muscle groups[10,11]. However, the present study did not show significant differences for lumbar muscles between the two methods. Our results corroborate with previous studies that reported no difference between these two types of training volume[17,18]. In the present study, both were efficient and presented a large effect size (MSG: d = 1.11 and SSG: d =0.87) for improvement in endurance, as pointed out previously for the dynamic test.

On the other hand, it is possible that these differences between single vs. multiple sets depend on the type of training, nature of the task, or muscle group investigated. For back muscles, few studies have focused their interest on this investigation (i.e., training volume). A recent study with regard specifically to lumbar extensor muscles compared single vs. multiple sets during a 6 week intervention in recreationally trained males[19]. Both groups were trained on a back extension machine with a complete range of motion with different flexion-extension angles (0-72°). This study only computed the maximal strength of the back as a clinical outcome. The authors concluded that single and multiple (n = 3) sets were both efficient methods for strength gains and reported a large ES (d = 0.89 and 0.95, respectively). This was in agreement with the present study, but with regard to the endurance variable. However, the present study did not observe any strength gains as reported by Steele et al.[18].

The discrepancies in our findings compared to the literature may be related to the experimental protocol in each study (testing and/or training[19]). Steele et al.[19] used a back machine for testing and training, while the present study used only a Roman chair exercise. The range of motion during the training was 0 - 72° (in Steele), while in the present study it was 0- 45°. Steele et al. assessed only males while our sample was paired by sex (50% females). Finally, the training load intensity was totally different, being progressively increased by 10%, while in the present study we used only 5% increases. Furthermore, our results are in agreement with a past study[8] that reported no gains in back strength from resistive training using a Roman chair exercise at 45°. These authors[8] suggested that this type of exercise was not targeted for a stimulus of overload of strength due to intensity per se (varying between 40-60% MVIC) but for endurance gains.

It must also be remembered that the improvement in the present study only in dynamic performance could be dependent on the specificity of the training performed. Both the endurance test and training were executed on the same set-up, with the same performance prescription[29]. Thus, further studies considering different types of set-up (evaluation test versus training) should be explored for generalization of endurance gains in both isometric and dynamic contexts. From a rehabilitation context, the present study recommends both methods of training for back muscles.

In addition, Mannion et al.[30] demonstrated that after 3 months of therapy, patients with chronic LBP increased endurance time by 18% in the isometric Sorensen test after treatment with active physiotherapy, muscle reconditioning on devices, or low-impact aerobics. Verna et al.[20] evaluated the effects of endurance training in healthy individuals and found a 42% improvement in isometric endurance time using a single set on a variable-angle Roman chair after 8 weeks. Interestingly, in the present study the multiple set protocols was efficient in both isometric and dynamic endurance, while the single set was efficient only in the dynamic context, although there were no significant differences between the protocols. We cannot assume that one method is better than another for back muscles; each one has its advantages and disadvantages depending on the context employed in the exercise practice.

Additionally, our training protocol produced positive results for the mechanical variables only because physiological fatigue estimates from EMG were apparently stable across the training time sessions. Sung[31] reported no differences for EMG estimates from back muscles after 4 weeks of training for individuals with CLBP, which is in agreement with the present study. Previous studies[32,33] also observed increased static mechanical endurance of trunk extensor muscles after therapy without any significant changes in EMG measurements in relation to back muscle fatigue. In fact, it is possible that neural adaptations were primarily responsible for gains in back muscle endurance across 8-10 weeks of training of moderate intensity[20]. Furthermore, strengthening exercise programs for the lumbar extensor muscles are not related only to the physiological effects but also enhance the metabolic exchange of the lumbar discs through repetitive movement, as performed during the Roman chair exercise (cycles of trunk flexion and extension)[34]. In other words, the repetition of movement *per se* during the training and not muscle loading can bring benefits of conditioning for back muscles in sensitive mechanical variables, compared with physiological measurements[34].

Finally, it is important to point out that EMG estimates were used only in an isometric context where no time effect was reported. Again, the specificity of training versus the assessment test could have influenced these results. Perhaps if EMG estimates had been used during dynamic performance, the results would be contrary to the present, giving evidence for positive improvement in physiological variables. More studies are still necessary to better elucidate this issue.

In this perspective, lumbar extensor muscle endurance is an important clinical outcome for CLBP prevention. Therapists and trainers should pay attention in order to prescribe more specific exercise programs for low back muscle endurance training, especially considering the volume of sets during the prescription of exercise[34,35]. The results of the present study are important because they provide support for the appropriate use of both single and multiple sets during the training of lumbar extensor muscle exercises in young untrained individuals. The present study did not find a superiority of one volume over the other. However, physical performance among individuals with CLBP could be influenced by many factors. For example, strengthening exercises (moderate to near-maximal contraction) could overload ligaments and vertebral discs and thus elicit more pain in individuals with weak back muscles[36]. For these reasons, we suggest that this type of exercise should be used in the final phase of a rehabilitation program when applied in individuals with CLBP. It would be interesting to improve the coordination and stabilization of deep trunk muscles during the first phase of a rehabilitation program rather than the strength and/or endurance[36]. Some guidelines recommend exercises of trunk stabilization where the intensity of exercise is < 40% of maximal contraction[32,36]. These exercises would help to improve lumbar stability before making greater efforts in extension of the trunk using exercise machines or the Roman chair, which could overload the passive structures of the spine.

In addition, stabilization of deep trunk muscles would help to decrease the influence of factors such as pain or fear of pain during movement. In the final phase of a rehabilitation program, back muscles would be more prepared for strengthening exercises, as well as which the psychosocial factors would not affect the force production as much [36]. On the other hand, there is little agreement as to which exercise programs are the most effective in patients with CLBP[37], limiting clear judgment of which exercise should be used for each phase of a rehabilitation program. Clinical experience and knowledge of exercises should also be considered for making better clinical decisions, since each individual can present a specific problem and generalizations should be made with caution.

There are some limitations of the present study that need to be considered here. The duration of the training was only 10 weeks, while some studies have worked with 12 weeks of training for better results[8,29], especially with regard to the effects on EMG estimates and strength variables. Moreover, EMG estimates were reported only for the isometric test, which limits the specificity of training in a dynamic context. The sample recruited was restricted to young students, without affection of the lumbar spine in CLBP disorders. Future research is needed to address the clinical applicability of set volume in individuals suffering from CLBP.

Conclusion

Both training volumes, single and multiple sets, are efficient for mechanical endurance gains (time limit and number of repetitions) after a 10-wk training program on a 45º Roman chair. No changes in strength or EMG estimates were reported here. These results have implications for prescription of training lumbar extensor musculature in healthy people, programs for prevention of CLBP, and, in future, rehabilitation of individuals with CLBP.

Acknowledgments

Rubens A. da Silva received a research grant from the National Foundation for the Development of Private Higher Education (FUNADESP, Brazil). Leonardo Shigaki was funded by the *Fundação Araucária* fellowship during Master studies in the Rehabilitation Sciences Program UEL/UNOPAR. We gratefully acknowledge the assistance of physical therapy students of the university, for recruitment of participants and data collection.

The authors declare no conflicts of interest.

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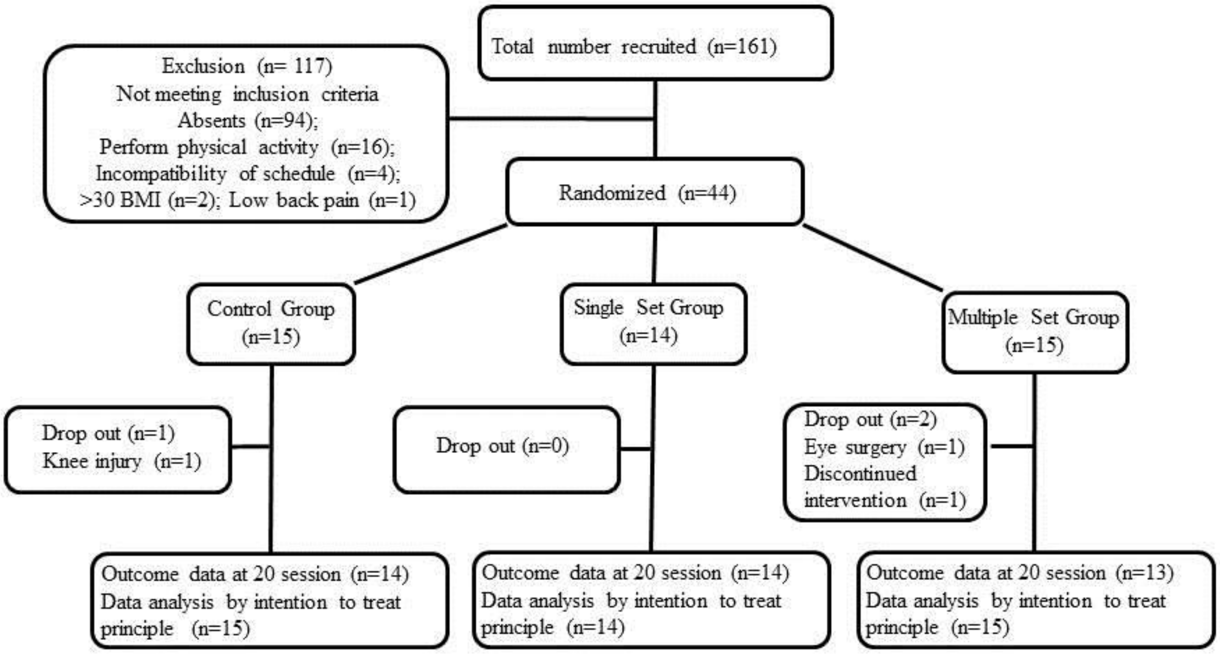

Figure 1. Flow diagram of the study.

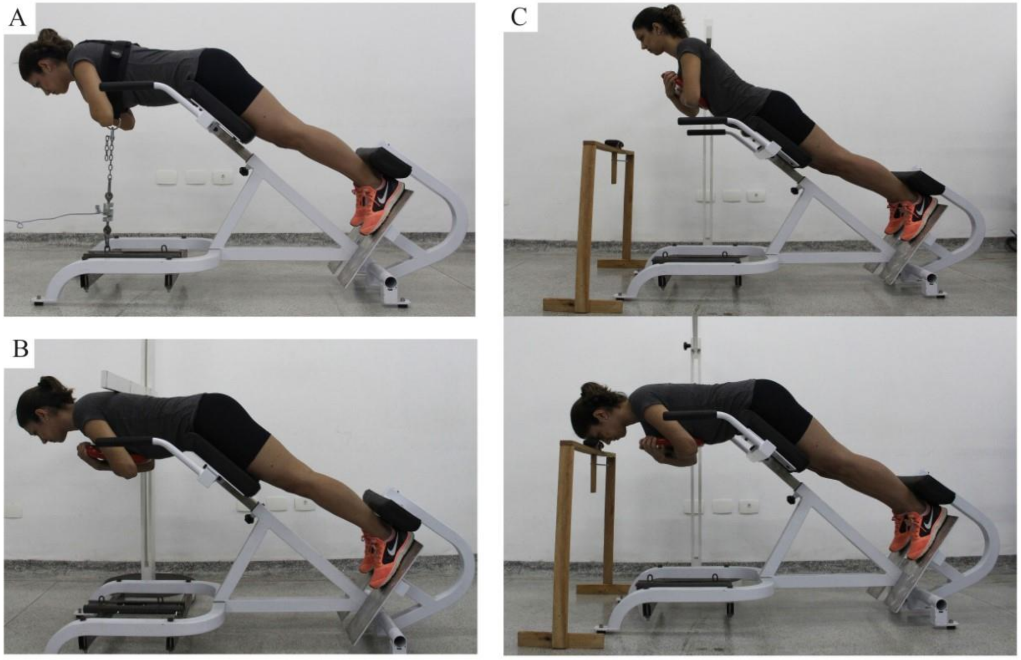

Figure 2. Maximal voluntary isometric contraction during back strength assessment (A). Modified Sorensen test – isometric back endurance from 50% MVIC including weight of trunk (B), and dynamic endurance test on Roman chair – dynamic back endurance from 50% MVIC including weight of trunk (C).

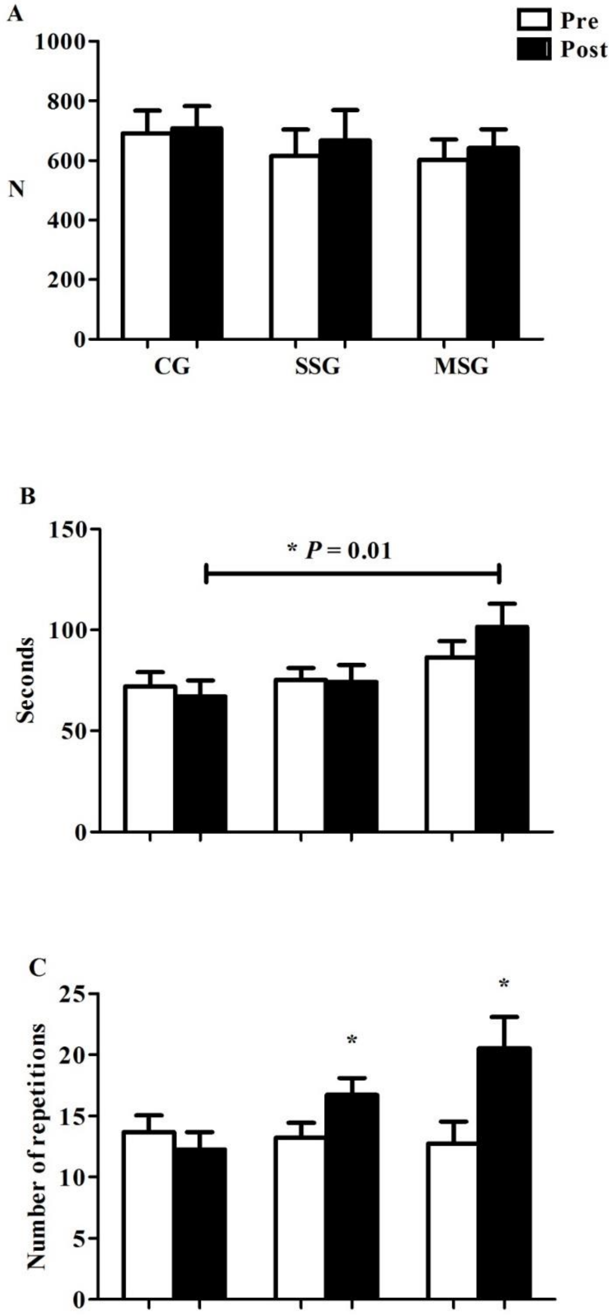

Figure 3. The values are mean ± SD. (A) Back strength - Maximal voluntary isometric contraction. (B) Isometric endurance during modified Sorensen test; Post hoc revealed significant differences between MSG and control, independent of time (* *P* <0.01). (C) Dynamic endurance test – significant effect of time where both MSG and SSG presented endurance gains (* *P* <0.05). Legend - CG: Control group. SSG: Single set group. MSG: Multiple set group.

Table 1. Baseline characteristics of the participants.

	GC (n=15)	SSG (n=14)	MSG (n=15)
Age (yr)	20.93 ± 3.61	21.71 ± 2.33	21.73 ± 2.78
Weight (Kg)	66.24 ± 13.30	63.94 ± 15.74	66.72 ± 12.80
Height (cm)	1.69 ± 0.07	1.67 ± 0.10	1.68 ± 0.07
BMI (Kg/cm2)	23.10 ± 3.87	22.63 ± 3.34	23.36 ± 3.38
UBM (Kg)	25.90 ± 8.34	21.97 ± 6.78	24.73 ± 7.37

Values are means ± SD. CG: Control group. SSG: Single set group. MSG: Multiple set group. BMI: Body mass index. UBM: upper body mass. All groups were homogeneous from randomization.

Table 2. Effect of training on mechanical variables: maximal strength, isometric and dynamic back endurance.

Variables	**Times**	**Groups**			**ANOVA; F (*P* values)**		
		GC	**SSG**	**MSG**	**Groups**	**Times**	**Interaction**
MVIC (N)	Pre	690 ± 294	614 ± 323	603 ± 254	*F=0.53* (0.591)	*F=0.31* (0.572)	*F=0.02* (0.972)
	Post	708 ± 284	667 ± 372	641 ± 235			
Time-limit (s) Sorensen test	Pre	72.1 ± 27	75.2 ± 22	86.5 ± 31	*F=4.90* (0.012*)	*F=0.21* (0.641)	*F=0.81* (0.442)
	Post	67.2 ± 30	74.3 ± 30	101.6 ± 44			
Number of repetitions Dynamic test	Pre	13.6 ± 5	13.2 ± 4	12.7 ± 7	*F=2.36* (0.101)	*F=5.60* (0.021*)	*F=3.72* (0.021*)
	Post	12.2 ± 5	16.7 ± 5	20.5 ± 9			

Mean values with standard deviation (±SD). Variables: MVIC = maximal voluntary isometric contraction (N); Time-limit (s) from isometric Sorensen test. Number of repetition from dynamic endurance test. Times: pre- and post-intervention. Three experimental groups: CG: Control group, SSG: Single set group and MSG: Multiple set group. *Statistical significant differences from ANOVA ($P < 0.05$).

Table 3. Effect of training on physiological variables (EMG) during isometric back endurance.

Variables	**Times**	**Groups**			**ANOVA; *F* (*P* values)**		
		GC	**SSG**	**MSG**	**Groups**	**Times**	**Interaction**
NMFslp (%/s) MU-L5	Pre	-0.36 ± 0.29	-0.50 ± 0.19	-0.44 ± 0.28	*F=0.43* (0.651)	*F=2.90* (0.091)	*F=0.70* (0.501)
	Post	-0.59 ± 0.34	-0.60 ± 0.30	-0.56 ± 0.27			
NMFslp (%/s) IL-L3	Pre	-0.31 ± 0.29	-0.38 ± 0.21	-0.36 ± 0.20	*F=0.59* (0.554)	*F=1.21* (0.263)	*F=0.77* (0.465)
	Post	-0.41 ± 0.28	-0.47 ± 0.25	-0.33 ± 0.11			
$MF_{intercept}$ (Hz) MU-L5	Pre	56 ± 15	64 ± 11	55 ± 13	*F=2.70* (0.071)	*F=0.10* (0.923)	*F=0.82* (0.443)
	Post	52 ± 12	63 ± 18	62 ± 9			
$MF_{intercept}$ (Hz) IL-L3	Pre	52 ± 12	52 ± 12	49 ± 6	*F= .74* (0.474)	*F=.10* (0.923)	*F=.35* (0.701)
	Post	48 ± 7	54 ± 13	51 ± 8			

Mean values with standard deviation (±SD). Variables: NMFslp: the slope from the median frequency by EMG and time relationship divided by their corresponding intercept value (obtained from the linear regression analysis) and multiplied by 100 to yield normalized EMG index of muscle fatigue. MU-L5: electrode at the multifidus at the L5 level; IL-L3: electrode at the iliocostalis lumborum at the L3 level.

Times: pre- and post-intervention. Three experimental groups: CG: Control group, SSG: Single set group and MSG: Multiple set group. Not significant effects were reported from ANOVA (*P* > 0.05).