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Original Research

Acute Effects of Inter-set Stretching on Performance and Metabolic Parameters of Resistance-trained Men

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ABSTRACT

International Journal of Exercise Science 15(4): 231-244, 2022. The present study investigated acute muscular performance and metabolic responses to resistance training (RT) with inter-set stretching (ISS). Seventeen resistance-trained men (age: 30.0 ± 5.6 years; body mass: 81.8 ± 13.4 kg; height: 173 ± 6.2 cm; RT experience: 4.6 ± 1.7 years) completed the ISS and traditional training (TT) protocol seven days apart in a randomized order. In both protocols, 7 sets of the seated cable fly exercise were performed with a 10-repetition maximum (10-RM) load. During the ISS protocol, subjects completed inter-set passive static stretching of the agonist muscles for 45 seconds, while a passive rest (no stretching) was adopted for the same duration in the TT protocol. The change in maximal bench press strength (1-RM), muscle swelling (ultrasound) of the pectoralis major (PM_{MS}), and blood lactate were assessed immediately following each protocol. Additionally, the total load lifted (TLL) and internal training load (ITL) were assessed in both protocols. There was no difference between protocols for the change in maximal bench press 1-RM ($p > 0.05$). There were higher values for PM_{MS} ($p < 0.05$) and blood lactate ($p < 0.05$) following the TT versus the ISS protocol. The TT resulted in higher TLL ($p < 0.05$) and ITL values ($p < 0.05$) versus the ISS protocol. Resistance training with inter-set stretching results in lower acute performance and metabolic responses versus traditional training with passive rest between sets. Therefore, inter-set stretching might be applied within a periodized program on lower intensity days to reduce the overall stress of a session.

KEYWORDS: Static stretching, resistance training, resistance training method, volume, muscle thickness

INTRODUCTION

Chronic muscular adaptations expressed as strength and hypertrophy are promoted by regular resistance training (RT). In order to enhance these adaptations, different RT methods are frequently used by coaches and practitioners; one such method is inter-set static stretching (ISS) (4). ISS of the agonist muscle during the rest interval between sets has been suggested to increase the time under tension during training sessions, which may be important in order to maximize the hypertrophic response of the skeletal muscle. Therefore, implementing ISS could be able to enhance the hypertrophic effect by increasing total time under muscle tension and its associated neuromechanical, and metabolic stimuli (23). Although relatively few studies about ISS have been conducted, acute muscular performance is negatively affected by inter-set stretching (5,20,30). Padilha et al. (26), for example, observed a significantly lower total work performed when resistance-trained individuals were submitted to a 40 second-ISS protocol when compared to a traditional training schedule (no stretching between sets). Distinct results were reported by Marin et al. (18), where no difference was observed in the total volume performed between traditional and stretching protocols. Differences regarding the training level of the participants and the exercises adopted between Padilha et al. (26) and Marin et al. (18) may help to explain these divergent results. However, in terms of chronic RT adaptations, Evangelista et al. (8) reported that ISS was more effective to increase vastus lateralis muscle thickness than using a passive rest interval between sets.

The main premises for the adoption of ISS by RT practitioners are the higher acute levels of metabolites (blood lactate) and more pronounced muscle swelling (23). The increase in metabolites (e.g., lactate, inorganic phosphate and hydrogen ions) may promote the release of anabolic hormones and increase the recruitment of higher-threshold motor units (6,31) . In addition, metabolite accumulation promotes the muscle swelling response due to reactive hyperemia (31). This increase in muscle swelling is detected by intrinsic volume sensors, such as integrin proteins, which result in the activation of anabolic pathways (15).

As stretching disrupts regional blood flow and reduces oxygen delivery to the muscle, it can augment metabolite accumulation (23). Theoretically, performing ISS might result in greater lactate accumulation and acute muscle swelling versus traditional RT that incorporates a passive rest interval. Marin et al. (18), for example, observed that a 1 minute- ISS protocol induced higher responses in blood lactate levels when compared to a traditional scheme. It is important to note that the exercise performed in the latter was a multi-joint one (bench press) for 6 sets. Then, it is still not clear if the same results would be observed when adopting single-joint exercises with higher volumes. Therefore, the aim of the present study was to compare performance and metabolic outcomes following a traditional training schedule versus ISS in resistance-trained men. It was hypothesized that ISS would result in more pronounced reductions on training volume but higher metabolic stress.

METHODS

Participants

Volunteer recruitment was carried out through online advertisings and only men volunteered to participate in the experiment. Seventeen resistance-trained men (30.0 ± 5.6 years; total body mass: 81.8 ± 13.4 kg; height: 173 ± 6.2 cm; RT experience: 4.6 ± 1.7 years; bench press exercise one repetition maximum [1-RM]: 112.4 ± 13.8 kg; relative bench press one-repetition maximum [1-RM_r]: 1.4 ± 0.3) participated in this study. The sample size was justified by a priori power analysis based on previous findings from Marin et al. (18), in which blood lactate levels were assessed as the outcome measure with a target large effect size of 1.20 (using t-test for dependent samples), an alpha level of 0.05, and a power (1-β) of 0.80 (7). The sample size was determined using G*Power version 3.1.3.

All volunteers performed RT for a minimum of 3 days per week and the exercise (i.e., cable fly) adopted in the experimental sessions for at least 1 year before this study. In addition, participants were free of any pre-existing musculoskeletal disorders and stated that they had not taken anabolic steroids, creatine and/or caffeine-containing supplements for a minimum period of 6 months prior to the study. A minimum 1-RM bench press equal to their total body mass was also adopted as inclusion criteria. This study was approved by the University's research ethics committee (protocol 2.094.535) and was conducted in accordance with the Declaration of Helsinki and the ethical standards of the International Journal of Exercise Science (25). All subjects read and signed an informed consent document.

Protocol

This study followed a cross-over design. Subjects were asked to visit the laboratory for three sessions as follows: Session 1) measures of anthropometric data; baseline bench press 1-RM and cable chest fly 10-RM tests; and familiarization with OMNI and Well-Being scales, Sessions 2) and 3) in random order, the experimental protocols were completed (i.e., ISS or TT) and followed by blood samples, ultrasound images, and bench press 1-RM testing. The experimental sessions were separated by 7 days. All subjects were instructed to maintain their usual nutrition habits, and to refrain from any exercise other than activities of daily living 72 hours before performing experimental protocols.

In a random order, subjects completed the following protocols: inter-set stretching (ISS) and traditional training (TT). In both protocols, subjects were instructed to perform seven repetition maximum sets with a 10-RM load in the seated cable fly exercise with 45 seconds rest between sets. This exercise was adopted since the participants reported to usually finish their training sessions with single-joint exercises, which would better fit with aims of familiarization. A standard cadence of 4 seconds per repetition (2 seconds concentric and 2 seconds eccentric) was adopted using a metronome (Metronome Beats; Stonekick, London, England). In the ISS protocol, subjects did a passive inter-set static stretch for the agonist muscles (i.e., pectoralis major and anterior deltoid) (Figure 1) during the 45-second rest interval (17).

A visual discomfort scale ranging from 0 to 10 was used to monitor the intensity of stretching, where 0 = "no stretch discomfort at all" and 10 = "the maximum imaginable stretch discomfort" (30). Subjective values from 7 to 9 were used during the protocol (17). In the TT, a passive rest interval of 45 seconds was adopted between sets without stretching (13,30). Both protocols were accompanied by the same researchers. All subjects received verbal encouragement during the exercises.

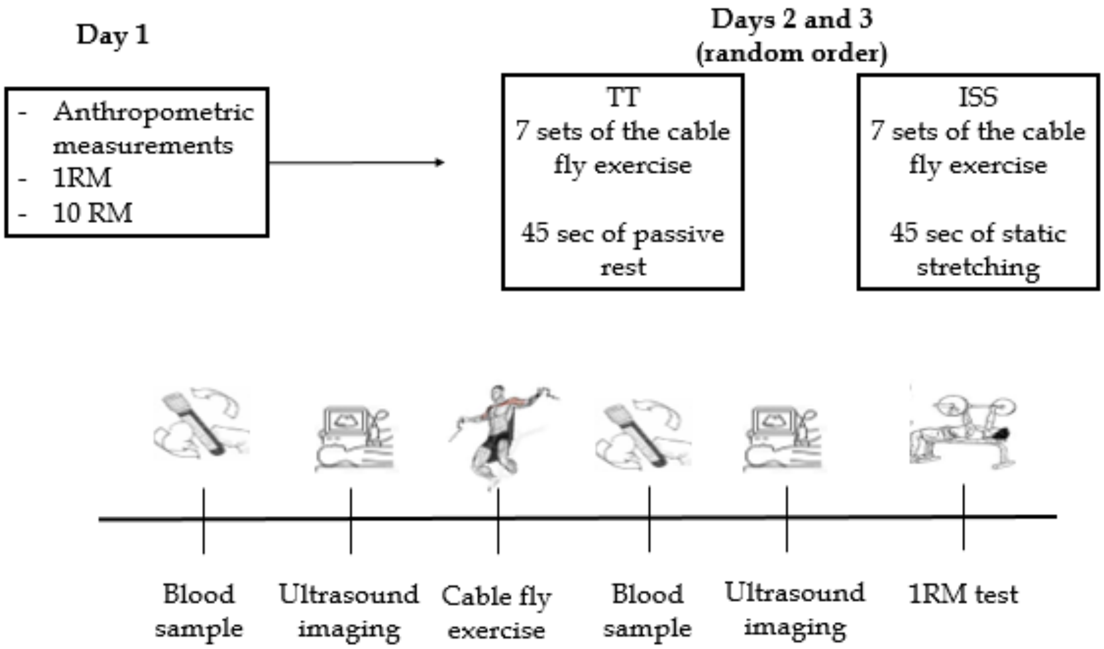

Figure 1. Experimental design of the study. 1-RM = one repetition-maximum test; 10RM = ten repetition-maximum test; TT = traditional training condition; ISS = inter-set stretching condition.

Maximum dynamic strength was assessed through 1-RM testing using the bench press exercise (1-RM$_{BENCH}$) in three different visits. In the 2nd and 3rd visits, the assessments were performed 10 minutes after each experimental protocol. The testing protocol followed previous recommendations by National Strength and Conditioning Association (27). A specific warm-up set for 5 repetitions was performed at ~50% of 1-RM, followed by 1 to 2 sets of 2–3 repetitions at a load corresponding to ~60–80% 1-RM. After the warm-up sets, subjects had 5 attempts to find their 1-RM load with 3-minute intervals between trials. The 1-RM was deemed as the maximum weight that could be lifted no more than once with proper technique. All testing sessions were supervised by the same researchers.

Ultrasound imaging was used to obtain measurements of muscle swelling (MS), as reported by the difference in muscle thickness (MT) values pre- and post- each experimental protocol. A trained technician performed all testing using an A-mode ultrasound imaging unit (Bodymetrix Pro System; Intelametrix Inc., Livermore, CA, USA). Following the application of a water-soluble transmission gel (Mercur S.A. – Body Care, Santa Cruz do Sul, RS, Brazil) to the measurement site, a 2.5-MHz linear probe was placed perpendicular to the tissue interface without depressing the skin.

Equipment settings were optimized for image quality, according to the manufacturer's user manual, and maintained constant for the testing sessions. When the quality of the image was deemed to be satisfactory, the image was saved to the hard drive and muscle thickness dimensions were obtained by measuring the distance from the subcutaneous adipose tissue–muscle interface to the muscle-bone interface, according to the methodology described by Abe et al. (2). Measurements were taken on the right side of the body at 1 site: pectoralis major muscle thickness (PM_{MS}). Measurements were standardized at 50% between the axillary line and the nipple.

Figure 2. Passive static stretching protocol adopted in the ISS condition.

To maintain consistency between tests in each protocol (ISS and TT), each site was marked with henna ink (reinforced during the week). To further ensure the accuracy of measurements, at least 3 images were obtained. If measurements were within 1 mm of one another, the figures were averaged to obtain a final value. The test-retest intraclass correlation coefficient (ICC) for the PM_{MT} was 0.966. The coefficient of variation (CV) and the standard error of the measurement (SEM) from our lab for this measure are 1.0% and 0.29 mm, respectively.

The total load lifted (TLL) for each session (sets x repetitions x external load(10)) was calculated over the 7 sets. Only repetitions performed through a full range of motion were included for analysis. The difference of the TLL between the 7^{th} and 1^{st} sets (ΔTLL set 1-7) was also calculated. The data were expressed in kilogram-force (kgf).

Subjects reported their session-rating of perceived exertion (sRPE), according to the OMNI-Resistance Exercise Scale (OMNI-RES), validated to measure RPE in recreationally resistance-trained men (29). Subjects were shown the scale 10 minutes after each session and asked: "How intense was your session?". Values ranged from 0 to 10, where 0 = "extremely easy" and 10 = "extremely hard". The internal training load (ITL) for each experimental session was calculated by multiplying the total time under tension of session in minutes (sum of 7 sets for TT and sum of 7 sets plus 45″ of passive stretching for ISS) by the sRPE (29). The data were expressed in arbitrary units (AU).

The well-being questionnaire (WB) assessed subjects fatigue, sleep quality, general muscle soreness, stress levels and mood on a five-point scale (scores of 1 to 5). WB was then determined by summing the five scores (21). The WB questionnaire was completed 10 min before each training protocol´s warm-up. This tool was used in order to monitor and ensure a homogenous state of well-being between conditions (TT and ISS), since it has been previously reported that psychological stress may negatively affect resistance exercise performance and recovery of resistance-trained individuals (33). The data were expressed in arbitrary units (AU).

Blood samples (25 μl) from a fingertip were collected pre, immediately post, 5 and 10 minutes after each protocol in heparinized capillary tubes and transferred to microtubes containing 50 μL of sodium fluoride at 1%. Only the highest value (immediately, 5- or 10-minutes post) was used to analyze lactate concentrations after each protocol. The lactate concentration was analyzed via an electro-enzymatic method with a lactate analyzer (YSI 2300 Stat Analyzer®; Yellow Springs Instruments, Yellow Springs, OH, USA) and was expressed in millimoles ($mmol^{-1}$).

Statistical Analysis
The normality and homogeneity of the variances were verified using the Shapiro-Wilk and Levene tests, respectively. Prior to analysis, all data were log-transformed for analysis to reduce bias arising from non-uniformity error (heteroscedasticity). The mean, standard deviation (SD), 90% and 95% confidence intervals (CI) were used after data normality was assumed. To compare mean change values for the 1-RM_{BENCH}, PM_{MS}, TLL, number of repetitions, sRPE, ITL, WB and Δkgf set 1-7 between-conditions (TT and ISS) a t-test for dependent samples was used. A 2x2 repeated measures ANOVA (interaction conditions [TT and ISS] × time [pre- vs post]) was used to compare the blood lactate analysis. A 2x7 repeated measures ANOVA (interaction conditions [TT and ISS] × sets [set 1, 2, 3, 4, 5, 6 and 7]) was used to compare the TLL. *Post hoc* comparisons were performed with the Bonferroni correction. Assumptions of sphericity were evaluated using Mauchly's test. Where sphericity was violated ($p < 0.05$), the Greenhouse–Geisser correction factor was applied. In addition, effect sizes in ANOVA were evaluated using a partial eta squared ($\eta^2{}_p$), with < 0.06, 0.06 - 0.14 and, > 0.14 indicating a small, medium, and large effect, respectively. The effect size (ES) between two means (TT vs ISS) was calculated to verify the magnitude of the differences by Cohen's d. The d results were qualitatively interpreted using the following thresholds: < 0.2, trivial; 0.2 - 0.6, small; 0.6 -1.2, moderate; 1.2 - 2.0, large; 2.0 - 4.0, very large and; > 4.0, extremely large. All analyses were conducted in SPSS-22.0 software (IBM Corp., Armonk, NY, USA). The adopted significance was $p \leq 0.05$.

RESULTS

A significant effect between conditions TT vs ISS in PM_{MS} ($p = 0.0002$, *ES* = 1.94, [90%CI = 1.04 to 2.84]), TLL ($p = 0.0002$, *ES* = 1.03 [90%CI = 0.52 to 1.54]), sRPE ($p = 0.001$, *ES* = 0.91 [90%CI = 0.51 to 1.31]), number of repetitions ($p = 0.001$, *ES* = 1.53 [90%CI = 1.02 to 2.04]) and ITL ($p = 0.0002$, *ES* = 0.91 [90%CI = 0.39 to 1.43]) was observed. No significant differences in $\Delta 1\text{-RM}_{BENCH}$

(p = 0.206, *ES* = 0.36 [90%CI = -0.02 to 0.74]) and WB (p = 0.940, *ES* = 0.03 [90%CI = -0.38 to 0.44]) was observed between TT vs ISS (Table 1).

Table 1. Comparison of conditions traditional training vs. inter-set stretching in dependent variables (mean ± SD).

Variables	TT	ISS	Mean Difference	Δ%	TT	ISS
Δ1-RMBENCH (kg)	19.3 ± 5.3	21.5 ± 6.7	-2.2 [-5.8 to 1.3]	11.5	0.206	0.36
PMMS (mm)	5.5 ± 1.7	2.6 ± 1.2*	2.92 [1.71 to 4.12]	52.7	0.0001	1.94
TLL (kgf)	979 ± 251	687 ± 313*	292 [130 to 455]	29.9	0.002	1.03
sRPE (AU)	8.8 ± 1.0	9.8 ± 0.5*	1.0 [0.5 to 1.5]	11.3	0.001	0.91
Repetitions (n)	32.8 ± 6.5	21.9 ± 7.6*	10.8 [6.7 to 14.8]	33.0	0.001	1.53
ITL (AU)	279 ± 67	215 ± 74*	64 [21 to 107]	23.0	0.006	0.91
WB (AU)	19.6 ± 2.5	19.6 ± 2.2	0.1 [-1.6 to 1.7]	0.3	0.940	0.03

Note. TT = traditional training; ISS = inter-set stretching; Δ1-RMBENCH = delta pre - post one maximal repetition test in bench press exercise; PMMS = pectoralis major muscle swelling; TLL = total load lifted; sRPE = session rate of perceived exertion; ITL = Internal Training Load; WB = Well Being Status. * p < 0.05 vs TT.

A significant main effect of time ($F_{1,16}$ = 12.155, p = 0.003, η^2_p = 0.432) and group x time interaction ($F_{1,16}$ = 540.111, p = 0.0001, η^2_p = 0.971) was observed for blood lactate. There was a significant effect of pre vs post in TT (p = 0.0001, mean difference = 5.5 mmol^{-1}, CI95% = 4.8 to 6.3 mmol^{-1}) and ISS (p = 0.0001, mean difference = 7.4 mmol^{-1}, CI95% = 6.5 to 8.2 mmol^{-1}). A significant effect of TT vs ISS in post training (p = 0.001, mean difference = 2.2 mmol^{-1}, CI95% = 1.1 to 3.3 mmol^{-1}) was observed for blood lactate (Figure 2).

A significant main effect of time ($F_{6,96}$ = 8.436, p = 0.0001, η^2_p = 0.316) and group x time interaction ($F_{6,96}$ = 10.706, p = 0.0001, η^2_p = 0.401) was observed for TLL among the 7 sets. Sets 2-7 were significant different than set 1 in both conditions (TT and ISS). Sets 2-7 in ISS were significant different for sets 2-7 in TT. A significant effect of TT vs ISS was observed in Δ kgf set 1- set 7 (p = 0.001, *ES* = 0.96 [90%CI = -0.48 to 1.44], mean difference = 58 kgf, CI95% = 21 to 96 kgf) (Figure 3).

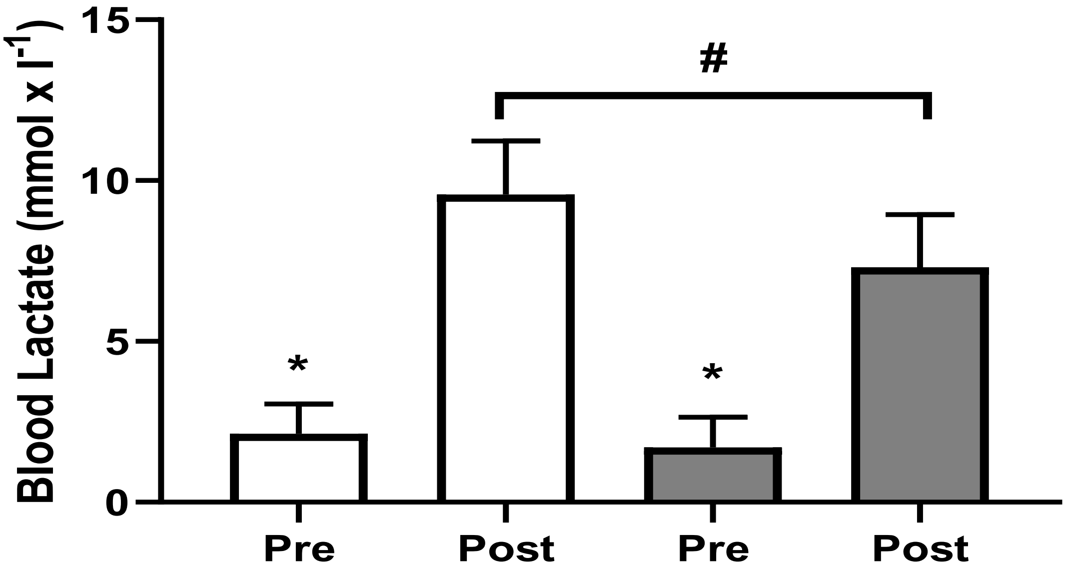

Figure 3. Mean values (bars) of blood lactate analysis in the pre vs post for traditional training (TT - white columns) and inter-set stretching training (ISS - gray columns). * $p < 0.05$ vs Post. # $p < 0.05$ between conditions.

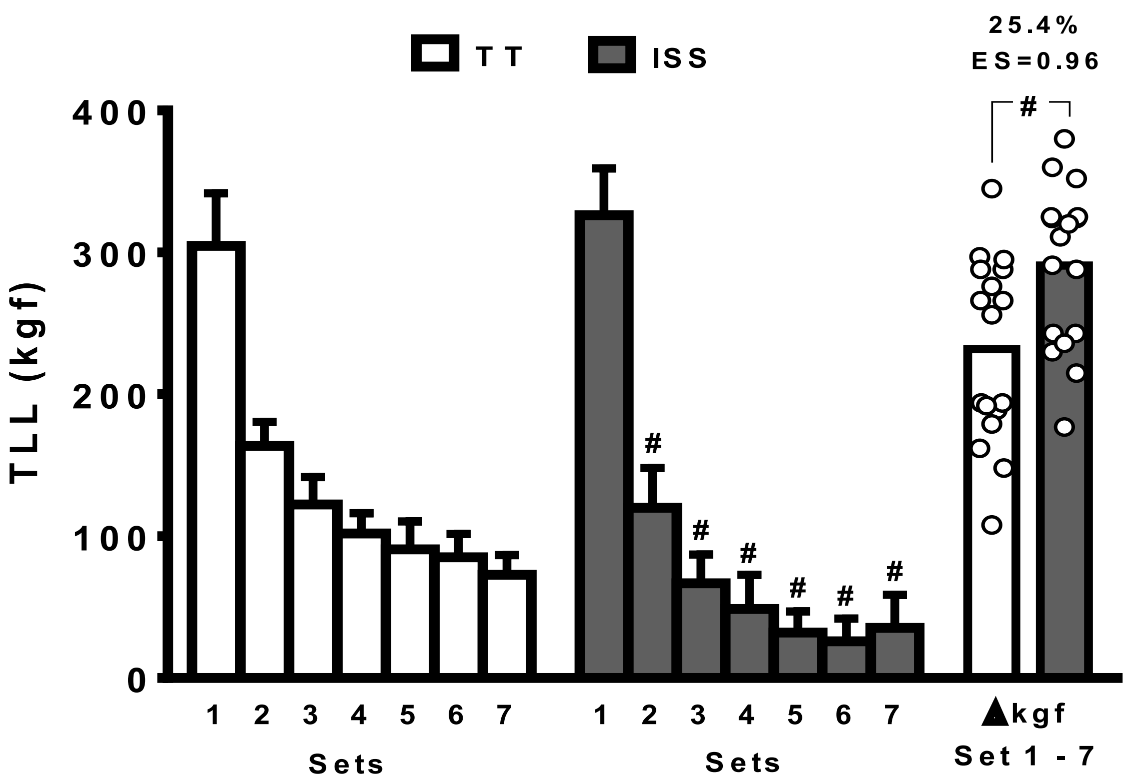

Figure 4. Total load lifted (TLL) in the 7 sets in traditional training (TT) and inter-set stretching (ISS). Univariate scatterplot (right panel) represents the delta of individual differences in set 1 - 7 (Δ kgf set 1- 7) of TT and ISS. # $p < 0.05$ between conditions.

DISCUSSION

The aim of the present study was to compare the acute responses of two different RT methods (TT vs ISS) on muscular performance and metabolic outcomes in trained men. The initial hypothesis was only partially confirmed, as the ISS protocol resulted in lower TLL, but also lower muscle swelling and blood lactate responses as compared with the TT condition.

Partially confirming the initial hypothesis, a higher TLL was observed for TT compared to ISS (979 ± 251kgf vs 687 ± 313kgf, respectively; Δ = 29.9%). Such outcome is a result of a higher number of repetitions performed for the TT compared to the ISS protocol through the 7 sets of the exercise adopted (32.8 ± 6.5 vs 21.9 ± 7.6), respectively. These results are in accordance with those reported by Souza et al. (1), in which a significantly greater total number of repetitions were performed in the bench press exercise during a passive rest compared to 30 seconds of static stretching of agonist muscles. Padilha et al. (26) also reported that 25” of ISS induced detrimental effects on the performance of isokinetic leg extensions. Negative acute effects of inter-set stretching on muscle strength and neuromuscular performance have also been previously described by Di Mauro et al. (20) and Cramer et al. (5). Impairments in the elastic energy transfer between eccentric and concentric phases (induced by decreases in muscle-tendinous unit stiffness) and a reduction in muscle activation may explain the negative interference of stretching in strength-related performance (34).

In contrast to our findings, Marin et al. (18) described no significant difference in the total volume performed in the bench press exercise between passive vs stretching rest intervals. It is important to note that different exercises and number of sets were performed in the present study versus Marin et al. (18) (7 sets of seated cable fly and 6 sets of bench press, respectively), so ISS may elicit varying effects depending on the exercise volume and muscle groups. The current study adopted a visual subjective discomfort scale in order to assure that all subjects would be submitted to the same stretching perceived intensity. Therefore, it is plausible to assume that volunteers in our study were exposed to a more fatiguing stretching protocol compared to those in Marin et al. (18), since percentage decrements of the 1st set to the 7th set on TLL were higher during ISS protocol compared to the TT protocol (89.1% vs 76.1%, respectively).

No significant difference was observed in maximal strength decrement (Δ1-RM$_{BENCH}$) for the ISS compared to TT protocol (18.8% vs 16.9%, respectively). From the authors’ knowledge, this is the first study to assess the acute decrements in maximal dynamic strength after an inter-set stretching RT protocol. Previous studies aimed to assess the effects of stretching protocols performed prior to an RT exercise or session. Although the majority of findings describe detrimental effects of passive stretching on maximal strength values (13,30), the results of the present study seem to corroborate previous findings from Muir et al. (24) and Yamaguchi and Ishii (35). Although controversial results have been reported, the duration of stretching protocols seems to be the main variable affecting subsequent strength-related outcomes (28), with longer stretching protocols (>60 seconds) inducing higher decrements in strength compared to the shorter ones (<45 seconds) (13,30). In this sense, it can be suggested that the duration of the stretching (45 seconds) adopted in the present intervention was not able to induce significant decrements on 1-RM test values compared to the passive condition. Nevertheless, comparisons between the present findings and other investigations should be done with some caution, especially when taking into account the training level of the subjects and the muscles groups assessed. Moreover, the moment when 1-RM test was performed may have attenuated the deleterious effects of the inter-set stretching protocol on maximum dynamic strength. The 1-RM test was performed only after the post muscle thickness and blood lactate analysis (immediately, 5- and 10-minutes post). Mizuno et al. (22) observed that, after a static 5-minute stretching protocol of the plantar flexor muscles, the isometric maximal voluntary torque was significantly decreased immediately and 5 minutes after the stretching intervention versus the baseline value, and this change was recovered within 10 minutes. These results suggest that maximal voluntary force decrements due to static stretching are restored within a short time (10 minutes) (22). Additionally, since the present study only assessed muscle strength 10 minutes after each condition, repeated analyses on consecutive days following protocols must be encouraged in order to provide more extensive and reliable data about the possible influence of ISS protocol on this outcome. It is important to note that the findings of the present study regarding the acute effects of performing ISS on maximal strength outcomes may not necessarily be reproduced in other components of muscular fitness, as muscle power and endurance. Moreover, the adoption of different instrumentation for assessing muscle strength (e.g. linear encoder, force sensors, isokinetic dynamometer) must be encouraged in order to further understand our findings.

Internal training load (ITL) is a useful tool to monitor physiological stress experimented by an individual during a training session. A significant difference between conditions was noted such that TT produced superior ITL compared to ISS (279 ± 67 AU vs 215 ± 74 AU, respectively; Δ = 23.0%) even with lower RPE values (8.8 ± 1.0 AU vs 9.8 ± 0.5 AU for TT and ISS, respectively; Δ = 11.3%). This result may be explained by the fact that individuals experienced a higher total time under tension when performing TT compared to ISS (2.3 ± 0.4 min vs 1.7 ± 0.3 min, respectively; Δ = 30.2%). Additionally, higher TLL levels presented in TT protocol must be highlighted in an attempt to explain ITL outcomes, since there seems to exist a significant association ($r = 0.73$; $P < 0.05$) between the total work performed and internal load within an RT session (19). From a practical standpoint, RT practitioners that aim to implement a lower training stress during a specific phase of the program may beneficiate from adopting the ISS protocol adopted in the current study due to a reduced total training volume. Contrastingly, if the goal of the session is to induce a higher perceived load, TT should be emphasized.

Different to the initial hypothesis, a higher increase in muscle swelling was observed for the TT condition compared to ISS (5.5 ± 1.7 mm vs 2.2 ± 1.2 mm, respectively; Δ = 52.7%). The acute change in muscle thickness (i.e. acute swelling) is hypothesized to be due to a shift in intracellular fluid, given that the change in muscle thickness occurs with a concomitant decrease in plasma volume (16). The acute cell swelling response has been proposed as a mechanism that favorably impacts the net protein balance (12). Since swelling is a purported mechanism that impacts net protein balance observed within an acute bout of RT and a significant positive correlation was found between muscle swelling and muscle hypertrophy (11), it is important to better understand if there are potential differences between RT-methods in the acute swelling response. Our findings can be explained by the higher external workload (TLL) and total time under tension experienced in the TT protocol. The muscle swelling is magnified in resistance exercise protocols that depend on anaerobic glycolysis, particularly those that involve moderate to higher repetitions with short rest intervals (31), resulting in a substantial accumulation of metabolic byproducts including lactate and inorganic phosphate, which in turn function as osmolytes and thereby draw additional fluid into the cell (9,32). Since the TT protocol resulted in higher TLL and total timer under tension, it is plausible to hypothesize that this condition involved greater contribution of the anaerobic glycolysis and consequently greater accumulation of metabolic byproducts, inducing, therefore, a higher muscle swelling response. Differently from the findings of the current study, Padilha et al. (26) did not observe differences in muscle swelling between ISS and TT conditions, which may be explained by the exercise (leg extension) and the shorter stretching protocol (25”) adopted. Further studies are encouraged to clarify the effects of ISS on muscle swelling outcomes.

For lactate concentrations, significant increases (pre-post) were observed for both protocols. However, a significant difference between conditions was observed in that the TT protocol resulted in higher increases versus the ISS protocol. These results seem to corroborate with previous findings from Lacerda et al. (14), in which RT- protocols with high volumes induced greater increases in lactate response. Contrary to our findings, Marin et al. (18) described greater increases in lactate concentration (32%) following an ISS protocol compared to a traditional one (passive rest). Differences in the stretching protocol and the exercise adopted (bench press) may explain such divergence. Different from our investigation, Marin et al (18) adopted a 60” stretching protocol between sets. In addition, the number of sets performed in the latter (6 sets) was lower than the current study (7 sets), which may help to justify these distinct results. It is also important to note that the present study described lactate values as the highest score when comparing three different time points (immediately, 5 and 10 min after each protocol). Marin et al. (18), in turn, did not report at what post-exercise time point lactate concentration was assessed, leading to possible sub maximal values in this variable. Additionally, no difference in the number of repetitions between protocols was reported by Marin et al. (18) [19]. Then, within an equated volume- condition, the protocol with a shorter rest interval (stretched condition) may have induced a higher acute metabolic stress (3).

To the authors’ knowledge, this is the first study to adopt a well-being scale in an intervention that assessed acute responses to ISS in RT. Subjects fatigue, sleep quality, general muscle soreness, stress levels and mood (21) were assessed immediately before performing each experimental protocol in order to guarantee that all volunteers were in a matched psychobiological condition, since those aforementioned variables, especially psychological stress, may negatively influence isometric peak power (33). No significant difference in WB was observed between TT and ISS conditions (19.6 ± 2.5 AU and 19.6 ± 2.2 AU, respectively: Δ = 0.3%). Future studies adopting such methodology are encouraged in order to clarify our findings.

It is important to note that the present study had some limitations. Firstly, no direct measure of joint angle was adopted during the stretching protocol. Second, data from pre-intervention nutritional habits were not collected, which might have influenced some of the performance and metabolic outcomes. However, subjects were asked to maintain their usual nutritional habits in order to minimize possible influences of such variable. Additionally, the present findings must not be extrapolated to a chronic context. Then, future interventions aiming to assess the chronic effects of ISS (i.e., muscle strength and hypertrophy) are encouraged. It is also important to highlight the absence of rigorous equipment to measure muscle strength outcomes. Moreover, our findings are specific to the population studied (trained men). Therefore, divergent results due to factors as age, training experience and gender, may be expected. Despite these limitations, the cross-over design adopted may by mentioned as a strength of the current investigation, since it may increase the statistical power of the study.

In conclusion, the present study suggests that resistance-trained subjects can experiment significant lower acute performance and metabolic responses when performing ISS. Additionally, dynamic maximal strength does not seem to be negatively affected by inter-set passive stretching. These findings may have relevant practical implications for those aiming to maintain higher training volumes, and more pronounced metabolic stress (TT). Conversely, inter-set stretching might be applied within a periodized program on lower intensity days to reduce the overall stress of a session.

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