Journal of Athletic Enhancement

Research Article A SCITECHNOL JOURNAL

Inter-Set Stretching Reduces Acute Neuromuscular and Metabolic Responses in Resistance-Trained Men

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Received date: 07 March, 2021; Manuscript No. JAE-21-27410;

Editor assigned date: 01 September, 2022; PreQC No. JAE-21-27410 (PQ);

Reviewed date: 11 September, 2022; QC No. JAE-21-27410;

Revised date: 22 September, 2022; Manuscript No. JAE-21-27410 (R);

Published date: 29 September, 2022; DOI: 10.4172/2473-4810.1000054

Abstract

Objective: The present study investigated the acute neuromuscular and metabolic responses to inter-set stretching (ISS) system.

Methods: Seventeen resistance-trained men (age: 30.0 ± 5.6 years; weight: 81.8 ± 13.4 kg; height: 173 ± 6.2 cm; RT experience: 4.6 ± 1.7 years) were submitted to both following training protocols: ISS and traditional training (TT). In both conditions, 7 sets of the seated cable fly exercise were performed with a load of 10RM. During ISS, participants were submitted to an inter-set passive static stretching of agonists muscles for 45 seconds, while a passive rest (no stretching) was adopted for the same duration in TT protocol. Maximal strength (1RM in the bench press exercise) and muscle swelling (ultrasound) of the pectoralis major muscle (PMMS) immediately post protocols, blood lactate concentration, total load lifted (TLL) and internal training load (ITL) were assessed in both protocols.

Results: No difference was observed for 1RM between conditions ($p > 0.05$). Significant higher values of PMMS ($p < 0.05$) and blood lactate ($p < 0.05$) were observed for TT compared to ISS. Additionally, TT induced higher TLL ($p < 0.05$) and ITL values ($p < 0.05$) compared to ISS.

Conclusions: In conclusion, ISS system induces lower acute neuromuscular and metabolic responses compared to TT.

Keywords: Static Stretching; Resistance Training; Resistance Training Method; Volume; Muscle Thickness

Introduction

Chronic adaptations related to muscle strength and hypertrophy are promoted by a regular resistance training (RT) program. In order to enhance these adaptations, different RT systems are frequently used by RT coaches and practitioners, although the evidence available does not allow the determination of whether these systems can induce significant increases in muscle strength and mass when compared to traditional RT [1].

Inter-set stretching (ISS) of the agonist muscle performed during rest period has been suggested to increase time under tension and metabolic stress of a given training session, which would result in larger RT induced chronic outcomes [2]. Although limited research about such RT intervention is available in the literature, acute neuromuscular performance has been shown to be negatively affected by inter-set stretching [3-5].

Although the use of ISS is common among bodybuilders and RT practitioners, there are a paucity of studies that investigated the effects of this RT method on chronic morphofunctional adaptations. Evangelista et al. 6 demonstrated that ISS was more effective to increase vastus lateralis muscle thickness than using passive rest interval, suggesting the potential of a slight benefit to the ISS method. However, the increase in rectus femoris, biceps and triceps brachii muscle thickness were similar between conditions [6].

Despite the questioning about the effectiveness of the ISS for maximize morphofunctional adaptations, the recommendations for performing the stretching between sets are based on some acute physiological effects on skeletal muscle [2]. Higher acute levels of metabolites (blood lactate) and a more pronounced muscle swelling are the main theoretical prerogatives of individuals and professionals that adopt such system. The increase of metabolites formation such as lactate, inorganic phosphate and hydrogen ions may potentiate the release of anabolic hormones and increase the recruitment of higher-threshold motor units which in turn enhances anabolic signaling [7,8]. In addition, metabolites accumulation favors muscle swelling response [8]. This increase in muscle swelling would be detected by an intrinsic volume sensor which would result in the activation of anabolic pathways [9].

As stretching disrupts regional blood flow and reduces the oxygen delivery to the muscle, it can augment metabolite buildup [2]. In this sense, theoretically, performing ISS might result in greater lactate accumulation and acute muscle swelling than traditional RT using passive rest interval.

Therefore, the aim of the present study is to compare neuromuscular and metabolic outcomes following ISS and traditional RT systems in resistance-trained men. It was hypothesized that ISS system results in more pronounced reductions on training volume and a higher metabolic stress.

Methods

Subjects

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 [1RM]: 112.4 ± 13.8 kg; relative bench press one repetition maximum [1RMr]: 1.4 ± 0.3) participate in the study. The sample size was justified by a priori power analysis based on a pilot study where the pectoralis major (PM) muscle thickness was 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 [10]. The sample size was determined using G∗Power version 3.1.3.

All volunteers were required to meet the following inclusion criteria: perform RT for a minimum of 3 days per week for at least 1 year; regularly perform (minimum frequency of once a week) the exercise (cable fly) utilized in the experimental sessions; and familiarization in the strength tests (bench press) for at least 1 year before entering the study; to be free from any existing musculoskeletal disorders; present no history of injury with residual symptoms in the trunk and upper limbs within the last year; state that they had not taken anabolic steroids, creatine and/or caffeine containing supplements for a minimum period of 6 months prior the study; answer negatively all questions on the Physical Activity Readiness Questionnaire (PAR-Q); and had a minimum 1RM bench press of at least equal to total body mass. This study was approved by the University's research ethics committee (protocol 2.094.535). All subjects read and signed an informed consent document.

Experimental design

This study followed a cross-over design. Participants were asked to visit the laboratory in the following three different occasions: 1) getting anthropometric data; answering PAR-Q; bench press 1RM and cable fly 10RM tests, and familiarization with OMNI and Well-Being scales; 2 and 3 getting blood samples, ultrasound images, bench press 1RM test and performing randomly one of the experimental protocols. The 1st and 2th visits and the 2nd and 3rd visits were interspaced by 72 hours and 1-week periods, respectively. All volunteers were instructed to maintain their usual nutrition habits and refrain from any exercise other than activities of daily living 72 hours before performing experimental protocols.

In a random order, participants were submitted to the following 2 protocols: inter-set stretching (ISS) and traditional training (TT). In both conditions, volunteers were instructed to perform a maximal number of repetitions until the point of concentric muscular failure with a load corresponding to 10RM in the seated cable fly exercise for 7 sets. A standard cadence of 4 seconds/repetitions was adopted using a metronome (Metronome Beats; Stonekick, London, England). In the ISS protocol, subjects were submitted to a passive inter-set static stretching in agonists muscle groups (pectoralis major and anterior deltoid) (Figure 1) during a 45 second interval rest.

A visual discomfort scale ranging from 0 to 10 was used to monitor the intensity of stretching experimented [5]. Subjective values from 7 to 9 were used during the protocol. In the TT, a passive rest period of 45 seconds was adopted, without the execution of any stretching exercise. Both protocols were accompanied by the same researches. All volunteers received verbal encouragement during the exercises.

Figure 1: Passive static stretching protocol adopted for ISS condition.

Maximum Dynamic Strength (1rm)

Maximum dynamic strength was assessed through 1RM testing using the bench press exercise (1RMBENCH) in the three different visits. For the 2nd and 3rd visits, the assessments were performed 10 minutes after each experimental protocol. The testing protocol followed previous recommendations by Haff and Triplett. A specific warm-up set of the given exercise of 5 repetitions was performed at ~50% 1RM followed by 1 to 2 sets of 2–3 repetitions at a load corresponding to ~60–80% 1RM. After the warm-up sets, subjects had 5 attempts to find their 1RM load with 3-minute intervals between trials.

The 1RM was deemed as the maximum weight that could be lifted no more than once with the proper technique. Decrements in bench press 1RM (Δ1RMBENCH) values between the 1st visit and post each experimental protocol were recorded. All testing sessions were supervised by the same researchers.

Muscle swelling (MS)

Ultrasound imaging was used to obtain measurements of muscle swelling (MS), being reported as the difference between the muscle thickness (MT) values post and pre 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 a generous application of a water-soluble transmission gel (Mercur S.A. – Body Care, Santa Cruz do Sul, RS, and Brazil) to the measured 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 methodology described by Abe et al. measurements were taken on the right side of the body at 1 site: pectoralis major muscle thickness (PMMT). Measurements were standardized in 50% between the distance of axillary line and the nipple.

To maintain consistency between the tests in each protocol (ISS and TT), each site was marked with henna ink (reinforced during the week). To further ensure accuracy of measurements, at least 3 images were obtained. If measurements were within 1mm of one another the figures were averaged to obtain a final value. The test-retest intraclass correlation coefficient (ICC) for PMMT 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.

Total load lifted (TLL)

Total load lifted (TLL) of each session (sets x repetitions x external load) was calculated by the sum of TLL of the 7 sets performed. Only repetitions performed through a full range of motion were included for analysis. The Δkgf set 1-7 described the difference in the TLL between sets 7 and 1 (e.g. TLL in the set 7 minus the TLL in the set 1). The data were expressed in kilogram-force units (kgf).

Internal training load (ITL)

Subjects reported their session-rating of perceived exertion (sRPE), according to the OMNI-Resistance Exercise Scale (OMNI-RES), validated to measure RPE in RT. Subjects were shown the scale 10 minutes after each session and asked: "How intense was your session?". 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. The data were expressed in arbitrary units (AU).

Well-being status (WB)

The well-being questionnaire (WB) assessed participants 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. The WB questionnaire was completed 10 min before each training protocol´s warm-up. Such tool was used in order to monitor and ensure a homogenous well-being state between conditions (TT and ISS). The data were expressed in arbitrary units (AU).

Blood lactate

Blood samples (25 µl) from the fingertips 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 values of the Δ1RMBENCH, PMMS, 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 (η2 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 PMMS ($p = 0.0002$, 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 Δ1RMBENCH ($p = 0.206$, 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).

Variables	TT	ISS	Mean Difference (CI 95%)	Δ%	P value	ES
Δ1RMBENCH (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	0.001	1.53
ITL (AU)	279 ± 67	215 ± 74*	64 [21 to 107]	23	0.006	0.91
WB (AU)	19.6 ± 2.5	19.6 ± 2.2	0.1 [-1.6 to 1.7]	0.3	0.94	0.03

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

Note: TT = traditional training; ISS = inter-set stretching; Δ1RMBENCH = 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 ($F_{1,16} = 12.155$, $p = 0.003$, η2p = 0.432) and group x time interaction ($F_{1,16} = 540.111$, $p = 0.0001$, η2p = 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).

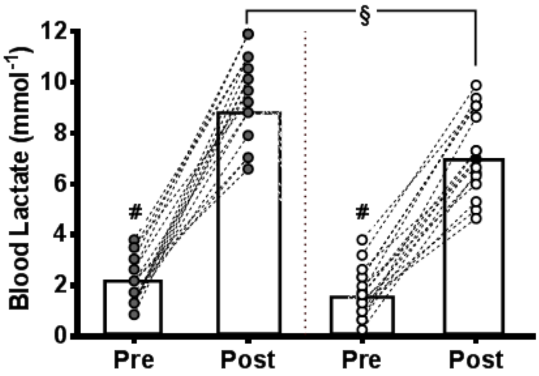

Figure 2: Mean values (bars) of blood lactate analysis in pre vs post traditional training (TT - gray circles) and inter-set stretching training (ISS - white circles). # $p < 0.05$ vs Post. § $p < 0.05$ between conditions.

A significant main effect of group x time interaction ($F_{6, 96}$ = 10.706, $p = 0.0001$, $\eta 2p = 0.401$) 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 Δkgf 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).

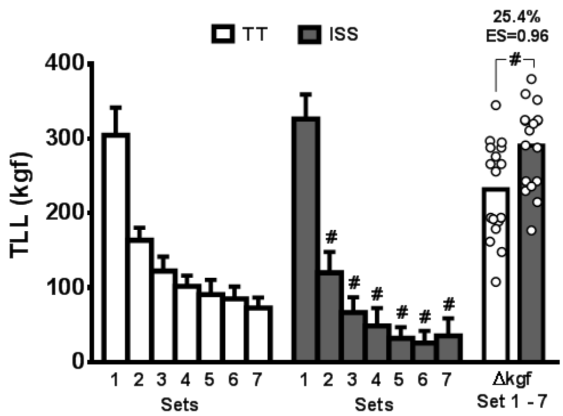

Figure 3: Total load lifted (TLL) in the 7 sets in traditional training (TT) and inter-set stretching (ISS). Univariate scatterplot (right painel) represents delta of individual differences in set 1 - 7 (Δkgf set 1- 7) of TT and ISS. # $p < 0.05$ between conditions.

Discussion

The aim of the present study was to compare the acute responses of two different RT systems (TT vs ISS) on neuromuscular and metabolic outcomes in trained men. Our initial hypothesis was that ISS condition would induce significant reductions on training volume and a higher metabolic stress compared to the TT one. The main finding of the present study is that ISS protocol induces lower TLL, muscle swelling and blood lactate responses compared to a TT condition.

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., in which a significant 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. Negative acute effects of inter-set stretching on muscle strength and neuromuscular performance have been previously described by Di Mauro et al. and Cramer et al. Impairments in the 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 outcomes.

Interestingly, differently from our findings, Marin et al. 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, additionally to the different exercises and number of sets performed in the present study and Marin et al. (7 sets of seated cable fly and 6 sets of bench press, respectively), our intervention adopted a visual subjective discomfort scale in order to assure that all participants 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., since percentage decrements of the 1st set to the 7th set on TLL were higher during ISS protocol compared to the TT one (89.1% vs 76.1%, respectively).

No significant difference was observed in maximal strength decrement (Δ1RMBENCH) for ISS compared to TT after experimental protocols (18.8% vs 16.9%, respectively). For 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 previously to a RT exercise or session. Although the majority of findings describe detrimental effects of passive stretching in maximal strength values, the results of the present study seem to corroborate previous findings from Muir et al. and Yamaguchi and Ishii.

Although controversial results have been reported, the duration of stretching protocols seems to be the main variable affecting subsequent strength-related outcomes, with longer stretching protocols (>60 seconds) inducing higher decrements in strength compared to the shorter ones (<45 seconds). In this sese, it may be suggested that the duration of the stretching (45 seconds) adopted in the present intervention was not able to induce significant decrements on 1RM 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 participants and the muscles groups assessed.

Moreover, the moment when 1RM was evaluated may have attenuated the deleterious effects of the inter-set stretching protocol on maximum dynamic strength. 1RM test was performed only after the post muscle thickness and blood lactate analysis (immediately, 5- and 10-minutes post). Mizuno et al. 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 compared with the pre intervention value, and this change was recovered within 10 minutes. These results suggest that the deficits of static stretching in maximal voluntary force are disabled in a short time (10 minutes). 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 a more reliable data about a possible influence of ISS protocol in this outcome.

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 total work performed and internal load within a RT session.

Acute metabolic responses in the present study were assessed through increases in muscle swelling and lactate concentration from pre to post training moments. The acute change in muscle thickness (i.e. acute swelling) is hypothesized to be a shift of intracellular fluid, given that the change in muscle thickness occurs with a concomitant decrease in plasma volume. The acute cell swelling response has been proposed as a mechanism that favorably impacts the net protein balance. This increase in muscle swelling would be detected by an intrinsic volume sensor which would result in the activation of anabolic pathways. Since swelling is a purported mechanism that impacts net protein balance observed with acute bout of RT and a significant positive correlation was found between muscle swelling and muscle hypertrophy, it is important to better understand if there are potential differences between RT-systems in the acute swelling response.

Differently 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%). To the authors' knowledge, this is the first study to assess the muscle swelling induced by ISS. Our result can be explained by the higher external work load (TLL) and total time under tension experienced in TT protocol. The muscle swelling is magnified by resistance exercise´s protocols that depend on anaerobic glycolysis, particularly those that involve moderate to higher repetitions with short rest intervals, 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. Since TT protocol results in higher TLL and total timer under tension, it is plausible to hypothesize that this condition resulted in greater contribution of the anaerobic glycolysis and consequently greater accumulation of metabolic byproducts, inducing, therefore, a higher muscle swelling response.

For lactate concentrations, significant increases (pre-post) were observed for both protocols. However, a significant difference between conditions was observed that TT resulted in higher increases compared to the ISS. These results seem to corroborate with previous findings from Lacerda et al. in which RT- protocols with high volumes induced more significant increases in lactate response. Contrary to our findings, Marin et al. 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 may explain such divergence. It is important to note that the present study described lactate values as the highest one when comparing three different moments (immediately, 5 and 10 min after each protocol). Marin et al., in turn, did not report at what post-exercise moment lactate concentration was assessed, leading to possible sub estimated values of such variable. Additionally, no difference in the number of repetitions between protocols was reported by Marin et al. Then, within an equated volume- condition, the protocol with a shorter rest interval (stretched condition) may have induced a higher acute metabolic stress, like previous findings from Aguiar et al.

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. Participants fatigue, sleep quality, general muscle soreness, stress levels and mood 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 has 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, participants 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.

Conclusion

In conclusion, the present study shows that resistance-trained individuals can experiment significant lower acute neuromuscular and metabolic responses when performing ISS. Additionally, dynamic maximal strength does not seem to be negatively affected by inter-set passive stretching. Those findings may have relevant practical implications for those aiming to maintain higher training volumes and a more pronounced metabolic stress. In such case, the use of passive rest intervals between RT sets must be the most viable option.

References

1. Mohamad NI, Nosaka K, Cronin J (2011) Maximizing hypertrophy: Possible contribution of stretching in the interset rest period. Strength Cond J 33: 81-7.
2. Cramer JT, Housh TJ, Weir JP, Johnson GO, Coburn JW, et al. (2005) The acute effects of static stretching on peak torque, mean power output, electromyography, and mechanomyography. Eur J Appl Physiol 93: 530-539.
3. Mauro HS, Moriggi JR, Dias SDC, Matos JM, Urtado CB (2015) Ten seconds of passive stretching reduces the maximum strength. Man Ther Posturology Rehabil J 13: 296.
4. Rubini EC, Costa ALL, Gomes PSC (2007) The effects of stretching on strength performance. Sport Med 37: 213-224.

5. Evangelista AL, Souza EO, Moreira DCB, Alonso AC, Teixeira CVLS, et al. (2019) Interset stretching vs. Traditional strength training. J Strength Cond Res 33: 159-166.
6. Dankel SJ, Mattocks KT, Jessee MB, Buckner SL, Mouser JG, et al. (2017) Do metabolites that are produced during resistance exercise enhance muscle hypertrophy? Eur J Appl Physiol 117: 2125–2135.
7. Schoenfeld BJ (2013) Potential mechanisms for a role of metabolic stress in hypertrophic adaptations to resistance training. Sport Med 43: 179-194.
8. Loenneke JP, Fahs CA, Rossow LM, Abe T, Bemben MG (2012) The anabolic benefits of venous blood flow restriction training may be induced by muscle cell swelling. Med Hypotheses 78: 151–154.
9. Eng J (2003) Sample size estimation: how many individuals should be studied? Radiology 227: 309-313.
10. Marchetti PH, Soares EG, Serpa EP, Nardi PSM, Vilela GDB, et al. (2014) Upper limb static-stretching protocol decreases maximal concentric jump performance. J Sport Sci Med 13: 945-950.