Interset Stretching vs. Traditional Strength Training: Effects on Muscle Strength and Size in Untrained Individuals

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Abstract

Evangelista, AL, De Souza, EO, Moreira, DCB, Alonso, AC, Teixeira, CVLS, Wadhi, T, Rauch, J, Bocalini, DS, Pereira, PEDA, and Greve, JMDA. Interset stretching vs. traditional strength training: effects on muscle strength and size in untrained individuals. *J Strength Cond Res* XX(X): 000–000, 2019—This study compared the effects of 8 weeks of traditional strength training (TST) and interset stretching (ISS) combined with TST on muscular adaptations. Twenty-nine sedentary, healthy adults were randomly assigned to either the TST ($n = 17$; 28.0 ± 6.4 years) or ISS ($n = 12$; 26.8 ± 6.1 years) group. Both groups performed 6 strength exercises encompassing the whole body (bench press, elbow extension, seated rows, biceps curl, knee extension, and knee flexion) performing 4 sets of 8–12 repetition maximum (RM) with a 90-second rest between sets. However, the ISS group performed static passive stretching, at maximum amplitude, for 30 seconds between sets. Both groups performed training sessions twice a week on nonconsecutive days. Muscle strength (i.e., 1RM) and hypertrophy (i.e., muscle thickness [MT] by ultrasonography) were measured at pre-test and after 8 weeks of training. Both groups increased 1RM bench press ($p \leq 0.0001$): ISS (23.4%, CI_{diff}: 4.3 kg–11.1 kg) and TST (22.2%, CI_{diff}: 5.2 kg–10.9 kg) and 1RM knee extension ($p \leq 0.0001$): ISS (25.5%, CI_{diff}: 5.6 kg–15.0 kg) and TST (20.6%, CI_{diff}: 4.4 kg–12.3 kg). Both groups increased MT of biceps brachii (BIMT), triceps brachii (TRMT), and rectus femoris (RFMT) ($p \leq 0.0001$). BIMT: ISS (7.2%, CI_{diff}: 1.14–3.5 mm) and TST (4.7%, CI_{diff}: 0.5–2.5 mm), TRMT: ISS (12.3%, CI_{diff}: 1.1–4.4 mm) and TST (7.1%, CI_{diff}: 0.3–3.1 mm), and RFMT: ISS (12.4%, CI_{diff}: 1.1–2.9 mm) and TST (9.1%, CI_{diff}: 0.7–2.2 mm). For vastus lateralis muscle thickness (VLMT) and sum of the 4 muscle thickness sites (ΣMT), there was a significant group by time interaction ($p \leq 0.02$) in which ISS increased VLMT and ΣMT to a greater extent than TST. Vastus lateralis muscle thickness: ISS (17.0%, CI_{diff}: 1.5–3.1 mm) and TST (7.3%, CI_{diff}: 0.7–2.1 mm), and ΣMT: ISS (10.5%, CI_{diff}: 6.5–9.0 mm) and TST (6.7%, CI_{diff}: 3.9–8.3 mm). Although our findings might suggest a benefit of adding ISS into TST for optimizing muscle hypertrophy, our data are not sufficient enough to conclude that ISS is superior to TST for inducing muscle hypertrophic adaptations. More studies are warranted to elucidate the effects of ISS compared with TST protocols on skeletal muscle. However, our findings support that adding ISS to regular TST regimens does not compromise muscular adaptations during the early phase of training (<8 weeks) in untrained individuals.

Key Words resistance training, muscle hypertrophy, combined regimens, static stretch

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Introduction

Strength training is considered to be the most effective means of increasing muscle strength and hypertrophy (20). It has been used across a wide variety of populations to improve athletic performance, body composition, functionality, and quality of life (17,27). In addition, adequate levels of flexibility are also desirable for main-

Table 1. Subjects' characteristics (mean ± *SD*).*

Variable	TST ($n = 17$)	ISS ($n = 12$)
Height (cm)	178.2 ± 8.1	171.5 ± 7.3
Body mass	81.8 ± 14.2	75.8 ± 11.9
BMI ($kg\cdot m^{-2}$)	25.7 ± 3.8	25.6 ± 2.9
Body fat (%)	18.4 ± 7.3	18.0 ± 6.7
Fat mass (kg)	15.8 ± 8.3	14.0 ± 6.6
Lean body mass (kg)	66.0 ± 7.8	61.8 ± 8.2

*TST = traditional strength training; ISS = interset stretching; BMI = body mass index.

taining both functionality and quality of life (14,28). In this regard, combining strength and flexibility training may be a good option for those seeking improvements in functionality and quality of life.

Although static stretching has demonstrated acute impairments in muscle strength, endurance, and power (24,29), some studies have shown that performing stretching exercise in a chronic fashion before strength training or on different days may optimize strength gains (15,16,18,28). Nevertheless, it is common for athletes and practitioners to implement stretching between sets when aiming to improve muscle recovery in sports or recreational exercises (10). Interestingly, despite minimal evidence available, it has been suggested that passive stretching implemented in the interset rest period may positively influence neuromuscular, metabolic, and hormonal responses by increasing total time under tension, which in turn would enhance strength training–induced adaptations (6,21,32).

To date, there is limited research available addressing the effects of interset stretching (ISS) on strength performance. However, the available studies have not supported the use of ISS to enhance strength gains. For example, Borges Bastos et al. (6) compared recreationally trained individuals performing whole-body hypertrophy-oriented (8 repetition maximum [RM]) strength training to the same training regimen combined with either ISS or stretching performed during warm-up (30 seconds total of passive static stretch for muscles involved in the strength training workout were performed). After 10 weeks, the authors found that muscular strength increased similarly across both groups. Moreover, Souza et al. (32) had trained subjects undergo whole-body hypertrophy-oriented (8RM) strength training and the same training regimen combined with ISS (30 seconds total of passive static stretch for the muscles involved in strength training session at the point of mild discomfort). Likewise, these authors reported similar strength gains between traditional strength training (TST) and ISS combined training after 8 weeks.

Concerning muscle hypertrophy, it is noteworthy to mention that potential mechanisms whereby ISS could optimize muscle mass accretion have not been elucidated. For example, animal and in vitro studies have demonstrated that passive tension (i.e., stimulation at lengthened position) and stretching can increase anabolic signaling (3,25,26). However, in humans, maximum-tolerated passive stretch has not demonstrated an increase in muscle protein synthesis (9). Contrastingly, Simpson et al. (30) demonstrated that loaded passive stretch training (6 weeks) increased MT in untrained subjects compared with a control group. Although the conclusions regarding the effectiveness of stretching training on muscle mass accretion are still equivocal (5,19,22,30), there is growing evidence that stretch training can induce muscular hypertrophy (19,30). However, there is a paucity of research on the effects of ISS combined with TST on muscle hypertrophic adaptations.

In addition, although ISS has been recommended for trained populations (21), identifying its effects in untrained individuals might be advantageous for strength and conditioning professionals. Therefore, the purpose of this study was to investigate the effects of TST compared to ISS combined with TST on muscle strength and hypertrophy adaptations in untrained individuals. We hypothesized that

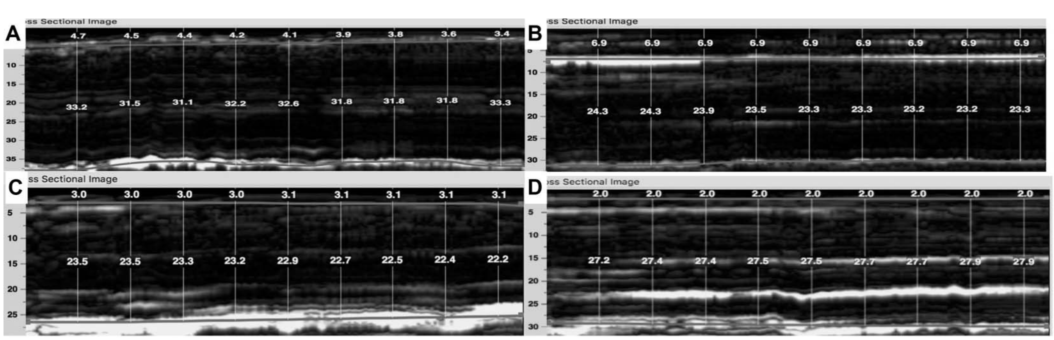

Figure 1. Overview of the muscle thickness assessments for (A) vastus lateralis, (B) rectus femoris, (C) biceps brachii, and (D) triceps brachii.

Table 2. Strength and flexibility training regimens throughout 8 weeks.*

Strength training program		
Exercises	Sets	Repetitions
Bench press	4	8–12RM
Seated row	4	8–12RM
Seated dip machine	4	8–12RM
Arm curl	4	8–12RM
Knee extension	4	8–12RM
Knee flexion	4	8–12RM
Passive stretch program		
Agonist muscles stretched	Repetitions	Duration
Chest	4	30 s
Latissimus dorsi	4	30 s
Biceps	4	30 s
Triceps	4	30 s
Quadriceps	4	30 s
Hamstrings	4	30 s

*RM = repetition maximum.

strength gains would be similar between groups; however, muscle hypertrophic adaptations would favor the ISS group.

Methods

Experimental Approach to the Problem

A randomized, parallel-group, repeated-measures design was used to investigate the effects of TST and TST combined with ISS on muscular strength and hypertrophic adaptations. Both groups trained twice a week for 8 weeks. The total number of sets and repetitions were equated between groups; however, the ISS group performed 30 seconds of passive static stretching at the maximum amplitude during the 90-second rest interval between sets. Maximum strength and MT were assessed at pre-test and after 8 weeks of training by means of 1RM and ultrasonography of the biceps and triceps brachii, rectus femoris, and vastus lateralis muscles.

Subjects

Forty healthy sedentary males volunteered to participate in this study. The following parameters were used as exclusion criteria: positive clinical diagnosis of diabetes mellitus, smoking, musculoskeletal complications, and cardiovascular alterations confirmed by medical evaluation. The volunteers were randomly assigned by simple randomization to one of the 2 groups: TST (mean ± *SD*; $n = 20$, age: 28.0 ± 6.4 years) or ISS ($n = 20$, age: 26.8 ± 6.1 years). During the study, 11 individuals dropped out due to personal reasons. Thus, data from 29 (TST $n = 17$; ISS $n = 12$) were included in the statistical analysis. None of the participants had any previous experience with resistance training and were not undergoing regular endurance training for at least 6 months before the experimental period. All the participants read and signed an informed consent. The current study was approved by the School of Medicine Review Board of the University of São Paulo. Table 1 shows subjects' main demographics.

Procedures

Maximum Dynamic Strength Assessment. Maximum dynamic strength was assessed through 1RM testing using the bench press and knee extension exercises (Nakagym, SP, Brazil). The testing protocol followed previous recommendations by Haff and Triplett (12). Subjects reported to the laboratory having refrained from any exercise other than activities of daily living for at least 72 hours before pre-testing at the start of the study and at least 72 hours before post-testing at the conclusion of the study. In brief, subjects warmed up for 5 minutes on a treadmill (Movement Technology, São Paulo, Brazil) at 60% of maximum heart rate followed by 2 exercise-specific warm-up sets. During the first set, subjects performed 5 repetitions at ~50% of the estimated 1RM followed by one set of 3 repetitions at a load corresponding to ~60–80% of the estimated 1RM with a 3-minute rest interval between sets. 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. Verbal encouragement was given throughout testing. All testing sessions were supervised by the research team to be deemed valid. The test-retest intraclass correlation coefficient (ICC), coefficient of variation (CV), and the *SEM* from our laboratory for 1RM bench press were 0.989, 0.8%, and 2.05 kg, respectively. The ICC, CV, and *SEM* for 1RM knee extension were 0.990, 0.7%, and 1.95 kg, respectively.

Muscle Thickness Assessment. Ultrasonography was used to determine the muscle thickness (MT) of the biceps brachii and brachialis (BIMT), triceps brachii (TRMT), rectus femoris (RFMT), vastus lateralis (VLMT), and sum of the 4 MT sites (ΣMT) using an ultrasound-imaging unit (BX2000; Bodymetrix, BodyMetrix, BX2000; IntelaMetrix, Inc., Livermore, CA, USA) with a wave frequency of 2.5 MHz. The ultrasound probe was applied perpendicularly to the skin for measurement. A water-soluble gel was used on the transducer to aid acoustic coupling and remove the need for excess contact pressure on the skin. Muscle thickness was defined as the distance between the interface of the muscle tissue and subcutaneous fat to the bones. Imaging was performed on the right side of the subjects' body. The subjects were oriented to fast for 3 hours before the testing, and MT assessments were performed at the same time of day at pre- and post-testing. For the BIMT and TRMT, assessments were performed at 60% distal between the lateral epicondyle of the humerus and the acromion process of the scapula; for the RFMT and VLMT, assessments were performed at 50% distal between the lateral condyle

Figure 2. Sequence of stretching exercises performed during the experimental protocol. (A) Chest and shoulder stretching; (B) elbow flexor stretching; (C) latissimus dorsi stretching; (D) elbow extensor stretching; (E) knee extensor stretching; (F) knee flexor and hip extensor stretching.

of the femur and greater trochanter. For upper-body assessments, the subject's arms were hanging by side completely relaxed and the participants were sitting comfortably; for lower-body assessments, the subjects were resting supine on an examination bed with theirs knee fully extended and relaxed (Figure 1). The examined limb was secured to minimize unwanted movement. Muscle thickness was assessed by the same blinded researcher who was careful in applying as minimal pressure as possible when placing the probe on the subjects' skin. To increase test-retest consistency, each site was marked with henna ink and remarked every week. In addition, in an effort to ensure that swelling in the muscles from training did not obscure results, images were obtained 48–72 hours before commencement of the study and 48–72 hours after the final training session. This is consistent with research showing that an acute increase in MT returns to baseline within 48 hours after an RT session (23). To further ensure accuracy of the MT assessments, at least 3 images were obtained for each site. The mean of the 3 assessments was used for statistical analysis. The test-retest ICCs from our laboratory for TRMT, BIMT, and VLMT are 0.998, 0.996, and 0.999, respectively. The CVs for these measures were 0.6, 0.4, and 0.6%, respectively. The *SEM*s for these measures were 0.42, 0.29, and 0.41 mm, respectively.

Familiarization. All subjects completed 2 familiarization sessions interspersed by a minimum of 72 hours before the commencement of experimental protocol, both of which occurred one week after maximum dynamic strength and MT assessments. During these sessions, subjects were familiarized with the exercises and their proper respective exercise techniques.

Training Regimens. Subjects underwent a nonperiodized hypertrophy-oriented whole-body ST regimen twice a week (48 hours between training sessions) for 8 weeks. The target intensity was 8–12RM for each exercise. Four sets were performed for each of the exercises: bench press, seated row, seated dip machine, arm curl, knee extension, and knee flexion. The exercises were performed with free repetition tempo, and a 90-second rest interval was allowed between sets. Exercises and repetition schemes remained the same for

Table 3. Summary of study outcomes (mean ± *SD*).*

Variable	Group	Pre	Post	ES	*p* (time)	*p* (group)	*p* (group by time)
Bench press (1RM) (kg)	ISS	32.9 ± 6.6	40.6 ± 7.0	0.86	0.0001	0.31	0.82
	TST	36.2 ± 10.2	44.2 ± 11.0	0.89			
Knee extension (1RM) (kg)	ISS	40.3 ± 8.0	50.6 ± 7.8	1.18	0.0001	0.82	0.39
	TST	40.5 ± 9.0	48.9 ± 9.5	0.96			
BIMT (mm)	ISS	32.2 ± 7.2	34.5 ± 6.7	0.39	0.0001	0.55	0.14
	TST	31.3 ± 4.7	32.8 ± 4.6	0.25			
TRMT (mm)	ISS	22.4 ± 4.6	25.2 ± 5.1	0.55	0.0001	0.45	0.19
	TST	24.4 ± 5.1	26.1 ± 5.2	0.35			
RFMT (mm)	ISS	16.0 ± 4.0	18.0 ± 4.3	0.53	0.0001	0.75	0.20
	TST	15.8 ± 3.4	17.3 ± 3.4	0.39			
VLMT (mm)	ISS	18.0 ± 4.7	21.1 ± 16.0	0.66	0.0001	0.74	0.02
	TST	19.8 ± 4.6	21.2 ± 4.4	0.31			
ΣMT (mm)	ISS	89.5 ± 11.8	98.9 ± 14.9	0.74	0.0001	0.95	0.01
	TST	91.4 ± 13.2	97.6 ± 13.1	0.48			

*ES = within-group effect size; 1RM = 1 repetition maximum; ISS = interset stretch group; TST = traditional group; BIMT = biceps muscle thickness; TRMT = triceps muscle thickness; RFMT = rectus femoris muscle thickness; VLMT = vastus lateralis muscle thickness; ΣMT = sum of the 4 muscle thickness sites.

all 8 weeks in both groups. If a subject was unable to complete the required repetitions, the load was dropped by 2–10% for upper-body exercises and 2–15% for lower-body exercises. However, if a subject was able to do one or two more repetitions over his assigned repetition goal (e.g., 13–14 repetitions), the load was increased by 2–10% for upper-body exercises and 2–15% for lower-body exercises (1). The ISS group performed passive static stretching at the maximum amplitude, defined as the maximum pain-free range of motion. Subjects were oriented to stretch just before the point of pain/discomfort for 30 seconds during the 90-second interset rest interval. The stretching exercises were applied to the same muscle groups worked during ST exercises. (Table 2 and Figure 2A–F). The subjects were advised to refrain from performing any type of additional exercise regimen throughout the study duration. Research staff supervised all training sessions providing verbal encouragement and ensuring the subjects performed the correct amount of sets and repetitions required.

Statistical Analyses

After normality (i.e., Shapiro-Wilk) assurance, a 2-sample *t*-test was used to detect differences between groups at pre-testing. A mixed model was performed for each dependent variable (e.g., maximum dynamic strength and MT) assuming group (ISS and TST) and time (pre and post) as fixed factors and subjects as a random factor (SAS 9.4; SAS Institute, Inc., Cary, NC, USA). Whenever a significant F-value was obtained, a post hoc test with Tukey's adjustment was performed for multiple comparison purposes. In addition, we presented upper and lower limits of 95% confidence intervals of within-group comparisons (CI_{diff}). Finally, within-group effect sizes were calculated as follows: mean-post minus mean-pre, pooled *SD* (7). The significance level was set at $p \leq 0.05$. Results are presented as mean and *SD*.

Results

Maximum Dynamic Strength

No significant differences between groups were detected at pre-testing for bench press and knee extension 1RM ($p \geq 0.05$). There was a significant main effect of time ($p \leq 0.0001$) for the bench press, in which both groups increased 1RM: ISS (23.4%, CI_{diff}: 4.3 kg–11.1 kg) and TST (22.2%, CI_{diff}: 5.2 kg–10.9 kg). Similarly, there was a significant main effect of time ($p \leq 0.0001$) in which both groups increased knee extension 1RM: ISS (25.5%, CI_{diff}: 5.6 kg–15.0 kg) and TST (20.6%, CI_{diff}: 4.4 kg–12.3 kg, Table 3).

Muscle Thickness

No significant differences between groups were detected at pre-testing for BIMT, TRMT, RFMT, and ΣMT ($p \geq 0.05$). Individual MT pre-post changes are presented in Figure 2. There was a significant main effect of time ($p \leq 0.0001$) for BIMT, in which both groups increased BIMT: ISS (7.2%, CI_{diff}: 1.14–3.5 mm) and TST (4.7%, CI_{diff}: 0.5–2.5 mm). Similarly, there was a significant main effect of time ($p \leq 0.0001$) in which both groups increased TRMT: ISS (12.3%, CI_{diff}: 1.1–4.4 mm) and TST (7.1%, CI_{diff}: 0.3–3.1 mm) as well as RFMT: ISS (12.4%, CI_{diff}: 1.1–2.9 mm) and TST (9.1%, CI_{diff}: 0.7–2.2 mm). For VLMT, there was a significant group by time interaction ($p \leq 0.02$) in which ISS increased VLMT to a greater extent than TST: ISS (17.0%, CI_{diff}: 1.5–3.1 mm) and TST (7.3%, CI_{diff}: 0.7–2.1 mm). In addition, there was a significant group by time interaction in which ISS increased ΣMT to a greater extent than TST: ISS

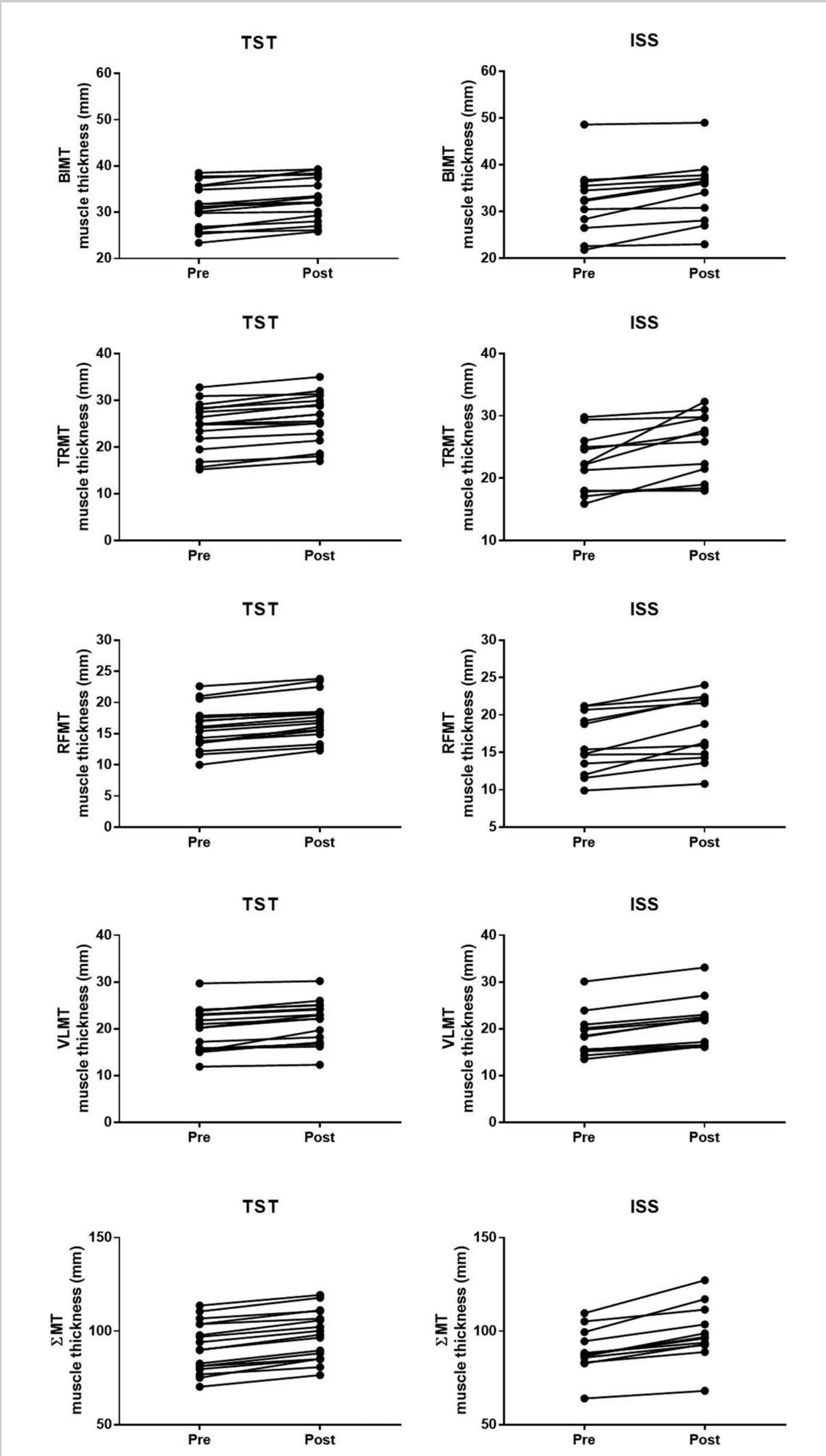

Figure 3. Individual responses for pre to post changes in muscle thickness. TST = traditional strength training; ISS = interset stretching; BIMT = biceps muscle thickness; TRMT = triceps muscle thickness, RFMT = rectus femoris muscle thickness; VLMT = vastus lateralis muscle thickness; ΣMT = sum of the 4 muscle thickness sites.

(10.5%, CI_{diff}: 6.5–9.0 mm) and TST (6.7%, CI_{diff}: 3.9–8.3 mm, Table 3 and Figure 3).

Discussion

The aim of this study was to investigate the effects of TST compared to ISS combined with TST on muscle strength and hypertrophy adaptations in untrained individuals. We partially confirmed our initial hypothesis, as our findings demonstrate that maximum dynamic strength increased similarly between groups. In addition, most MT sites measured increased in a similar fashion between groups. Only VLMT and ΣMT assessments demonstrated a greater rate of change favoring ISS compared with TST.

Few studies have examined the effects of ISS on muscle strength adaptations (6,10,32). Souza et al. (32) demonstrated similar improvements on lower- and upper-body strength in untrained individuals performing TST and ISS combined with TST after 8 weeks of training. Although our findings agree with the aforementioned study, comparison between these 2 studies should be taken with a degree of caution because we assessed maximum strength through 1RM, whereas Souza et al. (32) assessed strength endurance through an 8RM assessment. In addition, our results suggest that combining strength exercises and ISS does not compromise muscular strength adaptations. Our findings agree with previous research, which combined strength and stretch training protocols (16,28). Interestingly, although the subjects in Kokkonen et al. (16) performed flexibility training on different days from strength training sessions, Simao et al. (28) combined both training regimens on the same day in which the stretching protocol was performed before the strength training session. Therefore, it seems that adding ISS to the regular strength training does not compromise strength development when compared to either TST alone or stretching exercises combined with TST.

Despite a lack of conclusive evidence, it has been proposed that if the muscles are passively stretched during rest intervals between sets, the additional mechanical stimulus would enhance muscle hypertrophic adaptations (21). As expected, both training regimens (i.e., TST and ISS) promoted beneficial adaptations on muscle mass accrual in the current study. In addition, VLMT and ΣMT demonstrated greater rates of change on muscle hypertrophic responses in ISS compared with TST. Although our findings might suggest a benefit of adding ISS into regular strength training, they need to be interpreted with a degree of caution. Because this is an understudied topic in our field and there is a lack of available data on the effects of ISS combined with TST, it is difficult to compare our findings to current literature. Additionally, while exposure to chronic stretching has been shown to increase muscle growth in animals models (2,4,8,11,13,31), the data is equivocal for human trials (5,19,22,30).

Although we are the first to demonstrate that combining TST with ISS might induce favorable adaptations on muscle accrual, it is difficult to propose the possible mechanisms underlying our findings. Most mechanistic explanations which suggest that stretching activates anabolic signaling pathways should be taken with a degree of caution as they were generated from animals models studies (25,26) which might not translate to the complexity of humans. Moreover, an inherent limitation when comparing combined exercise regimens with single mode exercise (i.e., TST + ISS vs. TST) is that combined exercise regimens often impose more stress on the skeletal muscle. It is important to point out that our subjects had a very low training status. Therefore, although it is plausible to assume that additional work would be associated with greater muscle hypertrophy in untrained individuals, we cannot confirm whether that was responsible for enhancing muscle mass accretion. Finally, if we disregard the ΣMT assessments, only VLMT demonstrated greater rate of change in the ISS group. Therefore, our data are not sufficient enough to conclude that ISS would be more efficient compared with TST for inducing muscle hypertrophic adaptations.

Indeed, our study has inherent limitations; as we did not have a control group performing only passive stretching, we were not able to quantify the effects of our stretching protocol on muscle hypertrophy adaptations. Furthermore, the lack of diet control can be considered a confounding factor that could influence our dependent variables. Moreover, MT was measured only at a single point per muscle. Therefore, we do not know if combining ISS and TST would produce muscle hypertrophy in a regional manner (i.e., more distally or proximally along the muscle). Finally, the effects of ISS combined with TST in strength-trained individuals warrant further examination.

In conclusion, both the TST and ISS groups elicited improvements on muscle strength and thickness of the upper and lower limbs. Although our findings might suggest that ISS may augment muscle hypertrophy in untrained individuals, our findings are not definitive on the effectiveness of adding ISS to TST for muscle mass accrual. However, our findings do support that adding ISS to regular TST regimens does not compromise muscular adaptations during the early phase of training ($<$8 weeks).

Practical Applications

Strength and conditioning professionals working with untrained subjects focusing on improving muscle mass accrual may consider the insertion of 30 seconds of passive stretching during the rest intervals of the TST session as a variation strategy for inducing muscular hypertrophic adaptations. Moreover, as time is the most significant barrier to nonparticipation in exercise programs, ISS can be an interesting way to train different goals (i.e., muscular strength, hypertrophy, and flexibility) without lengthening the duration of training sessions.

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