Journal of Exercise Physiology **online**

**December 2014**
**Volume 17 Number 6**

**JEPonline**

Official Research Journal of the American Society of Exercise Physiologists

ISSN 1097-9751

# Static Stretching Volume is Associated with Maximal Repetition Performance

André Martins[1,2], Gabriel Paz[2], Patrícia Vigário[1], Gabriel Costa e Silva[2,3], Marianna Maia[2], Humberto Miranda[2]

[1]Rehabilitation Sciences Master's Program; Augusto Motta University Center (UNISUAM); [2]Brazil, Rio de Janeiro Federal University, Physical Education Post Graduation Program, Rio de Janeiro, RJ – Brazil; [3]Federal Rural University of Rio de Janeiro, Laboratory of Physiology and Human Performance, Seropédica, RJ – Brazil

## ABSTRACT

**Martins A, Paz A, Vigário P, Costa e Silva G, Maia M, Miranda H.** Static Stretching Volume is Associated with Maximal Repetition Performance. **JEPonline** 2014;17(6):24-33. The purpose of this study was to assess the effect of static stretching (SS) volume on repetition performance for upper and lower body exercises. Fifteen trained men participated. Ten repetition maximum (10RM) test and retest were applied to the bench-press (BP) and lying leg curl (LLC) exercises. Four protocols were used: non-stretching protocol (NS) - 3 sets on the BP exercise were performed followed by 3 sets for the LLC; P1 - one set of SS (30 sec) was applied for pectorals muscles and after a 1-min rest interval, 3 sets were performed on the BP exercise. Then, one set of SS was applied for the hamstrings muscles followed by 3 sets on the LLC exercise. A 4-min rest interval was used between sets for both exercises followed by a 3-min rest interval after the BP exercise during each protocol. All sets were performed repetition to failure with 10RM loads. During the P2 and P3 protocols the number of SS sets was 2 and 3, with a similar procedure adopted in NS. The total work for BP exercise was lower during P1 (P=0.003), P2 (P=0.0001), and P3 (P=0.0001) compared to the NS protocol. Similar results were found for the LLC exercise during P3 when compared to P1 (P=0.003) and P2 (P=0.045), and between P2 and P1 (P=0.001). Higher decreasing on repetition performance was noted in P3 compared to NS. Thus, the SS with one or multiple sets and small duration resulted in reductions in repetition performance with moderated loads in upper and lower body exercises.

**Keywords**: muscle Strength, Recovery, Resistance Training, Stretching

## INTRODUCTION

In general, flexibility training is considered to be a key component of physical exercise programs with the objective to increase the range of motion, prevent injuries, improve athletic performance, and develop quality of life and health (11,26). However, there is some disagreement in the published findings. For example, Franco et al. (10) and other researchers (19,21,23) have published findings that indicate a deleterious effect on strength performance induced by stretching exercises in an acute manner. The decrease in performance may originate from neural and/or mechanical factors that last ~1 hr after stretching (3,9).

Despite that stretching parameters may influence the strength performance (11,17,19,21,23,26), the stretching duration and/or number of sets on muscular performance seems to have been only minimally investigated. Franco et al. (11) observed that 40 sec of static stretching (SS) induced a significant reduction of ~85% in the bench press (BP) strength performance during a one repetition maximum (1RM) test. Interestingly, the authors (11) observed that a low volume of 20-sec SS did not have a significant effect on muscular endurance. On the other hand, Gomes et al. (12) also observed significant reductions (between 20.1% and 36.7%), regardless of the exercise intensity or muscle group on repetition performance during knee extension and the BP exercises with different load intensities (40%, 60%, and 80% of 1RM) after 3 sets of PNF stretching at a duration of 30 sec for the quadriceps femoris and the pectoralis major muscles.

Numerous studies (4,5,9,14,15,22,28,29) that have used a variety of different stretching protocols have recommended that they should not be performed prior to activities when great levels of strength production are required. However, in most cases these recommendations are based on studies in which the total volume of pre-test stretching is different than that typically recommended in the exercises programs. In this regard, the importance of the present study is in the total work response, analysis, and the effects produced by stretching on single or multiple sets of strength exercises. Without question, there are significant gaps in the literature that remain to be filled.

Thus, in consideration of the lack of studies that have investigated the effect of different stretching exercises and volume on strength performance, which could have an important practical application, the purpose of this study was to determine the acute influence of single and multiple sets of static stretching on the strength performance of the upper and lower limb muscles. Furthermore, the study aimed to compare different volumes of SS exercises on strength performance. The initial hypothesis is that all the stretching protocols will decrease the maximal repetition performance in trained men.

## METHODS

### Subjects

Fifteen male subjects with a mean age of ~26 with experience in resistance training participated in this study. Specifically, regarding the subjects' resistance training experience, they had to have: (a) at least 2 yrs of resistance training ~4 times·wk$^{-1}$; and hands-on familiarization with the exercises used in the present study. Any subjects who had functional limitations and/or medical conditions that might limit the resistance training practice and/or the performance of the 10RM tests were excluded. The study was conducted in accordance with the Declaration of Helsinki. It was approved by the university's ethic committee under the protocol nº 0064/2007. In accordance with institutional Resolution 196/96 from National Health Council, all subjects read and signed an informed consent form, which explained the testing procedures that would be used throughout the study. The subjects' characteristics are presented in Table1.

**Table 1. Participant Descriptive Data.**

| Variables | Means ± SD | Minimum | Maximal |
|---|---|---|---|
| **Age** (yrs) | 25.86 ± 2.25 | 20 | 28 |
| **Body Mass** (kg) | 83.36 ± 8.13 | 72.3 | 100.2 |
| **Height** (m) | 1.77 ± 0.06 | 1.71 | 1.90 |
| **Resistance Training Experience** (yrs) | 12.2 ± 5.22 | 8 | 16 |

SD: Standard Deviation

**Ten Repetition Maximum Testing**

The first two testing sessions consisted of measuring the subjects' strength, weight, and height. At each session, strength was assessed using a 10RM test for BP and lying leg curl (LLC) exercises (Life Fitness, IL, USA) (18). If the subject did not attain 10 repetitions in the first attempt, the weight was adjusted by 4 to 10 kg with a minimum of 5 min of rest before the next attempt. Only three trials were allowed per testing session with 10 min of rest was between exercises. The test and retest were conducted with a minimum rest interval of 48 hrs. The BP exercise and the LLC exercise were alternated during test and retest.

The following strategies were adopted to reduce the margin of error in the data collection procedures: (a) standardized instructions were given before the tests performance so that the subjects who were being tested would be aware of the entire routine involved in the data collection; (b) the subject who was being tested was instructed about the technique of the exercise execution; (c) all subjects received standardized verbal encouragement throughout the tests; (d) all tests were conducted at the same time of the day for every session; and (e) all measurements were performed by the same measurer.

To standardize the position to perform the BP exercise, the following steps were adopted: Initial position - the subject assumed the supine position with the hip and knees flexed at 90º. The shoulders were set at 90º of abduction and the elbows were flexed at 90º. For the concentric phase, the subject performed a complete shoulder horizontal adduction and elbow extension, and during the eccentric phase the subject actively controlled the shoulder horizontal abduction and elbow flexion to the initial position.

To standardize the position to perform the LLC exercise, the following steps were adopted: Initial position - the subject assumed the lying prone position with the knee fully extended and the hands gripped in the support in front of the head. For the concentric phase the subjects flexed the knee to approximately 110º and during the eccentric phase the knee extension were controlled to the initial position.

**Experimental Protocols**

After the 10RM testing sessions, the subjects underwent 4 days of experimental protocols with a minimal recovery interval of 48 hrs between the sessions. Four experimental protocols were randomly applied (Figure 1):

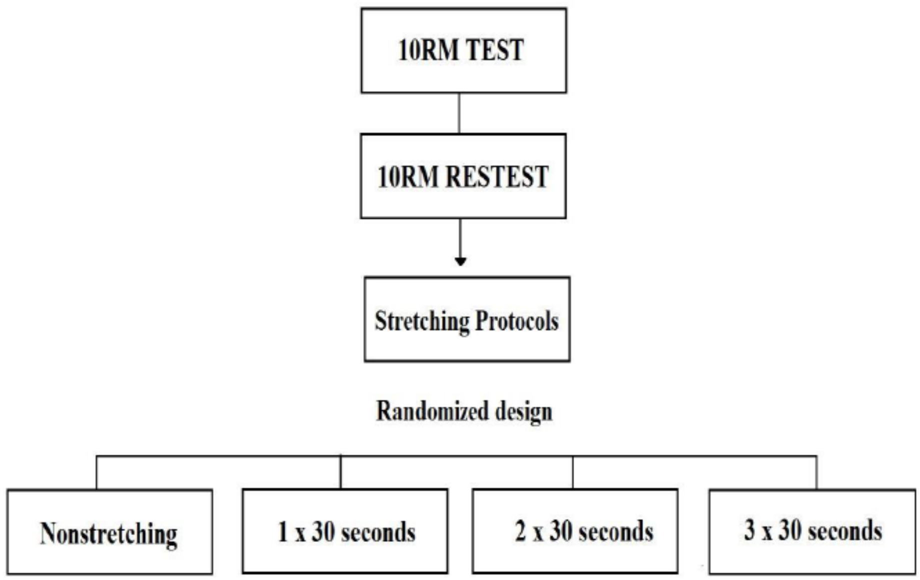


**Figure 1. Study Design.**

***Nonstretching Condition (NS)***
The subjects performed a 3-set repetition to failure on the BP exercise with 10RM loads. Then, after a 3-min rest interval, they performed 3 sets of the LLC exercise to failure with 10RM loads.

***One Set of Static Stretching (P1)***
The subjects performed 1-set of SS of the pectorals major muscles for 30 sec, which was followed by a 1-min rest interval. Then, the subjects performed 3 sets repetition to failure on the BP exercise with 10RM loads. The rest interval between the sets was 4 min in duration. After a 3-min rest interval, the subjects then performed a 30-sec 1 set of SS for the hamstrings muscles. One minute after the SS protocol, they performed 3 sets of the LLC exercise to failure with 10RM loads.

***Two Sets of Static Stretching (P2)***
The subjects performed the same methodological sequence with 2 sets of 30 sec of SS for both the pectorals major muscles and the hamstring muscles before the resistance exercises.

***Three Sets of Static Stretching (P3)***
The subjects performed the same protocol with 3 sets of 30 sec of SS. The number of repetitions completed per set was recorded for the BP exercise and the LLC exercise after each protocol. Strength performance was considered as the total work (number of sets x number of repetitions x load), which was determined for each protocol.

***Stretching Protocol***

The SS applied to the pectorals major muscles was consistent with the protocol previously conducted by Franco and colleagues (11). All subjects assumed a standing position that helped to preserve the anatomical curvature of the spine. Then, the researcher instituted a passive stretch through horizontal abduction of the shoulder joints with the elbow joints fully flexed. For the stretching of the hamstring muscles, the subjects were asked to assume the lying down supine position from which the researcher passively performer hip flexion with the knee extended. The anatomical curvature of the low back was maintained.

**Statistical Analysis**

Descriptive statistics are shown as mean ± standard deviation and minimum and maximum values. The Intraclass correlation coefficient (ICC) was calculated to determine the 10RM test–retest reliability. The ICC method adopted was $((MS_b – MS_w)/[MS_b + (k-1)MS_w)])$, where $MS_b$ = mean-square between, $MS_w$ = means-square within, and k = average group size. The normality and homoscedasticity of the data were analyzed with the Shapiro-Wilk test and the Bartlett criterion, respectively. All variables presented normal distribution and homoscedasticity.

Repeated measures of analyze of variance (ANOVA) one-way followed by Bonferroni post hoc were applied to investigate the differences in total work on resistance exercises according to SS protocols adopted. The value of $P \leq 0.05$ was considered statistically significant for all inferential analyses. Effect sizes were used to track the magnitude of change, and for all conditions were calculated and classified as proposed by Rhea (24), as the difference between pretest and post-test scores divided by the pretest SD. Statistical analysis was performed with software SPSS version 20.0 (Chicago, IL, USA).

## RESULTS

The ICCs for test and retest of 10RM were 0.95 for the LLC exercise and 0.91 for the BP exercise. Significant decreases on total work were noted for P1 (P=0.006), P2 (P=0.002), and P3 (P=0.0001) when compared to the NS protocol for the LLC exercise (Table 2). Additionally, significant lower total work was also found for P3 when compared to P1 (P=0.002) and P2 (P=0.003). The total work for the BP exercise was also significantly lower in P1 (P=0.003), P2 (P=0.0001), and P3 (P=0.0001) compared to the NS protocol. The decrease on total work was also observed in the comparison between P3 and P1 (P=0.003) and P2 (P=0.045), and between P2 and P1 (p = 0.001). The effect size was classified as trivial for all protocols and exercises (Table 3).

**Table 2. Total Work (Repetitions x Sets x Load) during Each Experimental Protocol. The Values are Mean ± SD.**

| Exercises | NS | P1 | P2 | P3 |
|---|---|---|---|---|
| **Lying Leg Curl** | 29.57 ± 1.91 | 27.21 ± 1.58* | 26.21 ± 1.92* | 24.21 ± 1.76*†‡ |
| **Bench Press** | 28.64 ± 1.59 | 26.07 ± 1.26* | 23.93 ± 1.43*† | 22.29 ± 1.79*†‡ |

*Significant difference for nonstretching protocol; †Significant difference for P1; ‡ Significant difference for P2; NS: nonstretching protocol; P1: 1 set of static stretching before resistance exercise; P2: 2 sets of static stretching before resistance exercise; P3: 3 sets of static stretching before resistance exercise.

**Table 3. Effect Size between the Experimental Protocols and Exercises Compared to NS Condition.**

| Exercises | NS | P1 | P2 | P3 |
|---|---|---|---|---|
| Lying Leg Curl | - | (Trivial) - 1.21 | (Trivial) - 1.73 | (Trivial) - 2.78 |
| Bench press | - | (Trivial) - 1.36 | (Trivial) - 2.47 | (Trivial) - 3.36 |

NS: nonstretching protocol; P1: 1 set of static stretching before resistance exercise; P2: 2 sets of static stretching before resistance exercise; P3: 3 sets of static stretching before resistance exercise.

## DISCUSSION

The key finding from this study was the significant decrease in the total work performed over the 3 consecutive sets for the LLC and the BP resistance exercises after different SS protocols for the hamstrings and the pectorals major muscles, respectively. These results are in agreement with previous researchers who reported a decrease in repetition performance after stretching protocols (8,11,27). In addition, the higher decrease in repetition performance was noted in the stretching protocol composed by three sets of 30 sec compared to NS. Thus, strength endurance performance seems to be related to the pre-stretching volume.

The effect of static stretching on muscle strength has been widely investigated by means of isometric (4,13,16), isokinetic (6,12,25), and dynamic (11,12,27) resistance training. In the current study, a significant decrease was noted for the P1, P2, and P3 stretching protocols for the BP and the LLC exercises compared to the NS protocol. These results are in agreement with several studies that reported a decrease in force production after SS of the agonist muscles (7,8,11,12,19). Nelson et al. (19) applied 5 exercises in a stretching protocol with 3 sets lasting 15 sec followed by a dynamic endurance test in which a reduction of muscular performance after stretching was observed. Fowles et al. (9) found a significant decrease in isometric force after a stretching protocol composed of one exercise with 13 sets of 135 sec of stimuli. These findings suggest that stretching volume (i.e., duration and number of sets) has a strict association with the strength reduction after SS exercises.

The results of the present study may be associated to some hypotheses previously describe in the scientific literature. The decrease in strength performance after stretching is often attributed to changes in the viscoelastic properties of the muscle, which in turn may alter the length-tension relationship (26). However, it should be pointed out that most of the studies that found a decrease in the force after the SS exercise employed more than one kind of exercise for the same muscle, with larger ranges and/or numbers of sets than those reported to be used in sport activities (1,2,21). In the current study, the SS protocol was applied before the resistance the BP exercise and the LLC exercise, respectively. Franco et al. (11) found a significant decrease of 10% to 12% on endurance performance (with 85% of 1RM) in the BP exercise after 1 set of SS (40 sec) in agonists (PM) versus the condition without the pre-exercise SS. Marek et al. (17) also observed a significant decrease in the activation of the quadriceps and peak of torque (10% to 15%) during knee isokinetic extension after four SS exercises for quadriceps muscles. These data suggest that stretching volume has a high association with the negative effect on repetition performance.

Additionally, Gomes et al. (12) found a decrease in repetition performance during the BP exercise and the leg extension exercise after 3 sets of SS for the pectoralis major and quadriceps muscles, respectively. The authors observed that the agonist SS promoted negative effects between 12% and 21% in repetition performance using different intensities (40%, 60%, and 80% of 1RM). However, Cornwell et al. (3) found a decrease in eletromyographic activity and stiffness after agonist SS. They hypothesized that reductions in stiffness were insufficient to cause a decrease in force production. Fowles et al. (9) found that electromyographic activity was significantly decreased for the first 15 min following SS, and that force decrements were the greatest during that time frame. Interestingly, electrical activity did return to normal after 15 min while force decrements remained for 60 min. These authors theorized that neural factors played a bigger role in strength decreases early on, but as time passed the reduction in maximum voluntary contraction originated peripherally in the muscle.

Knudson and Nofall (15) verified the effect SS on the strength in the hand grip test in 57 young subjects. After a linear regression analysis, it was determined that there was a significant drop in the log function of 88.8% when the tests were performed after 10 series of 10 sec stretching. The authors concluded that the meaningful reductions in strength following SS were likely to appear following 20 to 40 sec of SS. In agreement with Knudson and Nofall (15), the present results indicate that the use of SS for 30 sec significantly decreases the levels of strength production. Furthermore, the effect size was classified as trivial for all protocols and exercises when compared to the stretching condition. Despite the trivial magnitude, all the SS protocols used in the present study had a significant impact on the total work. This finding raises the concern whether the application of SS before resistance exercise has a greater impact on strength gains in long-term adaptations. In a similar manner to previous data in scientific literature, the present study has shown a reduction of repetition performance after SS even with a small duration (30 sec) and with only 1 set of SS. These results serve to support the existing data in the literature, particularly with regards to the response in different resistance exercises for the upper body muscles and the lower body muscle and the decrease in maximal repetition performance even when a single stretching exercise is used.

It is important to highlight that the current study has some limitations. There were no mechanical and/or neural evaluations to investigate the mechanisms responsible for the results. The development of future studies involving different variables is recommended, such as the number of sets, duration of stretch–hold position, rest duration between stretching sets, and populations of different ages, gender, and conditioning levels. It is also suggested that the chronic effects on the variables presented should be analyzed in that the chronic effects of stretching may be opposed to the immediate responses (20).

## CONCLUSIONS

The results from this study provide practical applications for strength and conditioning professionals using the SS method as part of their resistance training prescription to trained men. Our findings indicate that the SS protocol resulted in significant reductions in repetition performance with moderated loads (10RM) in the lower body and upper body exercises. Consequently, this stretching technique may not be recommended before athletic events or physical activities immediately before maximal repetition exercises and strength-based activities, respectively.

**Adress for Correspondence**: Gabriel Costa e Silva, Msc, Av Carlos Chagas Filho, Rio de Janeiro Federal University, Physical Education PostGraduation Program, Cidade Universitária. Rio de Janeiro 21941-590, RJ – BRAZIL. Email: gabriel_bill04@hotmail.com and Dr. Humberto Miranda (Email: humbertomiranda01@gmail.com

## REFERENCES

1. Avela J, Kyröläinen H, Komi PV. Altered reflex sensitivity after repeated and prolonged passive muscle stretching. ***J Appl Physiol.*** 1999;86:1283-1291.

2. Bradley PS, Olsen PD, Portas MD. The effect of static, ballistic, and proprioceptive neuromuscular facilitation stretching on vertical jump performance. ***J Strength Cond Res.*** 2007;21:223-226.

3. Cornwell A, Nelson AG, Sidaway B. Acute effects of stretching on the neuromechanical properties of the triceps surae muscle complex. ***Eur J Appl Physiol.*** 2002;86:428-434.

4. Costa e Silva G, Silveira A, Di Masi F, Bentes CM, Souza MS, Novaes J. Acute effects of different stretching methods on isometric muscle strength. ***Acta Scientiarum (Health Sciences).*** 2014a;36:51-57.

5. Costa e Silva G, Silveira A, Novaes J, Di Masi F, Conceição M, Dantas H. Acute effects of static and proprioceptive neuromuscular stretching on sprint performance in male swimmers. ***Med Sport.*** 2014b;67:119-128.

6. Cramer JT, Housh TJ, Johnson GO, Miller JM, Coburn JW, Beck TW. Acute effects of static stretching on peak torque in women. ***J Strength Cond Res.*** 2004;18:236-241.

7. Evetovich TK, Nauman NJ, Conley DS, Todd JB. Effect of static stretching of the biceps brachii on torque, electromyography, and mechanomyography during concentric isokinetic muscle actions. ***J Strength Cond Res.*** 2003;17:484-488.

8. Fortier J, Lattier G, Babault N. Acute effects of short-duration isolated static stretching or combined with dynamic exercises on strength, jump and sprint performance. ***Sci Sports.*** 2013;28:111-117.

9. Fowles JR, Sale DG, MacDougall JB. Reduced strength after passive stretch of the human plantarflexors. ***J Appl Physiol.*** 2000;89:1179-1188.

10. Franco BL, Signorelli GR, Trajano GS, Costa PB, Oliveira CG. Acute effects of three different stretching protocols on the Wingate test performance. ***J Sport Sci Med.*** 2012;11:1-7.

11. Franco BL, Signorelli GR, Trajano GS, Oliveira CG. Acute effects of different stretching exercises on muscular endurance. ***J Strength Cond Res.*** 2008;22:1832-1837.

12. Gomes TM, Simão R, Marques MC, Novaes J. Acute effects of two different stretching methods on local muscular endurance performance. ***J Strength Cond Res.*** 2011;25:745-752.

13. Herda TJ, Cramer JT, Ryan ED, McHugh MP, Stout JR. Acute effects of static versus dynamic stretching on isometric peak torque, electromyography, and mechanomyography of the biceps femoris muscle. ***J Strength Cond Res.*** 2008;22:809-817.

14. Klister BM, Walsh MS, Horn TS, Cox RH. The acute effects of static stretching on the sprint performance of collegiate men in the 60- and 100-m dash after dynamic warm-up. ***J Strength Cond Res.*** 2010;24:2280-2284.

15. Knudson D, Noffal G. Time course of stretch-induced isometric strength deficits. ***Eur J Appl Physiol.*** 2005;94:348-351.

16. Mcbridge JM, Deane R, Nimphius N. Effect of stretching on agonist–antagonist muscle activity and muscle force output during single and multiple joint isometric contractions. ***Scand J Med Sci Sport.*** 2007;17:54–60.

17. Marek SM, Cramer JT, Fincher AL, Massey LL, Dangelmaier SM, Purkayastha S, Fitz KA, Culbertson JY. Acute effects of static and proprioceptive neuromuscular facilitation stretching on muscle strength and power output. ***J Athl Train.*** 2005;40:94-103.

18. Miranda H, Simão R, dos Santos Vigário P, Salles BF, Pacheco MT, Willardson JM. Exercise order interacts with rest interval during upper-body resistance exercise. ***J Strength Cond Res.*** 2010;24:1573-1577.

19. Nelson AG, Kokkonen J, Arnall DA. Acute muscle stretching inhibits muscle strength endurance performance. ***J Strength Cond Res.*** 2005;19:338-343.

20. Nelson AG, Kokkonen J, Winchester JB, Kalani W, Peterson K, Kenly MS, Arnall DA. A 10-week stretching program increases strength in the contralateral muscle. ***J Strength Cond Res.*** 2012; 26:832-836.

21. Ogura Y, Mitahara Y, Naito H, Katamoto S, Aoki J. Duration of static stretching influences muscle force production in hamstring muscles. ***J Strength Cond Res.*** 2007;21:788-792.

22. Paz GA, Maia MF, Lima VP, Oliveira CG, Bezerra ES, Simão R, Miranda H. Maximal exercise performance and electromyography responses after antagonist neuromuscular proprioceptive facilitation: A pilot study. ***J Exerc Physiol (online).*** 2012;15:60-67.

23. Power K, Behm D, Cahill F, Carrol M, Young W. An acute bout of static stretching: Effects on force and jumping performance. ***Med Sci Sport Exerc.*** 2004;36:1389-1396.

24. Rhea M. Determining the magnitude of treatment effects in strength training research through the use of the effect size. ***J Strength Cond Res.*** 2004;18:918-920.

25. Sandberg JB, Wagner DR, Willardson JM, Smith GA. Acute effects of antagonist stretching on jump height, torque and electromyography of agonist musculature. ***J Strength Cond Res.*** 2012;26:1249-1256.

26. Sharman MJ, Cresswell AG, Riek S. Proprioceptive neuromuscular facilitation stretching: Mechanisms and clinical implications. ***Sport Med.*** 2006;36:929-939.

27. Souza AC, Bentes CM, Salles BF, Reis VM, Alves JV, Miranda H, Novaes J. Influence of inter-set stretching on strength, flexibility and hormonal adaptations. ***J Hum Kinetic.*** 2013;36: 127-135.

28. Winchester JB, Nelson AG, Landin D, Young MA, Schexnayder IC. Static stretching impairs sprint performance in collegiate track and field athletes. ***J Strength Cond Res.*** 2008;22:13-19.

29. Yamagushi T, Ishii K, Yamanaka M, Yasuda K. Acute effects of static stretching on power output during concentric dynamic constant external resistance leg extension. ***J Strength Cond Res.*** 2006;20:804-810.