Journal of Physical Education and Sport ® (JPES), 17(3), Art 186, pp. 1906 - 1911, 2017
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Effects of chronic stretching training on the torque of young adults

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Published online: September 30, 2017
*(*Accepted for publication September 07, 2017
DOI:10.7752/jpes.2017.03186

Abstract:

The aim of this study was to evaluate the effects of stretching training in the capacity of hamstring muscles torque maintenance in male young adults. Thirty-eight volunteers were randomly divided into two groups: Stretching Group (SG, n = 19) and Control Group (CG, n = 19). The training protocol consisted of three different static stretching exercises for hamstrings, performed in 3 repetitions, lasting 30s each, and 3 days.wk^{-1}, totalizing 270 seconds per session, during 6 weeks. Knee Range of Motion (ROM) was assessed by a goniometer and isometric peak torque (Pt), rate of torque maintenance (RTM - the resultant of the maximum and minimum isometric peak torque), rate of torque development (RTD - ΔForce/ΔTime) and impulse (I - area under the torque-time curve) were assessed through a load cell. Parametric results were analyzed by mixed model ANOVA. The ROM at post-training of SG was greater than at post-training of CG (163±4º *vs.* 141±3º Cohen's *d* = 5.25; p <0.001). The RTD increased after the stretching training when compared to pre post-training for both groups (23.34±8.8 N.s^{-1} *vs.*18.13±10.27 N.s^{-1}, Cohen's *d* = 0.54; p =0.044). Pt, RTM and I did not change. The stretching training for 6 weeks increased the ROM and RTD without interfering on the peak torque of young adult's hamstring muscles

Key words*:* muscle stretching exercises**,** peak torque, torque maintenance, flexibility

Introduction

Stretch training has been frequently performed aiming to increase joint range of motion (ROM) [Kallerud et al., 2013; Peck et al., 2014]. Recent studies have showed that acute effects of stretching exercise may negatively affect maximum force in a subsequent motor task (Pinto et al., 2014; Nakamura et al., 2014). However, when stretching exercises are performed in a regular basis (i.e., training effect, chronic manner), ROM gains are also accompanied by muscle force improvements (Chen et al., 2009; Kokkonen et al., 2010; Nelson et al., 2012).

Changes in neural activation, such as enhancement in excitation-contraction mechanism, can explain increases in the torque and in the ability to sustain longer contractions as result of stretching training (Kokkonen et al., 2007). This training response may assist the rate and duration of muscle response to change skeletal muscle viscoelastic properties increasing the extensibility of the tendon (Kubo et al., 2001) and of muscular components (aponeuroses, contractile and connective tissues) (Morse et al., 2008). It might also, modify the passive length-tension relationship of the muscle and, thus, influence peak and endurance torque (Weppler et al., 2010).

Some studies have reported the effects of stretching training performed from 3 to 10 weeks (3 or 5 days.wk^{-1}) (Kallerud et. al., 2013, Rubini, et. al., 2007). Studies that stretch training was performed during 8 or 10 weeks (3 days.wk^{-1}) they found an increase in the peak torque (Kokkonen et al., 2007; Chen et. al., 2009). However, when stretch training was conducted 5 days.wk^{-1}, during 6 weeks period, the angle of peak torque and work increased, whereas peak torque did not change (Ferreira et al., 2007). Other studies did not report torque changes when stretch training was performed during 4 weeks, 3 days.wk^{-1} (Laroche et al., 2008; Higgs et. al., 2009). The studies designed to determine stretching training effects on performance reported low to moderate effect sizes and are inconclusive (Kallerud et al., 2013). Thus, it is not known the effects of stretch training on the rate, the peak and the capacity to sustain torque.Therefore, the present study aimed to investigate the effects of stretch training during 6 weeks, performed 3 days.wk^{-1} on the range of motion (ROM) and knee joint torque of young adults.

Material & methods

Participants

Eighty-six individuals from local army school were invited to participate in the study. Fourteen were excluded because they were regularly engaged in training programs, while thirteen fail to comply with the Army

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Physical Fitness Test. In addition, 17 individuals refused to participate due to personal reasons. Finally, two individuals presented hip flexor shortening that could influence on the results. Thus, 40 participants (18.3±0.5 years-old; 72.6±7.2kg; 175±0.07 cm) were randomly assigned in two groups: Stretching Group (SG; n=20) and Control Group (CG; n=20).

The inclusion criteria was reach good or regular score in the military physical fitness test (individual physical performance for running, abdominal, bar bending and soil) and the individual could not be involved in strength exercise. The exclusion criteria was injury in the lower limbs in the 6 months preceding the study and hip flexor muscles shortening (Thomas test). The modified "Thomas" test was applied to determine muscle-tendon length of the hip uni- and biarticular flexor muscles (Sarraf et al, 2005).

After starting the experimental procedures, one participant of SG dropped out because he engaged on another training program and one individual of CG left the military school. Therefore, 38 participants successfully concluded all experimental procedures. The experimental procedures followed ethic standards and was approved by the Federal University of Parana Ethics Committee CAAE-0141.0.091.091-11 following the guidelines for data collection in humans, according to resolution no. 466/12, of 12/12/2012, of the National Health Council, as well as the ethical principles contained in the Declaration of Helsinki.

Muscle stretch training

The SG performed 3 types of static stretching exercises (two applied with assistance and one without) for the hamstrings 3 days.wk^{-1}, during 6 weeks. The exercises are showed in Figure 1 (Herda et al, 2008). Each stretching repetition was performed slowly until the participant reports the first signs of discomfort in the distal portion of the hamstrings and then the stretched position was maintained for 30s. Each exercise was repeated 3 times an interval of 10s between each repetition.

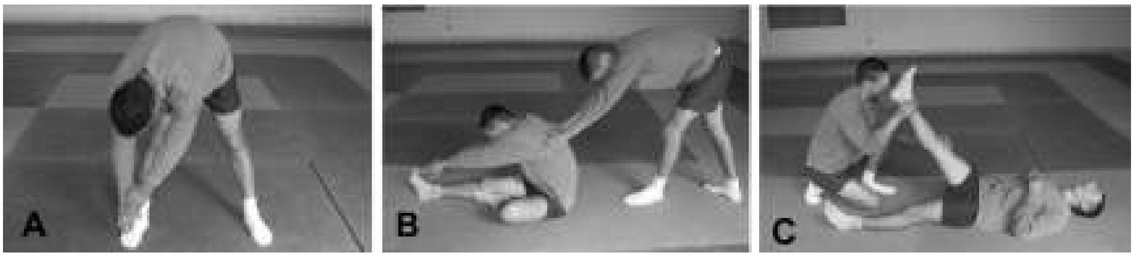

Fig. 1 Types of static stretching exercises performed on the hamstrings. Types of static stretching exercises performed to the hamstrings. (A) Hamstring stretching exercise in a stand position with no help; (B) Hamstring stretching exercise in a sit position with help; (C) Hamstring stretching exercise on supine position, with help (HERDA et al., 2008).

Hamstrings flexibility assessements

Flexibility was assessed by measuring the ROM of the knee joint during extension, starting from a hip joint flexed position, using a standard goniometer (*Dysport model*). Initially, the volunteer was positioned in a supine position lying with the hip and the knee of the tested limb flexed at 90º. Then, the knee joint was slowly and passively extended until the participant report the first signs of discomfort, this position was considered to measure the angle. The mean of three consecutive measurements an interval of 15s imposed between each repetition was used for analysis purposes. The full knee extension was considered as 0º and was used as a reference to indicate the limit of the knee joint extension (Gajdosik et al , 1983).

Knee torque assessments

Each participant was instructed to perform the knee flexion movement as fast as possible and to sustain a maximal isometric voluntary torque effort during 30s, without relaxing. A session was held for familiarization in order to train the tests, seven days before the data collection to monitor in synchronization to the computer connected to the load cell. The purpose of familiarization was for volunteers to learn the proper execution of the movement. The graphic showing the maximum voluntary isometric contraction had to present a single curve, i.e., it should avoid muscle relaxation or new muscle contractions, which could result in other peaks during data collection. Before data collection each volunteer performed a five-minute of cycling for warming-up on a stationary ergometer with no resistance and a heart rate ranging from 50% to 75% of the maximum (Franklin et al., 2000).

The peak torque was determined through the product between isometric peak force and the external distance between joint center and the point the load cell was attached to the segment. The rate of torque development (RTD) corresponded to the slope of the force-time curve (ΔForce/ΔTime) (Bento et al., 2010). A calibrated load cell (*Kratos, model* CZC500) was firmly attached to the segment by an inextensible cable and anchored near the malleolus by a Velcro strap system. The force-time signals were sampled at 1000Hz (*Kratos, model IK- 1C*) and converted into a digital format (*National Instruments, model NI USB 6218*).

The impulse (I) was calculated by determining the area under the torque-time curve [Ruggiero et al, 1988]. The ability of the participants to sustain a maximal effort was determined by the decrease in the rate of torque development during 30s. The rate of torque maintenance (RTM) was determined as the gradient between peak torque and the torque measured at the end of the test (Mohr et al., 2010; Terreri et al., 2001).

Statistical analysis

After data normality and homogeneity confirmation through *Shapiro-Wilk* e *Levene* tests, respectively, the dependent variables were compared running mixed model ANOVA, considering group (SG and CG) and time (pre and post-measurements) as factors. When significant differences were found the Bonferroni adjustment was applied to identify where diferences occurred. The effect size was calculated based on Cohen's *d* (Nakagawa e Cuthill, 2007). Data are presented as mean ± standard deviation. The significance value was fixed at < 5%.

Results

The SG at post-training (163.52 ± 4.5º) increased 14.67% ROM compared with pre-training measure (139.52 ± 5.9º; 95% CI: 137.07 to 141.97; *d* = 4.55; p <0.001). The GC at post-training (141.63 ± 3.8 º; 95% CI: 139.69 to 143.57; *d* = 5.25; p <0.001) increased 1.37% in comparison to CG at pre-training (139.68 ± 4.4º; 95% CI: 137.07 to 142.13; *d* = 0.47; p =0.032). In addition, the rate of torque development increased after the stretching training program comparing pre and post-training (18.13±10.27 $N.s^{-1}$ *vs* 23.34±8.8 $N.s^{-1}$; 95% CI: 17.37 - 24.10; *d* = 0.54; p =0.044). However, there was neither interaction nor main effects to RTM, Pt and I variables (p> 0.05). The results are reported in Table 01 and Figure 02.

Table 1. ROM, isometric peak torque, rate of force development, rate torque maintenance and impulse.

	CG PRE	POST	p	Cohen's *d*	SG PRE	POST	p	Cohen's *d*
ROM	139.68±4.4°	141.63±3.80º*	0.032	0.47	139.52±5.93º	163.52±4.50º**	<0.001	4.55
Δ	1.95±0.6				24.0±1.43			
Pt (Nm)	20.90±5.92	20.72±5.57	0.837	0.03	18.75±6.95	20.00±7.64	0.150	0.17
Δ	-0.18±0.35				1.25±0.69			
RTD ($N.s^{-1}$)	22.32±9.93	21.49±6.7	0.739	0.09	18.13±10.27	23.34±8.8*	0.044	0.54
Δ	-0.83±3.23				5.21±1,47			
RTM (%)	50.09±15.49	42.81±20.56	0.138	0.39	58.73±20.92	54.18±17.24	0.331	0.23
Δ	-7.28±5.07				-4.55±3.68			
I (Nm.s)	417.48±179.21	420.37±195.16	0.930	0.01	339.64±196.38	386.21±232.93	0.160	0.27
Δ	2.89±15.95				46.57±36			

CG: Control Group; SG: Stretching Group. ROM = Range of Motion; Pt= Peak torque, RTD= Rate of torque development, RTM= Rate of torque maintenance, I= Impulse. The data are mean ± standard deviation. *p=0.032 when it was compared pre CG to post CG. **p=0.0001 when it was compared post SG to pre SG and post SG vs pre and post CG.

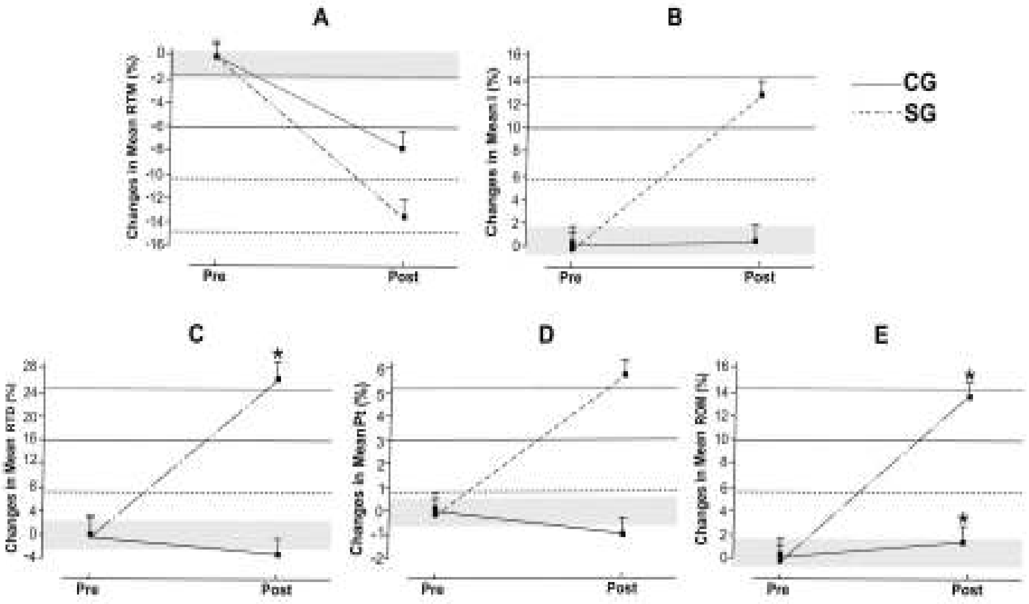

Fig. 2. Changes from baseline, in percentage of RTM, I, RTD, Pt, ROM. CG: Control Group; SG: Stretching Group. A, Rate of torque maintenance (RTM). B, Impulse (I). C, rate of torque development (RTD). D, Peak torque (Pt). E, Range of Motion (ROM). * p<0.05 compared to pre value. The data are mean ± standard deviation.

Dicussion

The aim of the study was to investigate whether six weeks of static hamstring stretching, performed 3 days.wk^{-1} would change the knee flexor ROM and joint torque of young male adults. The main outcome of the study revealed that the stretching protocol increased the knee ROM and the rate of torque development. Moreover, no detrimental effect on torque was observed.

Long-term stretching might remain as a safe strategy to increase ROM without negatively affecting performance, being especially indicated for sports which knee ROM improvements are crucial (ROGAN, et. al., 2013). However, some authors have recommended to exclude static stretching during the training session due to the probability of delaying performance during competition (Yamaguchi et. al., 2006).

Our results identified that static hamstring stretching performed in a routine increased 14% of ROM. This outcome reveals that 3 types of hamstring static stretching performed for 30-s each repetition, lasting 90s volume per type of stretching, in a total of 270s of stretching per session, 3 days.wk^{-1}, for six weeks was sufficient to improve ROM without decreasing isometric torque.

Some studies investigating the effects of 90s and 120s stretching volume per session observed ROM gains without modifying the muscle fascicle length, assessed by ultrasound (Konrad & Tilp, 2014; Lima et al, 2015). Also, the same studies did not find isometric and passive torque changes when 90s and 120s stretching volume was performed. On the other hand, when the stretching volume was augmented to 450s per session, it was detected an increase in the muscle fascicle length but they did not assess the torque (Freitas & Mil-homens, 2015). Thus, the increase in the fascicle length might depend on the stretching volume.

It was found an improvement in the flexibility assessed by the sit-and-reach test and linear sprinting, after 7 weeks of static hamstring stretching, 4 stretching exercises performed for 30-s twice with a 15-s rest between, in a total of 240s of stretching per session, 6 days.wk^{-1}, in young soccer players (Rodriguez et al., 2016). Also, it has been showed enhancement in the flexibility, 35m speed, explosiveness and agility performance, after static stretching training performed in a progressive duration protocol of 15s, 20s, 30s and 30s, during the first, second, third and fourth week of the stretching application, respectively, repeating twice a day, 4 days per week, for 4 weeks (Hadjicharalambous, 2016).

Nevertheless, it would be expected that if chronic stretching was capable to enhance the ROM, it could increase the muscle length and change the length-tension, which might improve the torque maintenance (Weppler et al., 2010; Ferreira et al., 2007). However, the stretching protocol performed in the present study improved only RTD without changing the peak of torque.

The enhancement in the RTD is usually verified when strength and plyometric exercises are performed in a high velocity (Tsoukos et al., 2017; Winchester, et. al., 2008). However, the increment detected in the RTD after the stretching training of the present study shows that the stretching may improve neuromuscular mechanisms, even when the exercise is performed in a slow velocity. This change in RTD should indicate that stretching training would potentially involve alterations in motoneuron recruitment and firing frequency due to some phenomena, such as a gain number of active cross-bridges due to an increase release of Ca^{+2}, an increased sensitivity of the myofilaments to Ca^{+2} and/or a gain force produced by each active cross-bridge (Place et. al., 2010).

Conversely, the stretching protocol of the present study did not change the peak of isometric torque and the capacity to sustain torque. These outcomes could be explained by four aspects: the stretching duration per repetition, 30s, and the stretching volume per session, i.e, 270s, was not a stimulus enough to enhance and maintain the torque; the stretching intensity was not monitored; the week frequency and the period of training. Moreover, the impulse did not present significant changes, indicating that changes in RTD were not able to generate momentum effects, as well.

Other authors did not find increase in the peak torque after 4 weeks static stretching, performed 3 times a week by young males, corroborating with the present data (Laroche et al., 2008). These researchers explained that stretching routine has no apparent effect on muscle force development that could possibly occur because of reduced reflex activity or reduced work absorption induced by stretching exercise. No significant increase was observed in the torque maintenance that might be associated with an activation of other muscles that act in synergy with the main agonist muscles. In general, this mechanism could be a manner of compensation and muscle strategy to support muscle strength (Smilde at al., 2016).

Conclusions

The findings of the current study can contribute to explain the effects of stretching training over the ROM and torque. However, the absence of muscle electrical activity analysis to explain the RTD improvement and skeletal muscle architecture examination to elucidate the effect of ROM gain in the muscle fascicle length may be considered limitations in the present study. Therefore, stretching protocol carried out regularly, as performed in the present study, is effective to increase the range of motion and RTD without changing Pt, I and RTM in young male adults.

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