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ORIGINAL

ACTIVE STRETCHING AND ECCENTRIC LENGTH-TENSION RELATIONSHIP OF HAMSTRING MUSCLES

ESTIRAMIENTO ACTIVO Y RELACIÓN LONGITUD-TENSIÓN EXCÉNTRICA DE LA MUSCULATURA ISQUIOSURAL

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ABSTRACT

The purpose of this study was to investigate the acute effect of an active lower limb stretching routine with a sports-related training load on the hamstring eccentric length-tension relationship. 49 recreational sportsmen completed three assessment sessions, an initial familiarization session and two experimental sessions (control and stretching in random order). Immediately after the interventions (stretching or control), eccentric isokinetic peak torque, maximum force angle and total work were measured in prone position. If the alteration of the eccentric length-tension relationship could be used as a primary risk factor of hamstring muscle strains, the findings of the present study tentatively suggest that static stretching would not be able to alter the relative risk of hamstring muscles.

KEY WORDS: eccentric strength, muscle strains, sports injuries, warm-up, torque, physical rehabilitation.

RESUMEN

El objetivo de este estudio fue investigar el efecto agudo de una rutina de estiramientos estático activos para la extremidad inferior, con parámetros de la carga contextualizados respecto a la realidad físico-deportiva, sobre la relación tensión-longitud excéntrica de la musculatura isquiosural. 49 deportistas recreativos completaron tres sesiones de evaluación, una inicial de familiarización y dos experimentales (control y estiramientos). Inmediatamente después de ambos tratamientos (control y estiramientos), se valoraron los parámetros isocinéticos pico de fuerza máxima excéntrico, ángulo de fuerza máxima excéntrico y trabajo total excéntrico empleando para ello una posición de tendido prono. Si la modificación de la curva tensión-longitud excéntrica puede ser utilizada como factor de riesgo primario de distensiones de la musculatura isquiosural, los hallazgos de este estudio sugieren que el estiramiento estático activo podría no alterar el riesgo relativo de lesión de la musculatura isquiosural.

PALABRAS CLAVE: fuerza excéntrica, desgarros musculares, lesiones deportivas, calentamiento, torque, rehabilitación física.

1. INTRODUCTION

Stretching routines as an essential part of the warm-up previous to a sports performance has been highly recommended with the aim of optimizing the functions of the skeletal muscle system, and, as a result, improvising the sports performance (Shellock & Prentice, 1985) and shrinking the risk of injury (Croiser, Forthomme, Namurois, Vanderthommen & Crielaard, 2002; Wiltvrouw, Mahieu, Danneels & McNair, 2004; Woods, Bishop & Jones, 2007).

However, recent evidence has questioned the traditional hypothesis that recommends stretching routines as a preventive measure to reduce the relative risk of injury (McHugh & Cosgrade, 2010; Thacker, Gilchrist, Stroup & Kimsey, 2004; Woods, Bishop & Jones, 2007). Along this line, some authors have suggested that performing stretching exercises could even increase this relative risk of injury (Shrier, 1999; Weldon & Hill, 2002).

However, neither of the previous theories related to the role of stretching exercises when preventing injuries is correctly verified, since the design of scientific studies involving this controversial issue is inappropriate. Therefore, Shrier (1999) and Woods, Bishop and Jones (2007) claim that those scientific studies about the effect of stretching exercises on the reduction of relative injury risk have also included warm-ups as co-interventions, as well as an inappropriate consideration of the optimum stretching load (intensity, duration and frequency) of the programs assessed. Along this line, another powerful bias or error of these studies' results could lie in the fact that all them investigate the effect of stretching on a total number of injuries occurred during a specific period of time, while the effect of stretching on a specific type of injury was obviated (McHugh & Cosgrade, 2010).

In order to be able to determine the role that stretching exercises have regarding injury prevention, McHugh & Cosgrade (2010), in a recent literature review, establish that the effect of stretching exercises on the probability of developing an injury should be evaluated in a specific pathology (Muscle strains, ligament tears, tendinopathies…) focusing the attention on a primary risk factor in particular. These authors justify their suggestion with the well proved fact that injury risks within sports is multifactorial and generally specific to the physical demands of the sport practiced.

Numerous epidemiological studies have reported that hamstring muscle strains are one of the most common injuries in sports involving activities with a high incidence of stretch-shortening cycle (football, basketball, volleyball), such us maximum accelerations and sudden braking, rapid direction changes and actions of jumping and falling (Agel, Arendt & Breshadsky, 2005; Bahr & Krosshaug, 2005; Hootman, Dick & Agel, 2007). In this sense, recent scientific studies indicate that the proportion of hamstring strains seems to have increased in the last few years, with a range of 12-16% of all sports injuries (Arnason, Gudmundsson, Dahl & Johannsson, 1996; Arnason, Sigurdssin, Gudmundsson, Holeme, Engebretsen & Bahr, 2004; Hawkins, Hulse, Wilkinson, Hodson & Gibson, 2001; Woods, Hawkins, Maltby, Hulse, Thomas & Hodson, 2004). At the same time, hamstring strains present the highest rate of all sports injuries’ relapse, with values around 12-34% (Orchard & Seward, 2002; Sherry & Best, 2004).

Injury incidence data warn that hamstring strains mainly occur during the last part of the swing phase or the early contact phase of the sprint, where hamstring muscles assume a function of sudden deceleration of knee extension to perform later an action of hip extension (Sherry & Best, 2004; Woods et al., 2004). This means that hamstring muscles must change quickly their function; moving from a eccentric contraction (tensile energy absorption) common of the slowdown of knee extension during the swing phase, to a concentric contraction (release of mechanical energy) as they are the main hip extensor along the gluteus maximus during the contact phase (Sugiura, Saito, Sakuraba, Sakuma & Suzuki, 2008, Thelen, Chumanov, Best, Swanson & Heiderscheit, 2005; Woods et al., 2004). It is precisely during these actions of rapid change of function, absorption (eccentric contraction) and release (concentric contraction) of energy in relative stretch position (angles around 0-40° of knee extension), where scientific studies show that the hamstring is more vulnerable to injury (Beynnon, Johnson, Abate, Fleming & Nichols, 2005; Solomonow, Baratta & D´Ambrosia, 1989; Verrall, Slavotinek, Barnes, Fon & Spriggins, 2001).

Therefore, a great number of authors have claimed that a deficit of eccentric strength and particularly hamstring alterations in the length tension relationship (angle where the moment of maximum strength and the energy absorption ability take place), could be considered as one of the most important primary injury risk factors of hamstring muscles (Croisier, 2004; WItvrouw, Mahieu, Danneels & McNair, 2004; Worrell & Perrin 1992).

From a practical point of view, if stretching exercises during warm-up procedures cause changes in the structure of the eccentric tension-length curve of hamstring muscles, such as the maximum strength moment occurring in the closest angles and/or the reduction of absorption ability or energy release (area under the tension-length curve), this could tentatively mean that sportsmen could find themselves in a vulnerable situation to suffer a hamstring muscles strain.

As a result, the most significant action from the point of view of injury prevention would be to investigate the acute effect of stretching routines on the eccentric length-tension relationship of hamstring muscles. This information could be of vital importance for coaches, physical trainers and other members of the physical activity and sports field, since it would allow them to make justified decisions related to the use of stretching exercises within the warm-up with the aim of reducing hamstring muscles relative injury risk.

However, from authors’ knowledge, there are no scientific studies related to the acute effect of stretching on the eccentric length-tension relationship of hamstring muscles. Therefore, the main aim of this scientific study is to investigate the acute effect of an active static stretching routine to the lower limb with load parameters contextualized with the physical sports situation on the eccentric tension-length relationship of hamstring muscles in recreational athletes.

2. METHOD

2.1. Participants

A total of 25 men (age = 21.3 ± 2.5 years old; height = 176.3 ± 8.4 cm; weight = 74.4 ± 10.8 kg) and 24 women (age = 20.4 ± 1.8 years old; height = 164.7 ± 7.6 cm; weight = 62.9 ± 8.6 kg) young adult recreational athletes (1-5 hours of moderate intensity physical sports activity, a total of 3-5 days a week) completed this study. All participants were asked to maintain their regular levels of physical activity and sports during the whole assessment process, although they were urged to avoid vigorous exercises 48 hours before each evaluation session.

The exclusion criteria established were the following: (a) to present musculoskeletal disorders such as tears in the quadriceps and hamstring muscles, fractures, surgery and/or pain in the spine during the last 6 months previous to the exploratory procedure; (b) to present delayed-onset muscle soreness (stiffness) during any of the two evaluation moments; and (c) not to attend one or more sessions of assessment throughout the data collection process. In addition, an additional exclusion criterion was established for female participants so that none of them could be immersed in the ovulation phase of their menstrual process throughout the data collection phase in order to minimize fluctuations in the rigidity of the muscle-tendon unit and the knee joint laxity (Bell, Myruk, Blackburn, Shultr, Guskiewuz & Padua, 2009**;** Eiling, Bryant, Petersen, Murphy & Hohmann, 2007). All inclusion and exclusion criteria were evaluated by two investigators with extensive experience in the scientific and clinical field (Bachelor of Medicine and Blachelor of Surgery with over 10 years experience). They used a questionnaire of medical and physical and sports assessment. All participants were informed (orally and through an information sheet) of the methodology used, as well as the aims and the study’s possible risks, and an informed consent was signed by each of them. The present study was approved by the Ethical and Scientific Committee of the University of Murcia (Spain).

2.2. Experimental design

A crossover research design, in which each participant performed all experimental treatments, was used to achieve the established objectives.

A week before the start of the experimental phase, all participants were subjected to a familiarization session in order to know the correct technical execution of the stretching exercises and the exploratory procedure to be used by practicing the different active static stretching exercises as well as numerous maximum and sub-maximum attempts of knee flexion and extension using different velocitys (60°/s and 180º/s) and muscle actions (concentric and eccentric). At the same time, another aim of this familiarization session was to minimize a possible learning bias on the results obtained over the entire data collection process. After the familiarization session, each participant was examined on 2 different occasions, with an interval of 72-96 hours between sessions. Thus, during the two experimental sessions in random order (using the software located in http://www.randomizer.org), all participants performed a treatment consisting of static stretching exercises (2 minutes rest) followed by an isokinetic testing (stretching session) or, on the contrary, they only performed the isokinetic testing (control session). The active static stretching routine lasted 12 ± 2 minutes, while isokinetic testing lasted 4 ± 1 minute.

Each assessment session (stretching and control) was carried out by the same two experienced clinicians (one controlled the correct position of the participant during stretching exercises and/or all of the exploratory process and the other directed the test) under the same environmental conditions and times in order to try to minimize the possible influence of the inter-examiner variability and circadian rhythms on the results (Atkinson & Nevill, 1998). Both examiners were blinded to the results obtained by participants in the different evaluation sessions (blind reviewers). In addition, participants were encouraged to perform each of the assessment sessions during the same days and times that they normally perform their physical sport sessions in order to minimize intra-subject variability (Sole, Hamrén Milosavljevic Nicholson & Sullivan practice 2007).

An assessment of the isokinetic strength of the knee joint eccentric flexion movement was carried out in order to determine the hamstring eccentric tension-length relationship individually. The fundamental justification for the use of isokinetic examination to determine the graphic form of the hamstring muscles eccentric tension-length relationship is the fact that: (a) previous studies have shown that the angle-force curve generated during eccentric isokinetic movement of the knee flexion is a good overall indicator of the hamstring muscles eccentric tension-length relationship (Brockett Morgan & Proske, 2001); (b) the most representative isokinetic indices of the angle-force curve (maximum peak force [MPF], maximum strength angle [MSA] and total work [TW]) demonstrated high inter-session reliability (standard error of measurement [SEM] < 10%, intraclass correlationship coefficients [ICC] > 0.90) (Impellizzeri Bizzini Rampinini Cereda & Maffiulet, 2008; Maffiuletti Bizzini Desbrosses, Babault & Munzinge, 2007; Sole et al 2007); and (c) its aim is to ensure that any difference occurred between experimental treatments (stretching and control) is a direct consequence of the stretching protocol carried out, since the selected mono-articular evaluation design minimizes enormously the error bias of possible alterations that a multi-articular exploratory design, for instance vertical jump tests or sprints, could present on force and power production due to intra and inter muscular coordination requires in the implementation of such actions (Manoel Harris-Love, Danoff & Miller, 2008).

2.3. Stretching routine

The active static stretching routine consisted on 5 different unilateral exercises designed to stretch the main lower limb muscle groups involved during race (gluteus, psoas, hamstrings, quadriceps, adductors). They show exercises that sportsmen and physically active people normally perform I their war-ups (figure 1).

Figure 1. Active static stretching exercises

The order of exercises was randomized for each participant in order to eliminate the bias that a specific sequence could present on the results obtained. Each stretching exercise was performed a total of two separated times, keeping the stretching position for 30 seconds (2x30s) thanks to the isometric activation of movement agonist muscle, which allows an improvement in agonist-antagonist muscle coordination (White & Sahrmann, 1994; Winters, Blake, Trost, Marcello-Binker, Lowe, Garber & Wainner, 2004). Both legs were stretched before performing the following exercise. A rest period between contra-lateral leg and/or a 20-s exercise was allowed. The exercise's intensity was established through the subjective and individual sensation of discomfort but not pain.

2.4. Assessment tool

An isokinetic dynamometer Biodex System-3 (Biodex Corp., Shirley, NY, USA) and its computer software was used to determine the most representative indices of isokinetic angle-force curve, that is MPF, MFA and TW during knee maximum eccentric flexion movements. Before the start of each assessment session, the isokinetic device was rigorously calibrated according to the usage instructions established by the commercial firm. The reproducibility of the registration system of the data from the isokinetic dynamometer has been assessed by independent previous studies reporting values of 0.99 in the ICC for functions of position, velocity and measurement force of articular arm (Drouin, Valovich-McLeod, Shultz, Gansneder & Perrin, 2004).

2.5. Isokinetic testing

In each experimental session, only the dominant leg (determined through the medical and physical sport evaluation questionnaire and defined as the preferred leg to kick a ball) was assessed. All participants adopted the prone position on the dynamometer stretcher with fixed hip at 0-10º of flexion and the head in a neutral position as the assessment position (figure 2). Lying prone position (0-10° hip flexion) was selected in place of the sitting posture widely used (80-110 ° hip flexion) for two main reasons: (a) participants in prone lying position, unlike the sitting position, reflect more accurately the body position during functional activities such as running; and (b) prone position best simulates the disposition of the hamstring force-length curve present during the last phase and the beginning of the contact phase of the ability to run at maximum velocity (Worrell, Deny, Armstrong and Perrin, 1990 curve; Worrell, Deny & Perrin, 1989).

The rotation axis of the dynamometer's telescopic arm was strictly aligned with the lateral epicondyle of the knee evaluated. The implement where the force was to be exerted was placed approximately 3 cm from the top edge of the ankle's medial malleolus in a relaxed position. The pelvis, the back of the thigh (near the knee) and the foot were strong and consistently banded in order to focus the movement only on the knee flexion. The range of motion of the assessment process was individually set between 0° (anatomical reference 0) and 90° of active knee flexion. All the configuration of the assessment process, including height and length of the stretcher, height and length of the dynamometer's telescopic arm and the separation between the stretcher and the telescopic arm were individually recorded for each participant during the familiarization session in order to maintain the same disposition during all the assessment sessions. In addition, the configuration of the telescopic arm's brake movement at the end of the range of motion was pre-set at their lowest values (categorized as "hard") to reduce the effect of the leg's slowdown during opposite joint movements (Taylor, Sanders, Howick & Stanley, 1991).

Figure 2. Testing position in prone

The assessment of the knee flexion angle-force curve was conducted through two maximum eccentric actions for each of the two different angular velocities, 60°/s and 180°/s, so that the lowest velocity (60°/s) was always evaluated first. This methodological aspect could facilitate the adaptation to the higher velocitys of knee's eccentric flexion and also reduce the risk of injury (Gaul, 1996). A 20s rest was allowed between consecutive muscle actions. A previous pilot study in our lab with 15 participants with similar characteristics to those of the present study (age and fitness level) showed that when participants had some fatigue they were unable to maintain constant production of the magnitude of energy required to activate and maintain the movement of the dynamometer's telescopic arm during the entire range of motion, producing unwanted braking actions. Therefore, the passive mode of isokinetic testing was selected to ensure that the entire range of motion was evaluated during each cycle.

Participants were verbally encouraged to push/resist as hard and fast as possible the telecopy arm throughout the whole range of motion using standardized keywords such as "resist", "push", "faster", etc.

2.6. Isokinetic measures

For isokinetic parameters MPF, MFA and TW the average of the two trials for each of the two different angular velocitys along the whole exploratory process was selected for subsequent statistical analysis due to the magnitude of the measurement error decreases with the increase of the number of attempts (Portney & Watkins, 1999; Sole et al, 2007). In this sense, Sole et al. (2007) found better precision values for the eccentric MPF index when they used to calculate it the average of the three attempts instead of the best of them.

The MFA and MPF indices represent the maximum force value and its corresponding angle obtained during the constant velocity phase (Brown, Whitehurst and Buchalter, 1994) of each isokinetic movement. Regarding the TW index, it was calculated as the area under the eccentric angle.force curve.

2.7. Reliability study

To determine the inter-session reliability of each of the isokinetic parameters used in this scientific study, a pilot study was conducted with 15 recreational sporsmen (8 men and 7 women) with similar characteristics to this study's participants, using the classic design pre-test and post-test (3-5 days between exploratory sessions). The results showed that all isokinetic parameters had a high inter-session reliability, with values of 0.84 to 0.96 for the ICC and <12% of SEM in all cases. In addition, there were no systematic bias between between the results of both exploratory sessions for each of the isokinetic parameters assessed.

2.8. Statistical Analysis

Prior to any statistical analysis, normal distribution of data was checked by the Kolmogorov-Smirnov test. A descriptive statistics for all isokinetic indices was performed by calculating the mean and standard error of the mean.

A general linear model for repeated measures (treatment [active stretching vs. control] × sex [men vs. women] × Velocity [60°/s vs. 180°/s]) was used to identify significant changes in the mean of values for each of the isokinetic strength indices assessed (Bonferroni post hoc test).

The statistical analysis was performed using SPSS (Statistical Package for Social Sciences v. 16.0 for Windows, SPSS Inc, Chicago) and the statistical significance was set at the level of 95% ($p < 0.05$).

Similarly, a post-hoc statistical power analysis was conducted using the statistical program G*Power 3.1.2 (Faul, Erdfelder & Buchner, 2009; Faul, Erdfelder, Lang & Buchner, 2007). A total of 49 participants were used for the analysis of statistical power. The level of statistical significance was set at $p<0.05$ and the size of effect (d) was set at 0.80.

3. RESULTS

Table 1 shows the descriptive statistics (mean and mean standard error) of isokinetic indices MPF, MFA and TW obtained for each of the experimental sessions (k = 2) during the eccentric movement of knee flexion at 60º and 180º/s separated according to participants gender.

Table 1: Descriptive statistics of isokinetic índices Maximum Peak Force MPF, Maximum Force Angle MFA and Total Work TW of knee eccentric flexion at 60º and 180º/s for both experimental sessions (control and static stretching)*

	Control		Static stretching	
	Men	**Women**	**Men**	**Women**
MPF (Nm)[1,2]				
▪ 60º/s	99,1 ± 4,1	54,1 ± 2,8	96,9 ± 5,0	60,4 ± 3,7
▪ 180º/s	86,1 ± 4,6	58,1 ± 3,4	89,2 ± 4,4	62,1 ± 3,9
MFA (º)[3]				
▪ 60º/s	31,2 ± 4,2	35,1 ± 2,9	34,1 ± 2,9	34,7 ± 3,4
▪ 180º/s	41,1 ± 3,5	41,3 ± 3,1	43,4 ± 2,8	39,5 ± 3,3
TW (J)[1,2]				
▪ 60º/s	111,5 ± 6,4	60,5 ± 3,6	113,1 ± 5,9	68,2 ± 4,6
▪ 180º/s	99,2 ± 5,6	60,7 ± 3,1	93,1 ± 5,8	65,1 ± 3,9

* Values presented as mean ± mean standard error for a sample of 25 men and 24 women.

N: Newton; m: meters; J: joules; º: degrees; s: seconds; [1]: significant effect of gender (p = 0.01); [2]: significant effect for men's velocity (p = 0.02); [3] significant effect for velocity (p < 0.02).

The statistical analysis of eccentric MPF and TW showed the inexistence of interaction for 3 factors (treatment × gender × velocity; p = 0.76), between treatment × velocity (p = 0.54) and treatment × gender (p = 0.63), but it did show a significant interaction between velocity × gender (p = 0.01), as well as the inexistence of significant effect per treatment (p = 0.79). For men, the value of eccentric MPF and TW variables decreased while angular velocity increased. This was not the case for women. In addition, absolute values of both variables were significantly higher in men than in women, regardless the angular velocity used.

The statistical analysis of the MFA did not show the existence of interaction for 3 factors (treatment × gender × velocity; p = 0.45), nor between treatment × velocity (p = 0.65), treatment × gender (p = 0.59) and velocity × gender (p = 0.57), nor significant effect for treatment and gender (p = 0.87). However, a significant interactive effect was shown according to velocity (p = 0.02), so that the mean values of the MFA parameter were lower for 60º/s velocity than to 180º/s, for both men and women.

Finally, the post-hoc analysis revealed a statistical power for this study of 0.75-0.85. Therefore, the sample size could be considered large enough to detect significant interactions (Morton, 2009).

4. DISCUSSION

The results of this study indicate that an active static stretching protocol for the lower limb, with contextualized load parameters regarding the physical and sports situation, produces no alterations in the hamstring tension-length relationship subjected to an eccentric action. This conclusion was based on the fact that the performed stretching exercises did not affect the structure od the angle-force curve expressed through the non-alteration of its most representative isokinetic parameters, that is MPF, MFA and TW.

Although the present study is the first which have determined the acute effect of active static stretching on the characteristics of the hamstring tension-length relationship subjected to eccentric action, the results obtained are consistent with the only two scientific studies (from the authors' awareness) that examined the acute effect of static stretching on the characteristics of the eccentric stress-length relationship of quadriceps in both men (Cramer, Housh, Johnson, Weir, Beck & Coburn, 2007) and asymptomatic women (Cramer, Housh, Coburn, Beck & Johnson, 2006).

In this sense, Cramer et al. (2007) found no significant changes in isokinetic indices PFM and AFM obtained during the eccentric extension knee movement at 60º and 300°/s after the application of a quadriceps passive static stretching protocol, with a total of 480s of stretching volume.

Previous scientific studies have shown that an acute load of static stretching similar to that used in the present study increases the range of functional movement, probably due to a reduced stiffness of the tensile stressed muscle-tendon unit, which theoretically should be translated into a change in the characteristics of the voltage-length relationship (Ogura, Miyahara, Naito, Katamoto & Auki, 2007). Surprisingly, the results of this study, along with findings from the two aforementioned studies (Cramer et al., 2006 and 2007) tentatively suggest that the possible changes in the stiffness of the hamstring muscles as a result of the application of stretching were not expressed through changes in the characteristics of the eccentric tension-length relationship.

Although the exact mechanism by which the active static stretching did not produce changes in the stress-length relationship is currently unknown, one possible theory could be based on the findings made by Wilson, Murphy and Pryor (1994), who observed that the muscle-tendon unit stiffness had a high and significant correlationship with the extent of production of concentric and isometric muscle strength, whereas such relationship was not observed for the production of eccentric strength. These authors concluded that the acute effect of static stretching on the tensile stressed mechanical properties of the muscle-tendon unit could depend on the mode of contraction (Wilson, Murphy & Pryor, 1994).

This theory has recently been supported by a series of studies carried out by Cramer's research team (2004, 2006, 2007a, 2007b and 2008), who observed that an acute load of 480 seconds of quadriceps static stretching produced changes on the concentric and isometric tension-length relationship structure, but not on the eccentric one, all this in asymptomatic adults.

Therefore, this study's results contradict the theory established by certain authours (Shrier, 1999; Weldon & Hill, 2002), who consider that static stretching exercises within the warm-up previous to a sports performance could increase the muscle injury relative risk since it generates a decrease in the magnitude of eccentric strength and an alteration of the absorption capacity of the strain energy of muscle-tendon unit stretched.

Another important contribution of this study that should be highlighted is the fact that no differences in the effect of stretching on the eccentric tension-length relationship by the participants' gender were found. These results suggest that men and women's muscle-tendon unit may respond in kind and magnitude to the active static stretching. These results are consistent to those found by a great number of previous studies (Behm, Bradbury, Haynes, Odre, Leonard & Paddock, 2006; Cramer et al., 2007b; Marek et al., 2005; Young Elias & Power, 2006).

One of the potential limitations of this study was the population used, although the n (49 participants) used in this study is higher than the used in previous studies (Cramer et al 2004, 2006, 2007a, 2007b; Herda, Cramer, Ryanm, Mchugh & Stout, 2008), all were homogeneous in age and level of fitness, and it may slightly limit the external validity of the results. Furthermore, in the present study the effect of static stretching routine on the range of motion and stiffness of muscle groups subjected to stretching was not directly evaluated. Therefore, it is not possible to accurately determine whether the performed stretching exercises increased the range of motion of various joints subjected to tensile stimuli, even if previous studies have demonstrated the efficacy of stretching routines with similar load parameters per muscle group (Ogura et al, 2007; Zakas, Doganis, Galazoulas & Vamvakoudis, 2006).

More scientific studies are needed to determine the acute effect of stretching routines on the eccentric tension-length curve of the hamstring muscles by using different techniques (dynamic, proprioceptive neuromuscular facilitation, passive static) and/or populations under study (high performance athletes, injured subjects).

5. CONCLUSIONS

The results of this study indicate that active static stretching protocol designed for the lower limb (2 sets of 30 seconds per muscle group) produces no alterations in the stress-length relationship subjected to a hamstring eccentric contraction in the population under study. Therefore, if the alteration of the eccentric tension-length curve (reduction in the magnitude of the maximum force and energy absorption capacity; alteration of the optimal angle of force production towards more closed positions of joint movement) may be used as a primary risk factor of hamstring strains, this study's findings suggest that the active static stretching protocol assessed could not change the hamstring injury relative risk.

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