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COMPARISON OF VISCOELASTIC STRESS RELAXATION RESPONSE BETWEEN FLEXIBLE AND INFLEXIBLE INDIVIDUALS

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The aim of this study was to compare the relaxation reaction after viscoelastic stress induced by passive static stretching during 30s between subjects with different flexibility performance. Eighteen male physical education students were randomly assigned to two groups according to flexibility level of knee extension. During the test the individuals should achieve 90% of maximal ROM and maintain the position for 30s while the stress relaxation was measured as relative decrease of torque. The results of this study show significant differences of range of motion (ROM) between the two groups, but no significant difference in stress relaxation. It can be concluded that viscoelastic stress relaxation is similar between subjects with significantly different flexibility performance after 30s passive static stretching.

KEY WORDS: Range of motion, viscoelastic properties, flexibility, stiffness

INTRODUCTION: When tissues are held at a constant length, the force at that length gradually declines and is described as the viscoelastic stress relaxation response (Taylor *et al*., 1990). In that way the stress relaxation is a biomechanical mechanism that depends on the viscoelastic properties of the muscular-tendon unit (MTU) and explains the increase of range of joint motion (ROM) after passive static stretching (Taylor *et al.,* 1990). During passive static stretching, the movement amplitude of the joint remains constant for a certain time in order to cause the viscoelastic relaxation. This biomechanical mechanism represents a tissue accommodation of the muscular-tendon structures that limits the movement amplitude of the joint (Magnusson *et al*., 1996). The limiting structures for ROM are muscle, tendon, skin, subcutaneous tissues, fascias, ligaments, joint capsule, cartilage and bone (Rieman *et al*., 2001; Halbertsma *et al*., 1999; Lieber and Shoemaker, 1992). From all of these structures, the deformation of the connecting tissues, mainly of the perimysium, seems to be the main factor for the passive resistance against stretching (Magnusson *et al*., 1996). The difference in flexibility performance between subjects may be explained by different viscoelastic properties. Since different viscoelastic reactions can be expected for subjects with different flexibility level, the aim of this study was to compare the relaxation reaction after viscoelastic stress induced by passive static stretching between subjects with different flexibility performance.

METHOD: Eighteen male physical education students were randomly assigned to two groups according to flexibility level of knee extension determined by the Flexmachine Test (Peixoto et al., 2007). While seated in the flexmachine with the shank in horizontal position, the ROM angle is defined as 90°. Subjects of Group 1 (high flexibility) were characterized by a ROM of knee extension between 95° and 135° whereas the subjects of Group 2 (low flexibility) had a ROM between 50° and 90°. Mean and standard deviation of age, body mass and height were 24,5±3,0 and 23,83±3,24 years, 66,3±10,47 and 68,05±14,89kg, and 170,3 ± 7,42 and 169,30±8,32cm for Group 1 (high flexibility) and Group 2 (low flexibility) respectively.
All subjects participated in recreational sports but had not participated in any strength or flexibility training program for lower extremities within the last 3 months prior to experiment. The subjects were free of any pathology of lower extremities or lower back at the time of testing and they were included in the study if they had a shortened hamstring defined as a 20

degree knee angle restriction to extension when positioned at 45 degree hip flexion. Only the right lower limb was tested. Prior to study subjects were informed about the purpose of the study and the procedures involved. The study was approved by the local Ethics Committee of the university in accordance with international standards and all subjects signed an informed consent.

Instrumentation: Flexibility performance of the hamstring muscle group was assessed by an isokinetic instrument (*flexmachine)* shown in FIGURE 1, which had been developed by the research group (Peixoto et al., 2007). This instrument consists of two chairs laterally attached to a lever arm where a force plate (Refitronic®, Schmitten, Germany) was positioned. The subject was seated with the trunk at a 95 degree angle to the seat and a 45 degree hip flexion. The pelvis and lower limb were firmly strapped to minimize compensatory movements. This position ensured that subjects' maximal ROM was caused by a tension on the hamstring muscles without involvement of posterior capsule. The lateral condyle of the femur was aligned to the mechanical axis of the *flexmachine* through horizontal and vertical dislocation of the instrument. The calcaneus was placed on the force plate located in the lever arm of the instrument. The torque was measured by the use of a force plate and gravity corrected by the weight of leg and foot. The lever arm angular velocity was a constant 5º/s. The electrical motor (SEW eurodrive, Belo Horizonte, Brazil) of the *flexmachine* which passively extended or flexed the subject's knee was activated by a two buttons remote control.

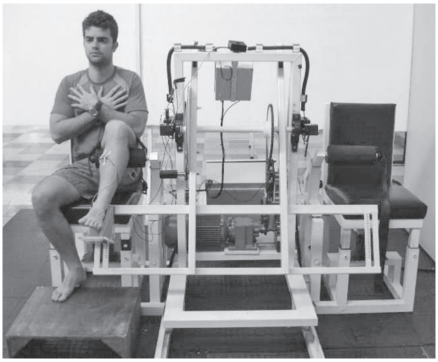

Figure 1: Flexmachine.

Electromyography (EMG) recording: Hamstring and triceps surae electrical activities were measured by Ag/AgCl surface electrodes (Kendall Midi-Trace® 200 Foam) at 1kHz. Hamstring electrodes were placed midway between isquial tuberosity and medial condyle. To place the electrodes over the medial gastrocnemius, subjects were asked to perform a plantar flexion against examiner's resistance. The electrodes were placed on one third of the distance between medial condyle and calcaneus according to McHugh et al. (1992). The EMG signal was full wave rectified and filtered by 15Hz second order Butterworth filter.

The EMG signal was recorded in order to assure that passive torque measures were not influenced by the contractile elements during stretch maneuvers. The registration of EMG signal of hamstring muscle started 2s prior to stretch and was used to calculate the hamstring resting activity (mean ± 2 standard deviation). Maximum ROM and maximum passive torque were considered as the highest registered values without exceeding the EMG resting activity. Therefore, muscle resistive torque due to stretch could be considered passive, since the torque-angle curve registered during stretch maneuver was performed without significant hamstring EMG activity.

Experimental Protocol: A familiarization session was performed at least 24 hours before testing session. At familiarization session body mass, height and lower leg mass were measured. Then volunteers were positioned on *flexmachine* and received all instructions. Each subject performed at least 3 trials until they felt secure to the instrument.

During the testing session, subjects were asked to push the first remote control's button to start the *flexmachine*, so that the lever arm started to move until the maximum tolerated knee ROM was reached. At the moment of the maximum tolerated knee ROM, the subjects pressed the second button, which returned the lever arm to starting position. ROM and torque were measured simultaneously during the whole test procedure. Three measures were obtained at each test and the mean was considered for further analysis.
After determination of flexibility level the subjects performed the passive static stretching test. During the test they should achieve 90% of maximal ROM and maintain the position for 30s while the stress relaxation was measured as relative decrease of torque (% of moment), which is the relative difference (%) between the initial (start of the 30s period) and final (end of the 30s period) passive torque.
Statistical Analysis: Shapiro-Wilks normality test was performed for investigated variables. Viscoelastic stress relaxation ($\triangle torque_{\%}$) and ROM was compared using independent *t* test. Data were analysed with PASW Statistics 18.0 software and statistical significance was established as α=0.05.

RESULTS AND DISCUSSION: Shapiro-Wilks test showed that normal distribution can be assumed for ROM and stress relaxation, so that parametric tests can be applied. The mean and standard deviation of ROM and stress relaxation of both groups are shown in table 1. No significant difference was observed in stress relaxation between the groups. However, ROM was significantly different between the groups.

Table 1
Means and standard deviation of the ROM and viscoelastic stress relaxation

Group	ROM (º)	stress relaxation (% of torque)
HIGH FLEXIBILITY	111,2 ± 9,9*	23,9 ± 6,3
LOW FLEXIBILITY	76,1 ± 10,1	27,9 ± 12,2

(* p<0,05 between groups)

The results of this study show significant differences of range of motion (ROM) between the two groups, but no significant difference in stress relaxation which corroborate the findings of Magnusson *et al*. (2000). While Magnusson *et al.* (2000) applied a 90s period of passive static stretching, this period lasted only 30s in the present study, but no significant difference in stress relaxation could be found in either of the studies. This means that stretching periods between 30 and 90 s result in a similar viscoelastic stress relaxation mechanism. Since stress relaxation follows an exponential function then highest reduction occurs during the first seconds (Taylor *et al*., 1990). Therefore, it was hypothesized that the relaxation after 30s would be different of that after 90s. Nevertheless, the results of this study could not confirm this hypothesis. Another important factor is the intensity of stretching, which was normalized in this study by maximal ROM. Since the individuals with high flexibility (G1) had a greater maximal ROM than the individuals with lower flexibility (G2), they also supported a higher maximal passive stretching moment, which was proved by Magnusson *et al*. (2000). According to Gajdosik *et al.* (2005) higher relative stretching intensities lead to higher stress relaxation. Therefore, it could be expected that the subjects with higher flexibility would also have a higher stress relaxation. Nevertheless, this could not be confirmed, either by Magnusson *et al*. (2000) or by the present study.
In the present study the criterion for differentiation of the two groups was the maximal ROM as a variable that represents passive stiffness. Nevertheless, passive stiffness which is one of the biomechanical characteristics of muscular-tendon tissues (Gajdosik *et al*., 1991), has only little common variance with maximal ROM (R^2 = 0.23; Aquino *et al*., 2006). Therefore, stress relaxation may be different if another criterion for differentiation of the groups, e.g. passive stiffness, were applied. Future studies should investigate this hypothesis.

CONCLUSION: It can be concluded that viscoelastic stress relaxation is similar between subjects with significantly different flexibility performance after 30s passive static stretching. The relation between passive stiffness and stress relaxation should be investigated in future studies.

REFERENCES:

Aquino, C.F.; Gonçalves, G.G.P.; Fonseca, S.T.; Mancini, M.C. Análise da relação entre flexibilidade e rigidez passiva dos isquiotibiais. Rev. Bras. Med. Esporte, v.12, n.4, p.195-200, ago. 2006.

Gajdosik, R.L. Effects of static stretching on the maximal length and resistance to passive stretch of short hamstring muscles. J. Orthop. Sports Phys. Ther., v.14, n.6, p.250-255, Dec. 1991.

Gajdosik, R.L.; Lentz, D.J.; McFarley, D.C.; Meyer, K.M.; Riggin, T.J. Dynamic elastic and static viscoelastic stress-relaxation properties of the calf muscle-tendon unit of men and women. Isokinetics Exerc. Sci., n.14, p.33-44, 2006.

Halbertsma, J.P.K.; Mulder, I.; Göeken, L.N.H.; Eisma, W.H. Repeated passive stretching: Acute effect on the passive muscle moment and extensibility of short hamstrings. Arch. Phys. Med. Rehabil., v.80, n.4, p.407-414, Apr. 1999.

Lieber, R.L.; Shoemaker, S.D. Muscle, joint and tendon contributions to the torque profile of frog hip joint. Am. J. Physiol., v. 263, n. 3 Pt 2, p. R586-R590, 1992.

Magnusson, S.P.; Simonsen, E.B.; Aagaard, P.; Sorensen, H.; Kjaer, M. A mechanism for altered flexibility in human skeletal muscle. J. Physiol., v. 497 (Pt 1), p. 291-298, 1996.

Magnusson, S.P.; Aagaard, P.; Simonsen, E.B.; Bojsen-Moller, F. Passive tensile stress and energy of the human hamstring muscles in vivo. Scand. J. Med. Sci. Sports, v. 10, n. 6, p. 351-359, 2000.

McHugh, M. P., Magnusson, S. P., Gleim, G. W., & Nicholas, J. A. (1992). Viscoelastic stress relaxation in human skeletal muscle. Med. Sci. Sports Exerc.*, 24*(12), 1375-1382.

Peixoto,G. H. C., Moreira Júnior, L. A., Bergamini, J. C., Bhering, E. L., Menzel, H. J., Pertence, A. E. & Chagas, M. H. (2007). The chronic effect of strength and flexibility training on stiffness and range of motion. *XXV ISBS Symposium*, Ouro Preto, Brazil; 436.

Riemann, B.L.; DeMont, R.G.; Ryu, K.; Lephart, S.M. The Effects of sex, joint angle, and the gastrocnemius muscle on passive ankle joint complex stiffness. J. Athl. Train., v.26, n.4, p.369-377, Dec. 2001.

Taylor, D.C.; Dalton, J.D.; Seaber, A.V.; Garrett, W.E. Viscoelastic properties of muscle-tendon units. The biomechanical effects of stretching. Am. J. Sports Med., v. 18, n. 3, p. 300-309, 1990.