COMPARISON OF HAMSTRING EXTENSIBILITY AND SPINAL POSTURE BETWEEN KAYAKERS AND CANOEISTS

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Abstract:

The aims of this study were: 1) to determine the differences in hamstring extensibility between kneeling and forward legs in a group of canoeists; 2) to compare hamstring extensibility between canoeists and kayakers; and 3) to compare the sagittal spinal posture and pelvic tilt in the maximal trunk flexion with knees extended in kayakers and canoeists. Ninety-nine young male paddlers (17.51±6.15 years) (35 kayakers, 35 right-side canoeists and 29 left-side canoeists) participated in this study. Hamstring muscle extensibility was determined in both legs throughout the passive straight-leg raise test (PSLR) and the sit-and-reach test. Sagittal spinal curvatures and pelvic tilt were measured in the maximal trunk flexion with knees extended (sit-and-reach test) using a Spinal Mouse. The hamstring extensibility of the forward leg was higher than the kneeling leg ones in both groups of canoeists (p<.001). No significant differences were found between the right and left legs in kayakers. The kayakers showed the highest values in PSLR, sit-and-reach test, lumbar angle and pelvic tilt, whereas the canoeists obtained the lowest values in the thoracic angle. There were no significant differences between the canoeists who paddle on the left and those that paddle on the right side of the canoe either in the spinal or in the pelvic postures. In conclusion, the asymmetric movement of canoeing is associated with differences in hamstring extensibility between the kneeling and forward legs. The canoeists showed higher extensibility in the forward leg than in the kneeling leg. Furthermore, a greater hamstring extensibility is associated with a lower thoracic angle and higher lumbar flexion and pelvic tilt in the sit-and-reach test.

Key words: *kayakers, canoeists, curves, kneeling leg, forward leg*

Introduction

In recent years, there has been an increasing interest in the study of hamstring muscles (*m. semimembranosus, m. semitendinosus* and *m. biceps femoris*) extensibility and spinal posture in athletes. Hamstring muscles are attached to the ischial tuberosity of the pelvis. As pelvis is considered the base of the spine and its anteroposterior orientation affects the spinal sagittal curvatures (Levine & Whittle, 1996), several studies have analyzed the influence of systematic sport training on hamstring extensibility and/or spinal posture (Kums, Ereline, Gapeyeva, Pääsuke, & Vain, 2007; López-Miñarro, Muyor, & Alacid, 2011b; Muyor, López-Miñarro, & Alacid, 2011b; Rajabi, Doherty, Goodarzi, & Hemayattalab, 2008). Flexibility of hamstring muscles is important in the prevention of muscular and postural imbalances, maintenance of the full range of joint movement and optimal musculoskeletal function. Shortened hamstring muscles may create imbalance in joints and faulty postural alignments that may lead to joint dysfunction (Praveen, 2011). Clinical observations have suggested that limited hamstring flexibility is very common in general populations (Hellsing, 1988) as well as in athletes (Witvrouw, Danneels, Asselmann, Dhave, & Cambier, 2003) and is associated with several musculoskeletal alterations, including specific lumbar disorders such as low-back pain (Biering-Sorensen, 1984) and changes in lumbo-pelvic rhythm (Esola, McClure, Fitzgerald, & Siegler, 1996).

Many studies have analyzed the hamstring extensibility in different athletes like paddlers (López-Miñarro, Alacid, Ferragut, & García, 2008a; López-

Miñarro, Alacid, & Muyor, 2009; López-Miñarro, Alacid, & Rodríguez, 2010a), cyclists (Muyor, et al., 2011b), runners (Trehearn & Buresh, 2009), rowers (Stutchfield & Coleman, 2006) and karate athletes (Probst, Fletcher, & Seelig, 2007). Some of these studies have revealed reduced hamstring extensibility when it is defined as a passive hip angle lower than 80° (Kendall, McCreary, & Provance, 1993). Other studies have found similar or lower straight-leg raise angles when comparing athletes with sedentary people.

When comparing extensibility values for both legs in sports such as cycling, running, and kayaking, most studies have found no significant differences between them (López-Miñarro, et al., 2008a, 2009, 2010a; Muyor, et al., 2011b). Some studies have analyzed the influence of training in tennis and soccer on hip rotation or muscle strength (Ellenbecker, et al., 2007; Rahnama, Lees, & Bambaecichi, 2005) and found bilateral differences with regard to the dominant side. Radaš and Trošt (2011) found sport-specific postural problems in relation to asymmetric overload. However, neither study has analyzed the influence of unilateral movements in canoeists with regard to the side on which they paddle.

Canoeists practice for many hours in a canoe, kneeling on one knee (the kneeling leg) which is placed on a knee brace on the low part of the craft, while the other leg (forward leg) is located at the front. Canoeists paddle only on the side of the kneeling leg (Figure 1). The trunk is flexed, with moderate lateral flexion and a slight rotation (Cox, 1992). It is hypothesized that this position may cause hamstring extensibility differences between the kneeling and forward legs. On the other hand, kayakers are sitting in the boat with their knees slightly bent, and body position and movements are similar on both sides of the body. The kayaking movement is bilateral and symmetrical and it requires a great inclination of the spine in the transverse plane (Cox, 1992). López-Miñarro et al. (2008a) compared hamstring extensibility between kayakers and canoeists, finding no significant differences between the two groups. However, no analysis regarding hand-paddling side was performed.

Figure 1. Canoeists′ position on the boat

Hamstring extensibility influences pelvic posture (Congdon, Bohannin, & Tiberio, 2005) and spinal curvatures (López-Miñarro & Alacid, 2010). Decreased extensibility of hamstring muscles has been associated with a greater thoracic kyphosis and a more posterior pelvic tilt when maximal trunk flexion with knees extended is performed. Consequently, these postures increase intervertebral stress (Beach, Parkinson, Stothart, & Callaghan, 2005), as well as thoracic and lumbar intradiscal pressure (Polga, et al., 2004; Wilke, Neef, Caimi, Hoogland, & Claes, 1999), predisposing subjects to spinal disorders (McGill, 2002). In a comparative study in paddlers, López-Miñarro, Muyor, and Alacid (2011a) determined that lower hamstring extensibility was associated with an increased thoracic spinal flexion and a posterior pelvic tilt when paddlers are sitting in a canoe. This may cause overloading of the spine during paddling practice.

For these reasons, the aims of this study were: 1) to determine the differences in hamstring extensibility between kneeling and forward legs in a group of canoeists; 2) to compare hamstring extensibility between canoeists and kayakers; and 3) to compare the sagittal spinal posture and pelvic tilt in the maximal trunk flexion, with knees extended, between kayakers and canoeists.

Methods

Participants

Ninety-nine young male paddlers (35 kayakers, 35 right-handed canoeists and 29 left-handed canoeists) participated in this study (Table 1). They were selected by the Royal Spanish Canoeing Federation as the best in their categories to participate in the National Development Camp between 2009 and 2011. Inclusion criteria were: previous experience training of more than four years and training volume of six or more hours a week at least three days a week. Paddlers were excluded if they presented pain induced or exacerbated by the testing procedures, injury-prevented participation in paddling training before testing or any known structural spinal pathology.

Variables

The Institutional Ethical Committee of the University of Murcia approved the study and a written informed consent form was obtained from the subjects or their parents before the experiment.

Hamstring muscles extensibility was determined in both legs using the passive straight-leg raise test (PSLR) and the sit-and-reach test. Sagittal spinal curvatures and pelvic tilt were measured in the sit-and-reach test using a Spinal Mouse sys-

Table 1. Characteristics of paddlers

	n	Age (years)	Height (cm)	Body mass (kg)
Kayakers	35	17.77±6.85	174.67±6.36	70.70±10.51
Canoeists (right-handed)	35	17.14±5.34	173.14±7.76	71.13±13.22
Canoeists (left-handed)	29	17.21±5.80	169.53±8.39	68.84±10.08

tem (Idiag, Fehraltdorf, Switzerland). The measurements were performed in a randomized order. The laboratory temperature was standardized at 24° C.

Prior to the measurement, all paddlers performed three minutes of standardized static stretching exercises aiming at the lower back and hamstring muscles. Exercises included seated lower-back stretch and unilateral supine hamstring stretch. Each exercise was done twice to the point of moderate discomfort and the position was held for 15 seconds. This warm-up was performed because: 1) the tests involved a considerable hamstring tension stimulus and 2) to lessen the effects of muscle lengthening from repeated trials during data collection (Castro-Piñero, Chillon, Ortega, Montesinos, Sjöström, & Ruiz, 2009). Furthermore, pre-stretching may decrease fluctuation or error in SLR measurements (Dixon & Keating, 2000).

Passive straight-leg raise test

Passive straight-leg raise test (PSLR) was conducted in a counterbalanced order. The subjects were positioned in supine position with the lower extremity at 0º of hip flexion. While the participant was in the supine position, a Uni-Level inclinometer (ISOMED, Inc., Portland, OR, USA) was placed over the distal tibia in order to measure the inclination. A Lumbosant was positioned under the lumbar spine and pelvis during the test (Santonja, Sainz de Baranda, Rodríguez, & López-Miñarro, 2007). The participant's leg was lifted passively by the tester into a hip flexion. The knee remained straight during the leg raise while the pelvis and the other leg were fixed by an assistant to avoid the posterior pelvic tilt. The criterion score of hamstring extensibility was the maximum angle (degree) read from the inclinometer at the point of the maximum hip flexion. Moreover, the ankle of the tested leg was restrained in maximum plantar flexion to avoid adverse neutral tension (Gajdosik, Leveau, & Bohannon, 1985). Two trials were given for each leg and the average on each side was used for subsequent analysis.

Straight-leg raise values were classified into four categories (SLR≥80º; SLR 75-79º; SLR 70-74º and SLR<70º). These categories were based on different reference values for determining decreased or normal hamstring flexibility: 80º (Kendall, et al., 1993), 75º (Ferrer, 1998) or 70º (Li, McClure, & Pratt, 1996; Gajdosik, Albert, & Mitman, 1994).

Maximal trunk flexion with extended knees (sit-and-reach test)

The subjects were required to sit with their knees straight, the legs together and the soles of the feet positioned flat against the end of a sit-and-reach box (height = 32 cm). A standard meter ruler was placed on the sit-and-reach box; 0 cm mark represented the point at which the subjects' fingertips were in line with their toes. With their palms downwards, the subjects placed one hand on the top of the other and slowly reached forward as far as possible. The subjects slid their hands along the box, keeping their knees as straight as possible, and held the resulting position for approximately five seconds while the spinal curvatures and pelvic inclination were measured.

Spinal curvatures and pelvic tilt measurements

The Spinal Mouse system (Idiag, Fehraltdorf, Switzerland), a hand-held computer-assisted electromechanical-based device was used to measure sagittal spinal curvatures and pelvic inclination in the sit-and-reach test.

Prior to the measurements, the principal researcher determined the spinous processes of C7 (starting point) and the top of the anal crease (end point) by palpation, and marked these points on the skin with a pencil. The Spinal Mouse was guided along the midline of the spine (or slightly paravertebrally in particularly thin individuals with prominent spinous processes) starting at the spinous processes of C7 and finishing at the top of the anal crease (approximately S3). The thoracic (T1-2 to T11-12) and lumbar (T12-L1 to the sacrum) spine and the pelvic tilt values (the difference between the sacral angle and the vertical) were collected. In the lumbar curve, positive values corresponded to lumbar kyphosis. As for the pelvic inclination, a value of 0º represented the vertical position. Thus, a greater angle corresponded to an anterior pelvic tilt while a lower angle (negative values) reflected a posterior pelvic tilt.

Statistical analyses

The hypothesis of normality was analyzed via Shapiro-Wilk test. Parametric data analysis methods were used because the data were normally distributed. Descriptive statistics of variables, including means and standard deviations, were calculated. One-way analysis of variance (ANOVA) was used to identify the differences among the three groups. Significant F-ratios were followed by Bonferroni's *post-hoc* analysis to examine pairwise group differences. A paired *t*-test was used to compare straight-leg raise values between both legs in each group. The level of significance was set at $p \leq .05$. Data were analyzed using the Statistical Package for Social Sciences (SPSS Inc, version 15.0, Chicago, IL, USA).

Results

The mean values of PSLR test are presented in Table 2. There were significant differences ($p<.001$) between the right and the left leg in both groups of canoeists. The forward leg values were significantly higher than those for the kneeling leg. No significant differences were found in kayakers between the legs. Additionally, the kayakers demonstrated greater hamstring extensibility values than the canoeists in both the PSLR and the sit-and-reach score. The proportions of paddlers in each category of straight-leg raise angle are presented in Table 3. The data revealed a greater proportion of canoeists with reduced hamstring extensibility.

Table 4 reports the mean values of spinal curvatures and pelvic tilt in the sit-and-reach test. Kayakers demonstrated the highest values in the sit-and-reach test, lumbar angle and pelvic tilt. The left-handed canoeists showed the lowest values in the SR score and pelvic tilt, whereas the right-handed canoeists had the lowest values in the lumbar angle. The kayakers showed the lowest values in the thoracic angle, in contrast to the left-handed canoeists, who obtained the highest scores. There were no significant differences in spinal and pelvic postures between the canoeists who paddled on either the right or the left side of the canoe.

Table 2. Mean ± standard deviation of passive straight-leg raise test in kayakers and canoeists

	PSLR right leg	PSLR left leg
Kayakers	74.66±12.77º	74.58±12.73º
Canoeists (right-handed)	64.31±13.94º	72.57±13.29º*
Canoeists (left-handed)	70.70±14.65º	61.80±11.49º*

PSLR: passive straight-leg raise test; *p<.001 respect to right leg.

Table 3. Percentage of paddlers in each category of the straight-leg raise angle

	Canoeists		Kayakers	
	kneeling leg	forward leg	Right leg	Left leg
SLR≥80º	17.18%	28.57%	68.57%	68.57%
SLR 75º-79º	12.50%	12.50%	11.43%	14.29%
SLR 70-74º	9.37%	18.75%	11.43%	11.43%
SLR<70º	60.93%	40.63%	8.57%	5.71%

SLR: straight-leg raise test

Table 4. Score, spinal curvatures and pelvic tilt in the sit-and-reach test

	Canoeists (right-side)	Canoeists (left-side)	Kayakers
SR score (cm)	-0.50±9.15	-3.22±7.79†	4.19±6.62
Thoracic angle SR (degrees)	64.97±9.56	67.00±9.75‡	59.50±13.22
Lumbar angle SR (degrees)	28.94±6.73	29.03±7.06	31.21±7.80
Pelvic tilt SR (degrees)	-12.80±10.49*	-16.47±7.90*	-6.89±11.97

SR: sit-and-reach test; *p<.05; † p<.01; ‡ p<.001 with respect to kayakers.

Discussion and conclusions

The main purpose of this study was to determine the differences in hamstring extensibility between the kneeling and the forward legs in a group of canoeists. Previous studies have measured hamstring extensibility in paddlers, but no differences between the kneeling and the forward legs in canoeists were analyzed. The principal finding was that in canoeists the forward leg extensibility values were significantly higher than the kneeling leg values. In straight-leg raise, the mean difference was approximately 6-11º between the legs. This fact is related to the asymmetric position and movement in the canoe. Canoeists practice for many hours in a kneeling position and this posture ensures that the forward leg has more movement than the kneeling leg during the stroke. Also, the knee of the forward leg is slightly flexed in the paddling action while the trunk and pelvis are moderately flexed. This position generates a slight stimulus of hamstring stretching; therefore, these factors would explain the differences in hamstring extensibility between the legs. In a previous study, López-Miñarro et al. (2008a) analyzed the differences between left and right legs in canoeists and reported no significant differences between them. However, no differentiation between paddling sides was done. As for the kayakers, no significant differences between the legs were found in the current study, perhaps due to the similar postures and movements that kayakers perform with both legs. These results are in accordance with previous studies (López-Miñarro, et al., 2008a, 2011a).

Some studies have also found sport adaptations on flexibility in different athletes. Stutchfield and Coleman (2006) analyzed a group of rowers and found differences with regard to leg dominance in the stroke. Probst et al. (2007) studied a sample of karate athletes. They indicated that greater hip flexor flexibility in the dominant leg may be a training effect related to repeated flexion of the hip joint during the early phase of kicking.

When hamstring extensibility values were analyzed between paddling disciplines, the kayakers reached greater hamstring extensibility values than the canoeist in both the straight-leg raise and sit-and-reach score. The kayakers showed the highest values in the sit-and-reach score, followed by the canoeists who paddled on the right and on the left side of the canoe, respectively. Those paddlers who achieved the highest values in the PSLR also reached the highest values in the SR. Similar results were obtained by López-Miñarro et al. (2008a, 2010), who also revealed the differences between kayakers and canoeists in extensibility. The greater extensibility of kayakers could be a consequence of their position in the boat as this position causes higher hamstring traction stimulus than the canoeist´s position (López-Miñarro, et al., 2010a). When the straight-leg raise values were classified in several angle categories (SLR≥80º; SLR 75-79º; SLR 70-74º and SLR<70º) the data distribution showed a moderate percentage of kayakers (31.43%) with the values lower than 80º. In the canoeists' group the percentages were far greater. The SLR angle of 80º was proposed by Kendall et al. (1993) as a cut-off score to indicate reduced hamstring muscle extensibility. However, some authors have proposed other cut-off angles. When taking 70º as the limit value for considering short or normal hamstring extensibility (Li, et al., 1996; Gajdosik, et al., 1994), the proportion of kayakers with a limited hamstring flexibility decreases. In contrast, there are many canoeists with SLR angles below this value, especially in the kneeling leg. In consideration of these angle references, the results suggest that a hamstring-specific extensibility program is necessary for this group of paddlers, especially for canoeists.

Previous research proposed to include hamstring stretching maintaining neutral spinal curvatures in kayakers because hamstring extensibility influences the position in the boat and trunk flexion positions (López-Miñarro, Muyor, & Alacid, 2011a,b). Moreover, it is important to design specific programs for canoeists with different stretching exercise volume depending on the side of paddling to compensate for the differences in extensibility between both legs.

The analysis of spinal posture in the sit-and-reach test showed greater thoracic curves in canoeists. This finding is in agreement with several studies involving paddlers (López-Miñarro, et al., 2009; López-Miñarro, Alacid, Ferragut, & García, 2008b; Muyor, Alacid, & López-Miñarro, 2011a). The greater thoracic curve in canoeists may be related to their lower hamstring extensibility (López-Miñarro, et al., 2008a) that produces changes in lumbo-pelvic rhythm. Lower hamstring extensibility reduces pelvic flexion and increases thoracic flexion (López-Miñarro & Alacid, 2010; López-Miñarro, Muyor, Belmonte, & Alacid, 2012). Furthermore, thoracic hyperkyphosis in standing is frequent in paddlers (López-Miñarro, et al., 2011b; Muyor, et al., 2011a), but may be associated with factors other than the posture and movement in the boat because thoracic kyphosis is significantly more reduced in the canoe than in relaxed standing position for both canoeists and kayakers (López-Miñarro, et al., 2011b).

The lumbar angle in the sit-and-reach test was higher in kayakers than in canoeists, similarly to the results reported by Lopez-Miñarro et al. (2008b). However, no significant differences were detected. The subjects with greater hamstring extensibility reached higher lumbar flexion values in the sit-and-reach test (López-Miñarro & Alacid, 2010; López-Miñarro, et al., 2011a). This posture is also related to the pelvic position when the maximal trunk flexion with knees extended is performed. In addition, the position of kayakers in their boat is sitting with knees slightly flexed. Thus, in this posture, the lumbar spine adopts a static and prolonged kyphotic posture (López-Miñarro, Muyor, & Alacid, 2010b). This posture has been related to a creep deformation in the spinal ligaments and associated with a higher intervertebral range of motion (Solomonow, 2004).

Pelvic inclination is related to hamstring extensibility (López-Miñarro & Alacid, 2010). The canoeists who paddled on the left side of the canoe showed the lowest values in pelvic tilt. Anterior pelvic tilt in the sit-and-reach is limited when hamstring muscles are shortened (Shin, Shu, Li, Jiang, & Mirka, 2004). Paddlers with lower extensibility presented a more posterior pelvic tilt in the sit-and-reach test and when sitting in a boat (López-Miñarro, et al., 2011a,c).

The results of the current study have several implications for the training process. The evaluation of hamstring flexibility is necessary because a high percentage of paddlers (more important in canoeists) show decreasing flexibility and this variable influences pelvic and spinal postures in trunk-bending positions and in the boat (López-Miñarro & Alacid, 2010; López-Miñarro, et al., 2011a,b,c). As for the canoeists, the evaluation of both legs using any angular test (knee extension or straight-leg raise tests) is recommended. A hamstring-specific extensibility program is more necessary for canoeists. This program should include a higher stretching volume for the kneeling leg.

An important limitation of the current study was that the sample size was small and included only young paddlers; thus, the results cannot be generalized to other populations and must be treated with some caution. Higher training exposure might change the evolution of spinal curvatures and hamstring extensibility. Longitudinal studies in elite paddlers are necessary to determine the influence of high training volume on hamstring muscle extensibility and spinal posture.

In conclusion, the asymmetric movement in canoeing is associated with differences in hamstring extensibility between the legs. Canoeing is related to higher extensibility in the forward leg. Furthermore, hamstring extensibility influences spinal and pelvic postures when maximal trunk flexion with knees extended is performed. Greater hamstring extensibility is associated with a lower thoracic angle and higher lumbar flexion, as well as with a greater pelvic tilt in the sit-and-reach test.

References

Beach, T., Parkinson, R., Stothart, P., & Callaghan, J. (2005). Effects of prolonged sitting on the passive flexion stiffness of the in vivo lumbar spine. *The Spine Journal, 5*(2), 145-154.

Biering-Sorensen, F. (1984). Physical measurements as risk indicator for low-back trouble over a one year period. *Spine, 9*(2), 106-119.

Castro-Piñero, J., Chillon, P., Ortega, F.B., Montesinos, J.L., Sjöström, M., & Ruiz, J.R. (2009). Criterion-related validity of sit-and-reach and modified sit-and-reach test for estimating hamstring flexibility in children and adolescents aged 6-17 years. *International Journal of Sports Medicine, 30*(9), 658-662.

Congdon, R., Bohannin, R., & Tiberio, D. (2005). Intrinsic and imposed hamstring length influence posterior pelvic rotation during hip flexion. *Clinical Biomechanics, 20*(9), 947-951.

Cox, R.W. (1992). *The science of canoeing.* Cheshire: Coxburn Press.

Dixon, J., & Keating, J.L. (2000). Variability in straight leg raise measurements. *Physiotherapy, 86*(7), 361-370.

Ellenbecker, T.S., Ellenbecker, G.A., Roetert, E.P., Silva, R.T., Keuter, G., & Sperling, F. (2007). Descriptive profile of hip rotation range of motion in elite tennis players and professional baseball pitchers. *The American Journal of Sports Medicine, 35*(8), 1371-1376.

Esola, M.A., McClure, P.W., Fitzgerald, G.K., & Siegler, S. (1996). Analysis of lumbar spine and hip motion during forward bending in subjects with and without a history of low back pain. *Spine, 21*(1), 71-78.

Ferrer, V. (1998). *Repercusiones de la cortedad isquiosural sobre la pelvis y el raquis lumbar.* [Effects of the reduced hamstring flexibility in pelvis and lumbar spine. In Spanish.] (Unpublished doctoral dissertation, Universidad de Murcia). Murcia: Faculty of Medicine.

Gajdosik, R.L., Leveau, B.F., & Bohannon, R.W. (1985). Effects of ankle dorsiflexion on active and passive unilateral straight leg raising. *Physical Therapy, 65*(10), 1478-1482.

Gajdosik, R.L., Albert, C.R., & Mitman, J.J. (1994). Influence of hamstring length on the standing position and flexion range of motion of the pelvic angle, lumbar angle, and thoracic angle. *Journal of Orthopaedic and Sports Physical Therapy*, *20*(4), 213-219.

Hellsing, A.L. (1988). Tightness of hamstring and psoas mayor muscles. A prospective study of back pain in young men during their military service. *Upsala Journal of Medical Sciences*, *93*(3), 267-276.

Kendall, F.P., McCreary, E.K., & Provance, P.G. (1993). *Muscle Testing and Function*. 4th revised ed. Philadelphia: Lippincott Williams & Wilkins.

Kums, T., Ereline, J., Gapeyeva, H., Pääsuke, M., & Vain, A. (2007). Spinal curvature and trunk muscle tone in rhythmic gymnasts and untrained girls. *Journal of Back and Musculoskeletal Rehabilitation, 20*(2-3), 87-95.

Levine, D., & Whittle, M.W. (1996). The effects of pelvic movement on lumbar lordosis in the standing position. *Journal of Orthopaedic & Sports Physical Therapy, 24*(3), 130-135.

Li, Y., McClure, P.W., & Pratt, N. (1996). The effect of hamstring muscle stretching on standing posture and on lumbar and hip motions during forward bending. *Physical Therapy, 76*(8), 836-849.

López-Miñarro, P.A., & Alacid, F. (2010). Influence of hamstring muscle extensibility on spinal curvatures in young athletes. *Science & Sports, 25*(4), 188-193.

López-Miñarro, P.A., Alacid, F., Ferragut, C., & García, A. (2008a). Valoración y comparación de la extensibilidad isquiosural entre kayakistas y canoistas de categoría infantil. [Measurement and comparison of hamstring extensibility between infantile kayakers and canoeists. In Spanish.] *Motricidad. European Journal of Human Movement, 20*, 97-111.

López-Miñarro, P.A., Alacid, F., Ferragut, C., & García, A. (2008b). Valoración y comparación de la disposición sagital del raquis entre canoístas y kayakistas de categoría infantil. [Measurement and comparison of sagittal spinal curvatures between infantile canoeists and kayakers. In Spanish.] *Cultura, Ciencia y Deporte, 3*(9), 171-176.

López-Miñarro, P.A., Alacid, F., & Muyor, J.M. (2009). Comparación del morfotipo raquídeo y extensibilidad isquiosural entre piragüistas y corredores. [Comparison of spinal curvatures and hamstring extensibility between paddlers and runners. In Spanish.] *Revista Internacional de Medicina y Ciencias de la Actividad F*ísica y del *Deporte, 9*(36), 379-392.

López-Miñarro, P.A., Alacid, F., & Rodriguez, P.L. (2010a). Comparison of sagittal spinal curvatures and hamstring muscle extensibility among young elite paddlers and non-athletes. *International SportMed Journal, 11*(2), 301-312.

López-Miñarro, P.A., Muyor, J.M., & Alacid, F. (2011a). Influence of hamstring extensibility on sagittal spinal curvatures and pelvic tilt in highly trained young kayakers. *European Journal of Sport Science, 12*(6), 469-474.

López-Miñarro, P.A., Muyor, J.M., & Alacid, F. (2011b). Sagittal spinal and pelvic postures of highly-trained young canoeists. *Journal of Human Kinetics, 29*, 41-48.

López-Miñarro, P.A., Muyor, J.M., & Alacid, F. (2010b). Sagittal spinal curvatures and pelvic tilt in elite young kayakers. *Medicina dello Sport, 63*(4), 509-519.

López-Miñarro, P.A., Muyor, J.M., Belmonte, F., & Alacid, F. (2012). Acute effects of hamstring stretching on sagittal spinal curvatures and pelvic tilt. *Journal of Human Kinetics*, *31*, 69-78.

McGill, S.M. (2002). *Low back disorders. Evidence-based prevention and rehabilitation*. Champaign, IL: Human Kinetics.

Muyor, J.M., Alacid, F., & López-Miñarro, P.A. (2011a). Sagittal spinal morphology in young highly-trained paddlers. *International Journal of Morphology, 29*(3), 1047-1053.

Muyor, J.M., López-Miñarro, P.A., & Alacid, F. (2011b). Influence of hamstring muscles extensibility on spinal curvatures and pelvic tilt in highly trained cyclists. *Journal of Human Kinetics, 29*(41-48), 15-23.

Polga, D.J., Beaubien, B.P., Kallemeier, P.M., Schellhas, K.P., Lee, W.D., Buttermann, G.R., & Wood, K.B. (2004). Measurement of in vivo intradiscal pressure in healthy thoracic intervertebral discs. *Spine Journal, 29*(12), 1320-1324.

Praveen, G. (2011). Comparison of cyclic loading and hold relax technique in increasing resting length of hamstring muscles. *Hong Kong Physiotherapy Journal, 29*(1), 31-33.

Probst, M.M., Fletcher, R., & Seelig, D.S. (2007). A comparison of lower-body flexibility, strength, and knee stability between karate athletes and active controls. *The Journal of Strength & Conditioning Research, 21*(2), 451-455.

Radaš, J., & Trošt, T. (2011). Posture in top-level Croatian rhythmic gymnasts and non-trainees. *Kinesiology, 43*(1), 64-73.

Rahnama, N., Lees, A., & Bambaecichi, E. (2005). Comparison of muscle strength and flexibility between the preferred and non-preferred leg in English soccer players. *Ergonomics, 48*(11-14), 1568-1575.

Rajabi, R., Doherty, P., Goodarzi, M., & Hemayattalab, R. (2008). Comparison of thoracic kyphosis in two groups of elite Greco-Roman and free style wrestlers and a group of non-athletic subjects. *British Journal of Sports Medicine, 42*(3), 229-232.

Santonja, F.M., Sainz De Baranda, P., Rodríguez, P.L., & López-Miñarro, P.A. (2007). Effects of frequency of static stretching on straight-leg raise in elementary school children. *Journal of Sports Medicine and Physical Fitness, 47*(3), 304-308.

Shin, G., Shu, Y., Li, Z., Jiang, Z., & Mirka, G. (2004). Influence of knee angle and individual flexibility on the flexion-relaxation response of the low back musculature. *Journal of Electromyography and Kinesiology, 14*(4), 485-494.

Solomonow, M. (2004). Ligaments: A source of work-related musculoskeletal disorders. *Journal of Electromyography and Kinesiology, 14*(1):49-60.

Stutchfield, B.M., & Coleman, S. (2006). The relationships between hamstring flexibility, lumbar flexion, and low back pain in rowers. *European Journal of Sport Science, 6*(4), 255-260.

Trehearn, T., & Buresh, R. (2009). Sit-and-reach flexibility and running economy of men and women collegiate distance runners. *Journal of Strength and Conditioning Research, 23*(1), 158-162.

Wilke, H., Neef, P., Caimi, M., Hoogland, T., & Claes, L. (1999). New in vivo measurements of pressures in the intervertebral disc in daily life. *The Spine Journal, 24*(8), 755-762.

Witvrouw, E., Danneels, L., Asselman, P., D´Have, T., & Cambier, D. (2003). Muscle flexibility as a risk factor for developing muscle injuries in male professional soccer players. A prospective study. *The American Journal of Sports Medicine, 31*(1), 41-46.

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USPOREDBA FLEKSIBILNOSTI MIŠIĆA STRAŽNJE STRANE NATKOLJENICE I POLOŽAJA KRALJEŽNICE U KAJAKAŠA I KANUISTA

Svrha ovog istraživanja bila je: 1) utvrditi razlike u fleksibilnosti stražnje strane natkoljenice između noge u kleku i prednje noge u skupini kanuista, 2) usporediti fleksibilnost stražnje strane natkoljenice između kanuista i kajakaša te 3) usporediti sagitalni položaj kralježnice i kut zdjelice u maksimalnoj fleksiji trupa ispruženih nogu u kajakaša i kanuista. U istraživanju je sudjelovalo devedeset i devet mladih (dob 17,51 ± 6,15 godina) muških kanuista i kajakaša (35 kajakaša te 35 kanuista koji veslaju s desne strane i 29 kanuista koji veslaju s lijeve strane). Fleksibilnost stražnje strane natkoljenice mjerena je na obje noge testovima: prednoženje pružene noge iz ležanja na leđima i testom '*sit-and-reach*'. Sagitalna zakrivljenost kralježnice i nagib zdjelice izmjereni su u maksimalnoj fleksiji trupa s pruženim nogama (test *sit-and-reach*) upotrebom sprave 'Spinal Mouse'. Utvrđeno je da je fleksibilnost stražnje strane natkoljenice prednje noge značajno veća od fleksibilnosti noge u kleku u obje skupine kanuista (p<0,001). Nije utvrđena statistički značajna razlika između fleksibilnosti lijeve i desne noge u kajakaša. Kajakaši su ostvarili najviše vrijednosti u testovima prednoženje iz ležanja, *sit-and-reach*, lumbalnom kutu i nagibu zdjelice, dok su kanuisti postigli najniže vrijednosti u prsnom kutu. Nije utvrđena značajna razlika u položajima kralježnice ili zdjelice između kanuista koji veslaju s različitih strana kanua. Zaključno, asimetrični pokreti u kanuu povezani su s razlikama u fleksibilnosti stražnje strane natkoljenice između noge u kleku i prednje noge. U kanuista je fleksibilnost prednje noge veća od fleksibilnosti noge u kleku. Osim toga, veća fleksibilnost stražnje strane natkoljenice povezana je s nižim prsnim kutom te većom lumbalnom fleksijom i većim nagibom zdjelice u testu *sit-and-reach*.

Ključne riječi: *kajakaši, kanuisti, zakrivljenost kralježnice, noga u kleku, prednja noga*

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