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ORIGINAL

SAGITTAL SPINAL CURVATURES AND PELVIC INCLINATION IN KAYAKERS

DISPOSICIÓN SAGITAL DEL RAQUIS E INCLINACIÓN PÉLVICA EN KAYAKISTAS

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ABSTRACT

The aim of the present study was to compare in different positions the sagittal spinal curvature and pelvic tilt in kayakers. One hundred and thirty kayakers between 15 and 20 years old (62 males and 68 females) participated in this study. Thoracic and lumbar curvatures and pelvic position were evaluated with a Spinal Mouse system in standing position, slumped sitting, maximal trunk flexion with knees flexed, sit-and-reach test, base position,right entry position and left entry position on a kayak ergometer. Thoracic kyphosis in the kayak ergometer was more reduced ($p<0.001$) than standing and slumped sitting. Lumbar spine adopted kyphotic postures when maximal trunk flexion was performed and in the kayak ergometer. This posture was related to posterior pelvic tilt. During paddling on ergometer the pelvic and lumbar tilt were lower in females. In conclusion, the posture observed in females while paddling on ergometer is defined by a more aligned spine and pelvis postures.

KEYWORDS: Spine, thoracic, lumbar spine, pelvis, sport, gender.

RESUMEN

El objetivo del estudio fue comparar la disposición sagital del raquis e inclinación pélvica en diferentes posiciones en kayakistas. A ciento treinta kayakistas entre 15 y 20 años (62 varones y 68 mujeres) se les evaluó, mediante un Spinal Mouse, la disposición angular del raquis torácico, lumbar e inclinación pélvica en bipedestación, sedentación relajada, máxima flexión del tronco en sedentación, test *sit-and-reach*, posición de base y de ataque en un kayak-ergómetro. La cifosis torácica en la piragua fue menor ($p<0,001$) que en bipedestación y sedentación relajada. El raquis lumbar se dispuso en inversión lumbar en las posturas de flexión del tronco y sedentación, favorecido por una posición de retroversión pélvica. Las mujeres adoptaron posturas de menor flexión lumbar y pélvica en el kayak-ergómetro. En conclusión, la posición de las mujeres en el kayak-ergómetro se caracteriza por posturas más alineadas del raquis y pelvis.

PALABRAS CLAVE: Columna vertebral, torácica, lumbar, pelvis, deporte, género.

1. INTRODUCTION

Systematic sport training while maintaining static postures during specific cyclic movements has been associated with adjustments in the spinal curvatures (48).

Several studies have assessed the sagittal spinal curvature in different sports: gymnastics (14), skiing (1), fighting (44), kayaking (17-22,29,36), rowing (49), football (51,52), cycling (37-41), and lifting (24,26,27). Other studies have compared the spinal curvatures in heterogeneous samples from different sports (3, 45), observing specific spinal adjustments according to the posture maintained and technical movements of each sport. These researchers have focused the analysis on standing position, seated and trunk flexion. However, the specific technical movements and postures of each sport were not analyzed.

Recently, some investigations have analyzed the sagittal spinal curvature during training in different postures, especially in adult cyclist who revealed a moderate standing thoracic hyperkyphosis. This thoracic angle was significantly reduced in different specific grips on the bike (37-39). Similarly, young canoeists have shown hyperkhyphotic postures in standing position but significantly lower in the specific attack position on the canoe (23). Analyzing the differences between genders, a recent study has found no pelvis or spinal postures differences in age-group kayakers (22). However the sagittal spinal curvatures have been demonstrated to be influenced by gender due to genetic, hormonal and environmental factors. Masharawi et al. (33) observed that females had lower thoracic kyphosis, as well as a lumbar spinal geometry which induced to a greater lumbar lordosis than men. Therefore, determining the differences in the spinal morphotype depending on the gender is necessary.

The practice of kayaking, especially the modality of flat water kayaking involve important spine movements, so training at high level on basis might generate meaningful adaptations to the sagittal spinal curvatures (2). Fernández et al. (7) have associated the practice of kayaking to thoracic hiperkyphosis and lumbar hyperlordosis. Out of the water the spine curvatures have been analyzed in different age-group kayakers, observing hyperkyphosis postures in standing position and a frequent tendency to lumbar kyphotic postures in maximum trunk flexion (17-19,21). The body posture assessment seems to be important since the postures adopted during cyclic movements with intervertebral flexion have been linked to increased intradiscal pressure and high risk of spinal imbalance (13,34,43,50). Additionally, a maintained intervertebral flexion may deform viscoelastic tissues, producing in turn an intervertebral flexion increase and a subsequent lumbar spine imbalance (35, 48).

Flat water kayakers carry out their trainings in a maintained seated position with a hip flexion around 110-115º and knees slightly bended (46). During paddling, there is a knee cyclic movement of alternated ipsilateral flexo-extension, coinciding the maximum knee extension with the attack position. At this particular position the hamstring extensibility plays an important role in the sagittal spinal curvature, therefore, the kayaker extensibility level might influence sagittal spinal curvatures and pelvis during paddling.

The different studies analyzing the hamstring extensibility in different population (athletes, sedentary people, etc…) based on gender, observed greater range of motion in females during the sit-and-reach test and straight leg raise test (21,25,31). Thus, this fact may also influence different sagittal spinal curvatures and pelvis between genders during paddling.

Therefore, the aims of the present study were: 1) to compare the thoracic and lumbar sagittal spinal curvatures and pelvic inclination in different positions (common daily postures, trunk flexion, and specific paddling position); and 2) to determine the influence of gender in hamstring extensibility as well as pelvis and spinal postures.

2. MATERIAL AND METHODS

2.1. Participants

One hundred and thirty paddlers between 15 and 20 years old volunteered for the present study. The sample belonged to a bigger project supported by the Séneca-Agency of Technology and Science Foundation (Murcia County) (II PCTRM 2007-2010) 11951/PI/09, entitled “Evolution of sagittal spinal curvatures, hamstring extensibility, low back pain, and anthropometric characteristics in elite paddlers”.

The sample distribution is presented in table 1 depending on the gender and the characteristics. The inclusion criteria were: training volume of 2-3 hours per day, 4-5 days per week and an experience of more than 4 years of practice. Conversely, the exclusion criteria were: low back pain within 3 months before the study and having a spinal disease detected.

Table 1. Characteristics of the sample (mean ± SD).

	Age (years)	**Heigh (cm)**	**BodyMass (kg)**
Males (n= 62)	16.77 ± 2.01	172.94 ± 12.15	72.44 ± 11.78
Females (n= 68)	16.74 ± 1.86	161.57 ± 13.57*	63.60 ± 12.37*

* p< 0.01 respect to males.

2.2. Procedures

An Institutional Ethical Committee of the University of Murcia approved the study and written informed consent form was obtained from the parents of all the children before participation and after having been informed about the study aims and methods.

The thoracic and lumbar sagittal spinal curvatures and pelvic inclination were randomly assessed in standing position, slumped sitting, maximal trunk flexion with knees flexed, sit-and-reach test, base position and bilateral entry position in a kayak ergometer. Additionally, hamstring extensibility was evaluated using the sit-and-reach and passive straight leg raise test.

Before the measurements, the spinal apophysis of the 7th cervical vertebra (C7) and 3rd sacra vertebra (S3) were identified by palpation and marked by a pencil. Subsequently, the sagittal spinal curvatures and pelvic tilt were measured using a Spinal Mouse system (Idiag, Fehraltdorf, Switzerland). The high validity and reliability observed by the Spinal Mouse in comparison with other radiographic techniques has been previously demonstrated (10). Between the two measurements performed by the same examiner in the same session, a 4 minutes rest was provided. The laboratory temperature was standardized at 24° C.

To take the measurements once the kayaker adopted the specific position, the Spinal Mouse was moved from the C7 mark to the S3 mark along the spinal apophysis. A subsequent digitalization by the software collected data about the sagittal spinal curvatures, angular spinal shape and pelvic inclination. Regarding the lumbar curvatures, negative values indicate lordosis and positive values inversion. As for the pelvis, a 0º value corresponds to the vertical position, being the positive values indicative of anterior pelvic tilt and the negative ones indicative of posterior pelvic tilt.

2.2. Postures analyzed

Standing position

The kayaker stands with feet separated the hips width, arms relaxed hanging on the sides and the look to the front. Once positioned, the kayaker remains motionless during the measurements.

Slumped sitting

The kayaker seats on the edge of the stretcher with knees flexed 90º, without the feet touching the floor and the hands on the thigh.

Sit-and-reach test

The kayaker was required to sit with the knees straight, the feet hip width, 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 rule was placed on the sit-and-reach box; with a 0 cm mark represented the point at which the subjects’ fingertips were in line with their toes. With palms down, subjects placed one hand on top of the other and slowly reached forward as far as possible. Subjects slid their hands along the box, keeping their knees as straight as possible, and hold the resulting position for approximately five seconds while the spinal curvatures and pelvic inclination were measured. If the tangent line depicted by the soles of the feet were not overcome (0 cm) it was considered a negative value whereas when this line was overcome it was considered positive values.

Maximal trunk flexion with knees flexed

The kayaker seats on a height-adjustable-chair with knees at 90º, the soles on the floor just below the knees. From that position a maximal flexion of the trunk was required.

Base position on the kayak ergometer

The kayaker seats on the ergometer with his/her regular footplate, seat and paddle grip set-up, the knees flexed at 15-20º and the paddle on the thighs

Entry position on the kayak ergometer

The kayaker performs a few cycles before stopping at the entry position (when the paddle enters the water). The measurements are bilaterally taken in a random order.

Hamstring extensibility

Passive straight leg raise test (PSLR) was conducted bilaterally in a counterbalanced order. Subjects were positioned in supine position with the lower extremity in 0º of hip flexion. While the participant was in the supine position a Uni-Level inclinometer (ISOMED, Inc., Portland, OR) 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 (47). 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 maximum hip flexion. Moreover, the ankle of the tested leg was restrained in maximum plantar flexion to avoid adverse neutral tension. The indications to correctly perform the test were given by the tester: “Let’s raise the leg slowly, relax it as much as possible. You have to endurance the stretch until you feel the pain behind the knee or the thigh and then let us know saying “enough.” ”

2.4. Data analysis

Descriptive statistics of each variable including means and standard deviations were calculated. After corroborating the normal distribution of the sample by the Kolmogorov-Smirnov test a two-way analysis of variance (ANOVA) was conducted to compare the sagittal spinal curvatures and pelvic inclination. The significance of the multivariate repeated-measures analysis was confirmed by Wilk´s lambda, Pillai trace, Hotelling trace, and Roy largest root tests, which yielded similar results. The sphericity assumption was tested using Mauchly´s test of sphericity. The Greenhouse-Geisser correction was applied if the assumption of sphericity was violated. If any significant difference was detected in the dependent variables for the main ANOVA effect ($p< 0.05$), a pairwise comparison was calculated using Bonferroni corrections for multiple comparisons, adjusting the significance value at 0.07 (0.05 by 7). To determine if any significant difference occurred between both lower limbs during the PLSR, a t-student test for independent samples was performed. The data collected was then analyzed by the SPSS software (v. 15.0) and the significant level was set at $p< 0.05$.

3. RESULTS

In the PSLR test the angular values for the right lower limb were 74.66 ± 12.77º and 80.28 ± 15.56º in males and females respectively ($p< 0.001$) whereas for the left lower limb the values were 74.58 ± 12.73º and 79.70 ± 15.81º, respectively ($p< 0.001$). However, no significant differences were detected between both sides. As for the sit-and-reach test females reached significant further than males (5.25 ± 6.70 and 8.04 ± 8.11 cm, respectively) ($p< 0.01$).

The mean angular values of the thoracic and lumbar curvatures and the pelvis inclination in the different positions assessed are presented in figures 1, 2 and 3, respectively. The significance values of the pair analysis for thoracic and lumbar curvatures and pelvic inclination respectively are provided in tables 2, 3 and 4, respectively. The repeated measures ANOVA revealed significant differences in the three variables (thoracic and lumbar curvatures and pelvic inclination). Similarly, the comparison between gender and positions also indicated significant differences ($p< 0.05$) especially in the lumbar spine and pelvis. In maximum trunk flexion and on the kayak ergometer females showed lower values in thoracic and lumbar flexion as well as in pelvic tilt than males.

In the standing position and slumped sitting the thoracic kyphosis was observed to be higher than on the ergometer ($p< 0.001$). In addition, comparing between genders, males revealed greater kyphosis than females but only significant differences were observed in the sit-and-reach test (figure 1).

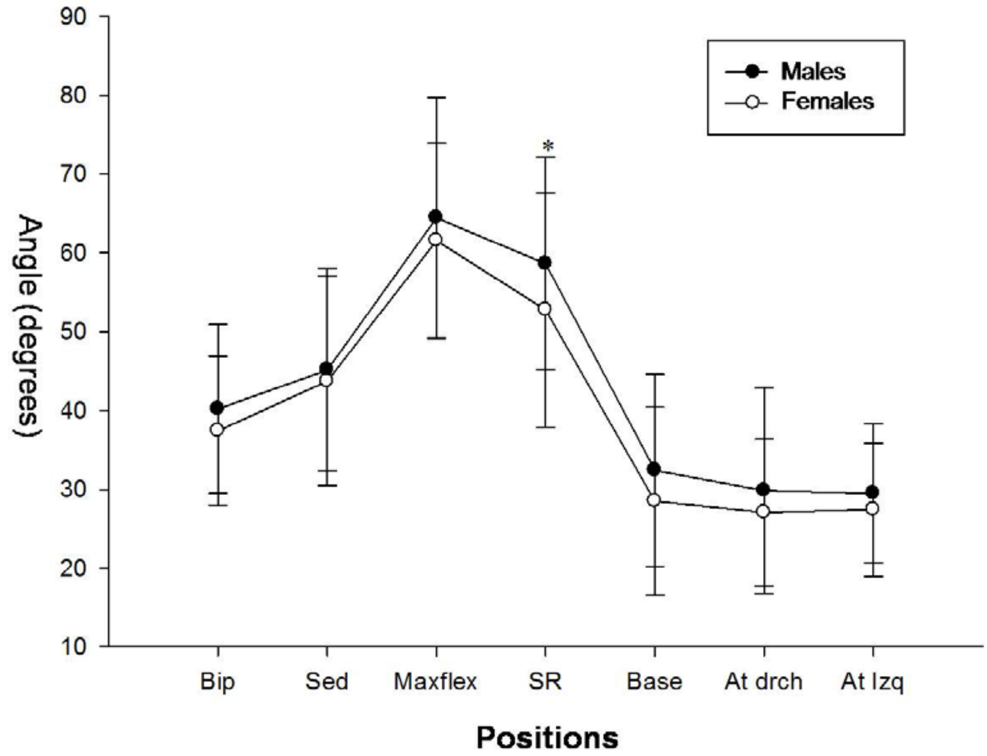

Figure 1. Mean ± SD of the angular values of the thoracic curvatures in the different positions assessed

Bip: standing; Sed: slump sitting; Maxflex: maximal trunk flexion while sitting; SR: sit-and-reach test; Base: base position on the kayak ergometer; At: entry position on the kayak ergometer; drch: right side; izq: left side. * $p < 0.01$ between males and females.

A kyphotic lumbar curvature was adopted in all sitting positions while a posterior pelvic tilt occurred simultaneously. On the kayak ergometer males adopted a greater lumbar flexion than females (figure 2).

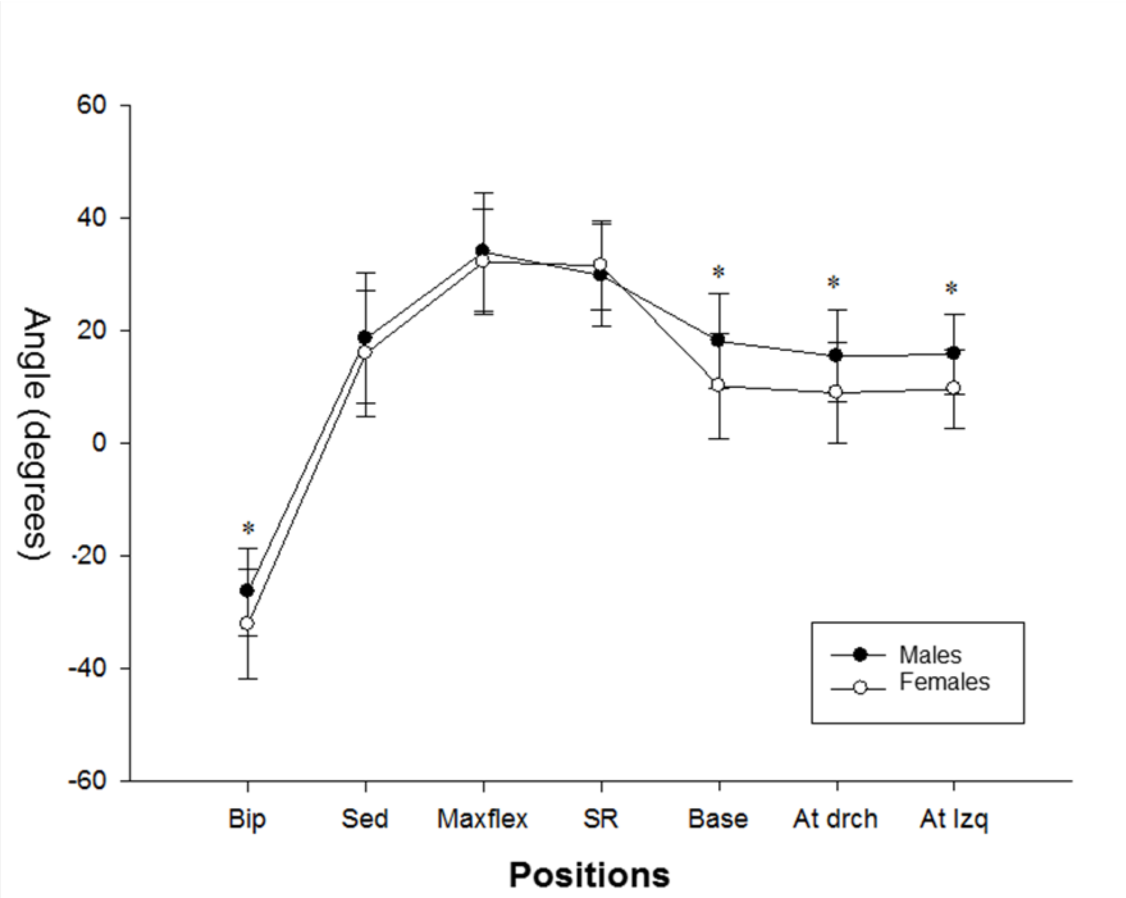

Figure 2. Mean ± SD of the angular values of the lumbar curvatures in the different positions assessed

Bip: standing; Sed: slump sitting; Maxflex: maximal trunk flexion while sitting; SR: sit-and-reach test; Base: base position on the kayak ergometer; At: entry position on the kayak ergometer; drch: right side; izq: left side. * *p*< 0.01 between males and females.

Analyzing the pelvic position, a significant posterior pelvic tilt could be observed on the ergometer, especially in males who presented greater posterior pelvic tilt in all positions studied. However, in slumped sitting position similar pelvis values were found for both genders (Figure 3).

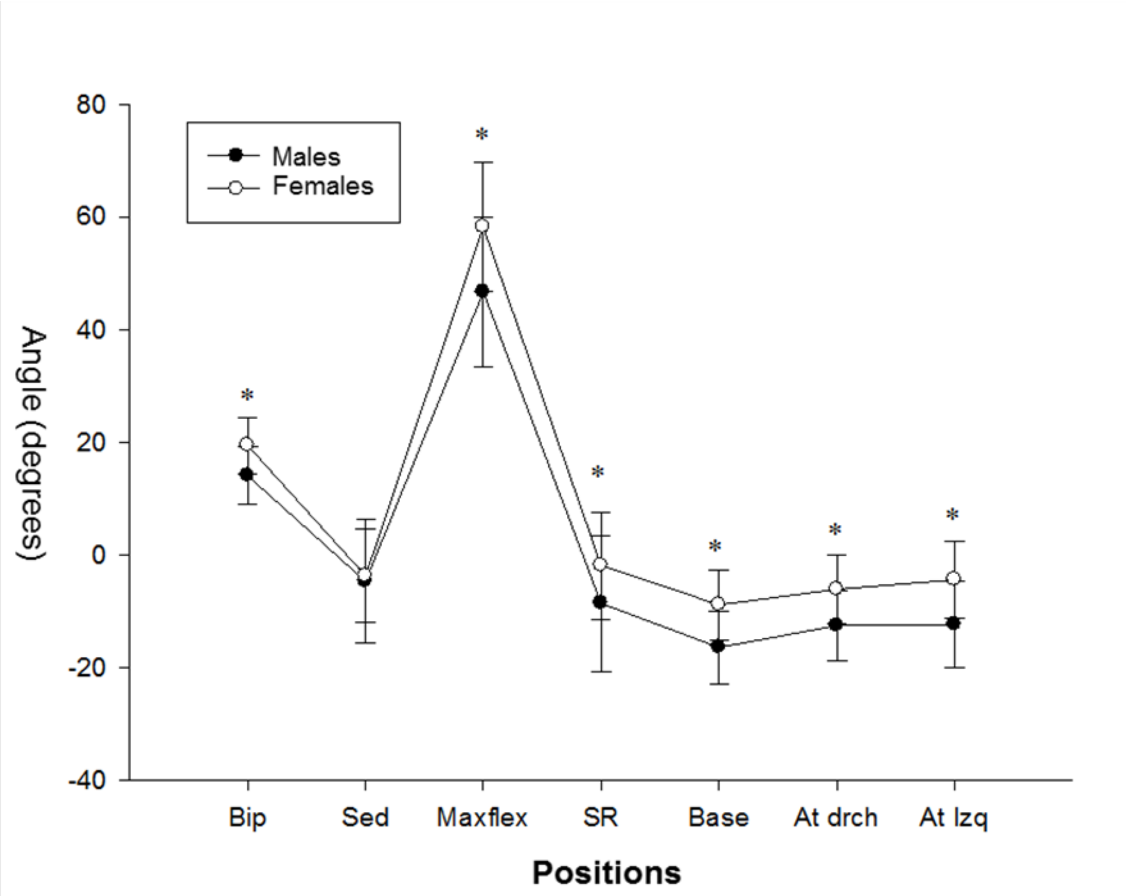

Figure 3. Mean ± SD of the angular values of the pelvis inclination in the different positions assessed

Bip: standing; Sed: slump sitting; Maxflex: maximal trunk flexion while sitting; SR: sit-and-reach test; Base: base position on the kayak ergometer; At: entry position on the kayak ergometer; drch: right side; izq: left side. * *p*< 0.01 between males and females.

Table 2. Pair comparisons of the spinal sagittal postures of the thoracic curvatures among the different positions and between genders (females shadowed)

	Bip	Sed	Maxflex	SR	Base	At drch	At izq
Bip	-	NS	*	*	**	*	*
Sed	NS	-	*	*	*	*	*
Maxflex	*	*	-	NS	*	*	*
SR	*	NS	**	-	*	*	*
Base	*	*	*	*	-	NS	NS
At drch	*	*	*	*	NS	-	NS
At izq	*	*	*	*	NS	NS	-

Bip: standing; Sed: slump sitting; Maxflex: maximal trunk flexion while sitting; SR: sit-and-reach test; Base: base position on the kayak ergometer; At: entry position on the kayak ergometer; drch: right side; izq: left side. * *p*< 0.001; ** *p*< 0.007; NS: no significant.

Table 3. Pair comparisons of the spinal sagittal postures of the lumbar curvatures among the different positions and between genders (females shadowed)

	Bip	Sed	Maxflex	SR	Base	At drch	At izq
Bip	-	*	*	*	*	*	*
Sed	*	-	*	*	NS	NS	NS
Maxflex	*	*	-	NS	*	*	*
SR	*	*	NS	-	*	*	*
Base	*	NS	*	*	-	NS	NS
At drch	*	*	*	*	NS	-	NS
At izq	*	**	*	*	NS	NS	-

Bip: standing; Sed: slump sitting; Maxflex: maximal trunk flexion while sitting; SR: sit-and-reach test; Base: base position on the kayak ergometer; At: entry position on the kayak ergometer; drch: right side; izq: left side. * $p< 0.001$; ** $p< 0.007$; NS: no significant.

Table 4. Pair comparisons of the pelvic inclination among the different positions and between genders (females shadowed)

	Bip	Sed	Maxflex	SR	Base	At drch	At izq
Bip	-	*	*	*	*	*	*
Sed	*	-	*	*	NS	NS	NS
Maxflex	*	*	-	*	*	*	*
SR	*	*	*	-	*	NS	NS
Base	*	*	*	*	-	*	*
At drch	*	*	*	NS	*	-	NS
At izq	*	*	*	*	NS	*	-

Bip: standing; Sed: slump sitting; Maxflex: maximal trunk flexion while sitting; SR: sit-and-reach test; Base: base position on the kayak ergometer; At: entry position on the kayak ergometer; drch: right side; izq: left side. * $p< 0.001$; NS: no significant.

4. DISCUSSION

The present study compared the sagittal spinal and pelvic curvatures in kayakers of both genders and in different positions on a kayak-ergometer. Prior investigation indicated meaningful percentages of thoracic spine hyperkyphosis (45º angles), as a result of the posture adopted while paddling during the training sessions (7,19,21). The main finding was the significantly lower thoracic kyphosis observed on the ergometer (9º and 13º in males and females respectively) than standing. Similarly, in the base position the mean differences analysis also revealed a significant reduction in thoracic kyphosis respect to the standing position (figure 1). This thoracic curvature has been associated with greater oxygen consumption (15) and larger range of motions of the humeral-scapula joint when the curvature is more aligned (5,8,12).

Thoracic kyphosis values were greater in males in all positions analyzed although only significant differences were detected in the sit-and-reach test. When the subjects adopt trunk flexion postures and hamstring muscles are under significant stiffness the differences between genders with regards to hamstring extensibility support this relationship. In contrast, these differences are reduced when the postures adopted generate less traction stimuli in the hamstring muscles as occurs on the kayak ergometer.

While sitting on the ergometer, an inversion in the lumbar curvatures occurred in both genders, especially in males who showed a significant greater flexion than females (45.3% and 27.7% respect to maximum lumbar flexion with knees flexed respectively; $p< 0.001$). The posture adopted on the ergometer during the training sessions as well as other common daily activities may imply lumbar curvature adjustments involving in turn lumbar spine rectifications. López-Miñarro et al. (19) found that only the 8.7% of kayakers presented lumbar rectification, being the hyperlordosis even more uncommon (22). In agreement with previous studies, the kayakers revealed average lumbar lordosis (20-40º), observing in females a significant greater lordosis associated with the larger anterior pelvic tilt while standing (figure 2). Moreover, the subjects with higher hamstring extensibility reached greater lumbar flexion when maximum trunk flexion with knees extended is performed (9, 21). However, in moderate trunk flexion positions, higher hamstring extensibility is associated to lower intervertebral bending.

Analyzing cycling, the sagittal spinal curvatures significantly change from a lordosis in a standing position to a kyphotic posture when sitting on the bike. The kyphotic posture is directly related with the handgrip, so, the lower and further from the center of gravity it is the higher the lumbar flexion (39, 41). Nevertheless, the hamstring extensibility level in cyclists has no relationship with the spine and pelvic postures on the bike (40). This fact might be explained by the greater pelvic flexion, the knee and hip positions on the bike while pedaling, where hamstring muscles are not meaningfully elongated.

Howell (11) analyzed the lumbar curvature of 17 women rowers by the sit-and-reach test, reporting a 76% of lumbar hyperflexion. In fact, high levels of lumbar flexion may be an advantage in generating greater craft acceleration. Stutchfield and Coleman (49) found no correlation between hamstring extensibility and lumbar flexion in rowers using the Schöber method, perhaps due to the low influence of the hamstring muscle on the pelvis position during rowing.

A prolonged sitting position with an inverted lumbar spine increases the intervertebral flexion capacity as a result of the viscoelastic deformation in the posterior arc ligaments of the vertebra (32, 35, 48). This fact may explain the greater lumbar kyphosis observed in kayakers in maximum trunk flexion positions respect to sedentary people (21) or runners (20). Similarly, Muyor et al. (37) revealed that flat-water kayaking is associated with greater intervertebral lumbar flexion, generating a high percentage of kyphosis morphotypes (18). A high lumbar flexion increased the risk of spine injuries (13,34), increasing the intradiscal pressure, compressive stress, antero-posterior shear forces (43, 50) and viscoelastic deformation (13, 34).

Most studies about the spine posture have neglected the analysis of the pelvis position. The pelvis is considered the base of the spine; therefore, any change in its disposition will also affect the sagittal spinal disposition (16). The pelvis range of motion is influenced by the hip angle as well as the knee position (4). In the current study the pelvis was positioned in a slight posterior pelvic tilt on the ergometer, especially in males, which may suggest a reduced hamstring extensibility which is very common in kayakers (19, 21). In fact, the more flexible kayakers presented lower posterior pelvic tilt and lumbar flexion angles (30). Moreover, when the pelvis is placed in posterior tilting greater lumbar flexion is required to align the trunk in a vertical line. Therefore, this might explain the fact that females revealed lower lumbar flexion on the kayak ergometer since their pelvis is placed more vertically with lower levels of posterior pelvic tilt.

The fact that females, in a standing position, showed greater pelvic anterior pelvic tilt may be related with the lower posterior pelvic tilt angle while sitting on the ergometer (figure 3). Anyway, when sitting slumped with knees flexed in 90º the pelvis adopt a slight posterior pelvic tilt in both genders, suggesting that the hamstring extensibility level affect the position adopted while paddling. Stretched-hamstring muscle positions where the origin and insertion are far away each other, directly affect the lumbo-pelvic rythm (4), limiting the pelvis capacity of antero flexion in the hip axis (6). In agreement with these findings Peharec et al. (42) observed gender differences in the pelvis range of motion while maximum trunk flexion and extended knees, especially and significantly in females whereas no differences in the lumbar curvature were detected.

Since the lumbar spine posture is highly related with the pelvis position (16), a proper pelvic workout should be included in the young kayakers training programs and schedules. Additionally, a stretching program for hamstring muscles might help in adopting more aligned postures while paddling on the boat.

5. CONCLUSIONS

The kayaking position while paddling is defined by a decreased thoracic kyphosis when comparing with standing or slumped sitting positions. Conversely, the lumbar spine adopted a kyphotic posture while the trunk is flexed, sitting and on the ergometer, supported by a posterior pelvic tilt position. Male kayakers presented greater posterior pelvic tilt and lumbar flexion postures in maximum trunk flexion and on ergometer analysis. These postural differences might be associated with the lower hamstring extensibility observed in males.

6. REFERENCES

1. Alricsson M, Werner S. Young elite cross-country skiers and low back pain-A 5-year study. Phys Ther Sport, 2006; 7: 181-4.
2. Ashton-Miller JA. Thoracic hyperkyphosis in the young athlete: a review of the biomechanical issues. Curr Sports Med Rep, 2004; 3: 47-52.
3. Boldori L, Da Soldá M, Marelli A. Anomalies of the trunk. An analysis of their prevalence in young athletes. MinervaPediatr, 1999; 51: 259-64.
4. Congdon R, Bohannon R, Tiberio D. Intrinsic and imposed hamstring length influence posterior pelvic rotation during hip flexion. ClinBiom, 2005; 20: 947-51.
5. Crosbie J, Kilbreath SL, Hollmann L, York S. Scapulohumeral rhythm and associated spinal motion. ClinBiom, 2008; 23: 184-92.
6. Esola MA, McClure PW, Fitzgerald GK, Siegler S. Analysis of lumbar spine and hip motion during forward bending in subjects with and without a history of low back pain. Spine; 1996; 21: 71-8.
7. Fernández B, Terrados N, Pérez-Landaluce J, Rodríguez M. Patología del piragüismo. ArchMedDep, 1992; 35: 315-8.
8. Finley MA, Lee MY. Effect of sitting posture on 3-dimensional scapular kinematics measured by skin-mounted electromagnetic tracking sensors. Arch Phys Med Rehabil, 2003; 84: 563-8.
9. Gajdosik RL, Albert CR, Mitman JJ. Influence of hamstring length on the standing position and flexion range of motion of the pelvic angle, lumbar angle, and thoracic angle. J Orthop Sports PhysTher, 1994; 20: 213-9.
10. Guermazi M, Ghroubi S, Kassis M, Jaziri O, Keskes H, Kessomtini W, Ben-Hammouda I, Elleuch MH. Validity and reliability of Spinal Mouse® to assess lumbar flexion. Ann Readapt Med Phys, 2006; 49: 172-7.
11. Howell D. Musculoskeletal profile and incidence of musculoskeletal injuries in lightweight women rowers. Am J Sports Med, 1984; 12: 278-81.
12. Kebaetse M, McClure P, Pratt NA. Thoracic position effect on shoulder range of motion, strength, and three-dimensional scapular kinematics. Arch Phys Med Rehabil, 1999; 80: 945-50.
13. Keller TS, Colloca CJ, HarrisonDE, Harrison DD, Janik TJ. Influence of spine morphology on intervertebral disc loads and stresses in asymptomatic adults: implications for the ideal spine. Spine J, 2005; 5: 297-300.
14. Küms T, Ereline J, Gapeyeva H, Pääsuke M, Vain A. Spinal curvature and trunk muscle tone in rhythmic gymnasts and untrained girls. J Back Musculoskelet Rehab, 2007; 20: 87-95.
15. Landers M, Barker G, Wallentine S, McWhorter J, Peel C. A comparison of tidal volume, breathing frequency, and minute ventilation between two sitting postures in healthy adults. Physiother Theo Pract, 2003; 19: 109-19.
16. Levine D, Whittle MW. The effects of pelvic movement on lumbar lordosis in the standing position. J Orthop Sports PhysTher, 1996; 24: 130-5.
17. López-Miñarro PA, Alacid F. Influence of hamstring muscle extensibility on spinal curvatures in young athletes. Sci Sports, 2010; 25: 188-93.

18. López-Miñarro PA, Alacid F. Cifosis funcional y actitud cifótica lumbar en piragüistas adolescentes. Retos. Nuevas tendencias en Educación Física, Deporte y Recreación, 2010; 17: 5-9.
19. López-Miñarro PA, Alacid F, Ferragut C, García A. Measurement and comparison of sagittal spinal curvatures between infantile canoeists and kayakers. Cult CienDep, 2008; 9: 171-6.
20. López-Miñarro PA, Alacid F, Muyor JM. Comparison of spinal curvatures and hamstring extensibility between paddlers and runners. RevIntMedCienc Ac, 2009; 36: 379-92.
21. López-Miñarro PA, Alacid F, Rodríguez PL. Comparison of sagittal spinal curvatures and hamstring muscle extensibility among young elite paddlers and non-athletes. IntSportMed J, 2010; 11: 301-12.
22. López-Miñarro PA, Muyor JM, Alacid F. Sagittal spinal curvatures and pelvic tilt in elite young kayakers. Med Sport, 2010; 63:509-19.
23. López-Miñarro PA, Muyor JM, Alacid F. Sagittal spinal and pelvic postures of high-trained young canoeists. J Hum Kin, 2011; 29: 41-8.
24. López-Miñarro PA, Rodríguez PL, Santonja F. Disposición sagital del raquis torácico al realizar el ejercicio de remo sentado con apoyo en el tórax. Revista Española de EducaciónFísica y Deportes, 2009; 12: 79-87.
25. López-Miñarro PA, Sáinz de Baranda P, Rodríguez-García PL. A comparison of the sit-and-reach test and the back-saver sit-and-reach test in university students. J Sports Sci Med, 2009; 8: 116-22.
26. López-Miñarro PA, Rodríguez PL, Santonja F, Yuste JL, García A. Sagittal spinal curvatures in recreational weight lifters. Arch Med Dep, 2007; 122: 435-41.
27. López-Miñarro PA, Rodríguez PL, Santonja FM, Yuste JL. Posture of thoracic spine during triceps-pushdown exercise. SciSports, 2008; 23:183-5.
28. López-Miñarro PA, Alacid F, Ferragut C, Yuste JL, García A. Valoración y comparación de la extensibilidad isquiosural entre kayakistas y canoistas de categoría infantil. Motricidad. EuropeanJournal of Human Movement, 2008; 20: 97-111.
29. López-Miñarro PA, Muyor JM, Alacid F, Vaquero-Cristóbal R, López-Plaza D, Isorna M (2013). Comparison of hamstring extensibility and spinal posture between kayakers and canoeists. Kinesiology, 2013;45: 163-70.
30. López-Miñarro PA, Muyor JM, Alacid F. Influence of hamstring extensibility on sagittal spinal curvatures and pelvic tilt in high-trained young kayakers. Eur J SportsSci,2012; 12: 469-74.
31. López-Miñarro PA, Vaquero R, Muyor JM, Alacid F, Isorna M. Validez de criterio del test sit-and-reach como medida de la extensibilidad isquiosural en piragüistas. Cult, Cien Dep, 2012; 20: 95-101.
32. Lu D, Le P, Davidson B, Zhou BH, Lu Y, Patel V, Solomonow M. Frequency of cyclic lumbar loading is a risk factor for cumulative trauma disorder. Muscle Nerve, 2008; 38: 867-74.
33. Masharawi Y, Dar G, Peleg S, Steinberg N, Medlej B, May H, Abbas J, Hershkovitz I. A morphological adaptation of the thoracic and lumbar vertebrae to lumbar hyperlordosisin young and adult females. Eur Spine J, 2010; 19: 768-73.

34. McGill SM. Low back disorders. Evidence-Based prevention and rehabilitation. Champaign, IL: Human Kinetics; 2002.
35. McGill SM, Brown S. Creep response of the lumbar spine to prolonged full flexion. ClinBiomech, 1992; 7: 43-6.
36. MuyorJM, Alacid F, López-Miñarro PA. Morfología sagital del raquis en palistas jóvenes de alto nivel. Int J Morphol, 2011; 29: 1047-53.
37. MuyorJM, Alacid F, López-Miñarro PA. Valoración del morfotipo raquídeo en el plano sagital en ciclistas de categoría máster 40. Int J Morphol, 2011; 29: 727-32.
38. Muyor JM, López-Miñarro PA, Alacid F. A comparison of the thoracic spine in the sagittal plane between elite cyclists and nonathlete subjects. J Back Musculoskelet Rehab, 2011; 24: 129-35.
39. MuyorJM, López-Miñarro PA, Alacid F. Comparación de la disposición sagital del raquis lumbar entre ciclistas de élite y sedentarios. CultCiencDep, 2011; 16: 37-43.
40. MuyorJM, López-Miñarro PA, Alacid F. Influence of hamstring muscles extensibility on spinal curvatures and pelvic tilt in highly trained cyclists. J Hum Kin, 2011; 29: 15-23.
41. Muyor JM, López-Miñarro PA, Alacid F. Spinal posture of thoracic and lumbar spine and pelvic tilt in highly trained cyclists. J Sports Sci Med, 2011; 10: 355-61.
42. Peharec S, Jerković R, Bacić P, Azman J, Bobinac D. Kinematic measurement of the lumbar spine and pelvis in the normal population. CollAntropol, 2007; 31:1039-42.
43. Polga DJ, Beaubien BP, Kallemeier PM, Schellhas KP, Lee WD, Buttermann GR, Wood KB. Measurement of in vivo intradiscal pressure in healthy thoracic intervertebral discs. Spine, 2004; 29: 1320-4.
44. Rajabi R, Doherty P, Goodarzi M, Hemayattalab R. Comparison of thoracic kyphosis in two groups of elite Greco-Roman and free style wrestlers and a group of non-athletic subjects. Br J Sports Med, 2008; 42: 229-32.
45. Räty H, Battié M, Videman T,Sarna S. Lumbar mobility in former elite male weightlifters, soccer players, long-distance runners and shooters. ClinBiom, 1997; 12: 325-30.
46. Sánchez JL,Magaz S. La Técnica. En: Sánchez JL, editor. Piragüismo (I). Madrid: COE; 1993. p. 101-386.
47. Santonja Medina FM, Sainz De Baranda Andújar P, Rodríguez García PL, López-Miñarro PA. Effects of frequency of static stretching on straight-leg raise in elementary school children J Sports Med Phys Fitness, 2007; 47:304-8.
48. Solomonow M. Ligaments: a source of work-related musculoskeletal disorders. J ElectromyogrKinesiol, 2004; 14: 49-60.
49. Stutchfield BM, Coleman S. The relationships between hamstring flexibility, lumbar flexion, and low back pain in rowers. Eur J Sport Sci, 2006; 6: 255-60.
50. Wilke HJ, Neef P, Hinz B, Seidel H, Claes LE. Intradiscal pressure together with anthropometric data - a data set for the validation of models. ClinBiomech, 2001; 1: S111-26.

51. Wodecki P, Guiguí P, Hanotel M, Cardinne L, Deburge A. Sagittal alignment of the spine: comparison between soccer players and subjects without sports activities. Rev ChirOrthopReparatriceAppar Mot,2002; 88:328-36.
52. Wojtys E, Ashton-Miller J, Huston L, Moga PJ. The association between athletic training time and the sagittal curvature of the immature spine. Am J Sports Med, 2000; 28: 490-8.

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