Sagittal Spinal Morphology in Highly Trained Adolescent Tennis Players

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Abstract
Sports with a predominance of forward-bending and extension postures have been associated with alterations in the sagittal spinal curvatures and greater risk of spinal injury. Because, the tennis players adopt these postures, the aims of this study were: 1) to describe spinal curvatures and pelvic tilt in male and female highly trained adolescent tennis players during relaxed standing posture and with thoracic spine corrected (in prone lying on the floor); and 2) to determine the frequency of thoracic hyperkyphosis and lumbar hypo/hyper lordosis in these postures. Forty adolescent tennis players (24 male and 16 female) aged 13-18 years, participated voluntarily in this study. The Spinal Mouse system was used to measure sagittal spinal curvatures and pelvic tilt. The mean values in the relaxed standing posture were 43.83° ± 7.87° (thoracic kyphosis), - 27.58° ± 7.01° (lumbar lordosis), and 13.38° ± 5.57° (pelvic tilt) for male tennis players, respectively; and 36.13° ± 6.69° (thoracic kyphosis), - 32.69° ± 5.06° (lumbar lordosis), 20.94° ± 5.36° (pelvic tilt) for female tennis players (p < 0.05 between genders in all spinal parameters). The male and female tennis players showed a frequency of 62.5% and 93.8% (p = 0.032) for neutral thoracic kyphosis, 83.3% and 93.8% (p = 0.062) in neutral lumbar lordosis, respectively. In conclusion, due to the high percentage of neutral spinal curvatures in both male and female tennis players, to practice tennis in these levels does not alter sagittal spinal morphology in the relaxed standing posture in adolescent highly trained tennis players.

Key words: Spinal mouse, posture, thoracic, lumbar, pelvic.

Introduction
The spine has several physiological curvatures in the sagittal plane. During development ages these spinal curvatures evolve as the changes resultant from posture and balance (Cil et al., 2005) and they are more sensible to alter the spinal morphology. In this sense, in athletes, Uetake et al. (1998) found that the vertebral curvatures had distinctive features and shapes depending on specific sport practised.

Tennis is an acyclic and one-sided sport that is classified in sports games as involving a racquet and a ball. Adolescent tennis players spend several years training to reach professional status. Fast movements of the trunk in flexion and extension in the sagittal and frontal plane, and rotational movements around the long axis are very common in this sport. In this sense, repetitive, strenuous, and intense training during developmental stage play an important role in the occurrence of trunk injuries or adaptation in the spinal morphology (Ellenbecker et al., 2009; Pluim et al., 2006). In this line, alterations in the lumbar spine joints and high levels of abdominal and lumbar muscle activation have been reported in elite adolescent tennis players (Alyas et al., 2007; Chow et al., 2009).

Alterations in physiological spinal curvatures have been associated to an increased risk of injury due to an increase of intervertebral stress (Beach et al., 2005), viscoelastic deformation of spinal tissues (Solomonow et al., 2003) or higher intradiscal pressure (Wilke et al., 1999). It is important to consider these implications in sports medicine and training to prevent possible spinal injuries. For these reasons, several studies have analysed the influence of specific postures on the spinal curvatures in sports where flexion-extension movements of the trunk are frequently carried out, such as in young ballet dancers (Nilsen et al., 1993), skiers, (Alricsson and Werner, 2006; Rachbauer et al., 2001), volleyball players (Grabara and Hadzik, 2009), soccer players (Wodecki et al., 2002), and rowers (Caldwell et al., 2003). Also, athletes in sport where the thoracic and/or lumbar spine are maintained in flexion, such as in paddlers (López-Miñarro et al., 2010; 2011), wrestlers (Rajabi et al., 2007), and cyclists (Muyor et al., 2011a; 2011b; 2012) have been analysed. However, to date no study has assessed the implications of this in tennis.

Sports with a predominance of forward-bending postures have been associated with greater thoracic kyphosis in standing (Rajabi et al., 2007). Alricsson and Werner (2006) reported an increased thoracic kyphosis in adolescent elite skiers after five years of intensive training. In canoeists, López-Miñarro et al. (2010) found a high frequency of thoracic hyperkyphosis in standing. However, when these athletes were in their canoes, the posture was characterized by reduced thoracic and lumbar curvatures. Muyor et al. (2011b; 2011c) reported similar findings in elite cyclists. These authors found a high frequency of thoracic hyperkyphosis in standing, but on the bicycle the thoracic spine was straighter than in the standing posture. Grabara and Hadzik (2009) observed asymmetries brought about by unilateral loads and a progressive thoracic kyphosis and a flattened lumbar lordosis in adolescent female volleyball players.

Because the sport-specific asymmetric work in tennis, combined with trunk flexion and hyperextension...
movements could generate morphological spine adaptations in adolescent tennis players, the aims of this study were: 1) to describe spinal curvatures and pelvic tilt in male and female highly trained adolescent tennis players during relaxed standing posture and with thoracic spine corrected (in prone lying on the floor); and 2) to determine the frequency of thoracic hyperkyphosis and lumbar hypo/hyper lordosis in these postures.

Methods

Participants

Forty adolescent tennis players (24 male and 16 female) aged 13-18 years, participated voluntarily in this study. Sample characteristics are shown in Table 1.

The inclusion criteria were 1) trained between 2-5 hours on a daily basis; 2) trained 5-7 times per week; 3) had played tennis in federated competitions at least 4 years The exclusion criteria were 1) a history of spinal pain in the three months prior to the study, 2) a history of spinal surgery, or 3) a medically diagnosed spinal disorder, e.g. scoliosis. Because the muscular fatigue could influence in the posture, all participants were instructed to avoid physical activity 24 hours prior to the study.

Procedures

This study was approved by the Ethics and Research Committee of the University of Almería (Spain). It was designed and conducted in concordance with the Ethical Standards in Sports and Exercise Science Research (Harris and Atkinson, 2009). All participants were informed of the procedures and signed a consent form prior to the measurements.

Sagittal spinal curvatures and pelvic tilt were measured in the relaxed standing position and prone position, using a Spinal Mouse system (Idiag, Fehraltdorf, Switzerland). The Spinal Mouse is an electronic computer-aided measuring device, which measures sagittal spinal range of motion and intersegmental angles in a non-invasive way, a so-called surface-based technique. The Spinal Mouse is a valid and reliable device to measure the spinal curvatures and pelvic tilt (Guermazi et al., 2006; Mannion et al., 2004; Post and Leferink, 2004).

All measurements were performed twice and the average was calculated. Each subject was evaluated by the same examiner in a single session. Prior to taking measurements, the main researcher determined the spinous process of C7 (starting point) and the top of the anal crease (end point) by palpation and marked the skin surface with a pencil. The Spinal Mouse was guided along the midline of the spine (or slightly paravertebrally, particularly in thin individuals with prominent processus spinous) starting at the processus spinous of C7 and finishing at the top of the anal crease (approximately S3) (Figure 1). For each testing position, the position of the thoracic (T1-2 to T11-12) and lumbar (T12-L1 to the sacrum) spine and the position of the sacrum and the hips (difference between the sacral angle and the vertical plane) were recorded. Negative values corresponded to lumbar lordosis (posterior concavity). The tennis players were examined wearing underwear and barefoot. No warm-up or stretching exercises were performed by the subjects prior to the test measurements. The measurements were performed in random order. There was a 5 minutes rest between the different tests. The laboratory temperature was standardised at 24° C.

Relaxed standing

The tennis players stood in a straight position on the floor with the eyes and ears in line horizontally, arms relaxed at the side of the body, knees close to individual full extension, and feet shoulder-width apart. To classify the posture in categories for thoracic kyphosis, the thoracic curvature classification proposed by Mejia et al. (1996) was used: values between 20° and 45° were accepted as neutral thoracic kyphosis, values below 20° were considered thoracic hypokyphosis, and values above 45° were considered thoracic hyperkyphosis. For the lumbar curvature, values between 20° and 40° were considered neutral, values below 20° were considered hypolordotic, and values above 40° were considered hyperlordotic (Tüzün et al., 1999).

Prone position

The tennis players laid face down on the floor with arms extended vertically over the head so as to raise the shoulders. The thorax and forehead remained in contact with the floor.

Statistical analysis

Means and standard deviations were calculated for all
variables. The hypotheses of normality and homogeneity of variance were analysed using the Kolmogorov-Smirnov test and Levene’s test, respectively. Pairwise comparison of means (Student t test) was used to examine the differences between male and female tennis players in relaxed standing posture. Paired t test was used to compare the thoracic spine between relaxed standing posture and lying on the floor.

Differences among categorical variables were evaluated using Fisher’s exact test. The data was analysed using the SPSS v.18.0. The level of significance was set at \( p \leq 0.05 \).

**Results**

The means and standard deviations of thoracic kyphosis, lumbar lordosis and pelvic tilt for both groups of tennis players are shown in Figure 2. In the relaxed standing posture, significant differences were found between male and female tennis players \( (p < 0.05) \). The male tennis players showed greater thoracic kyphosis, and lower lumbar lordosis and pelvic tilt than the female tennis players (Figure 2).

**Discussion**

One of the objectives in the present study was to determine the frequency of thoracic hyperkyphosis and lumbar hypo/hyper lordosis during the relaxed standing posture and to compare the results between male and female highly trained adolescent tennis players.

The main finding of the present study was that, when the tennis players were classified by thoracic and lumbar angle values proposed by Mejia et al. (1996) and Tuzün et al. (1999) respectively, a high percentage of the total sample showed angular values in the references of normality (75% neutral thoracic kyphosis and 87.5% neutral lumbar lordosis). Moreover, we found statistical reductions in thoracic spine in both genders when relaxed standing posture and lying on the floor were compared. These results reported that the cases with thoracic hyperkyphosis found in male and female tennis players were functional and not structural postures.

In the current study, the normality percentages have been greater than previous studies. López-Miñarro et al. (2010) found 37% of young kayakers having neutral thoracic kyphosis and 63% with hyperkyphosis, whereas the percentage in neutral lumbar lordosis was in concordance with the current study (87.5%). Muyor et al. (2011a) reported that 41.7% of elite cyclists showed neutral thoracic kyphosis and 58.3% thoracic hyperkyphosis.
It appears that these cyclists maintained the thoracic spine straighter on the bicycle than while standing on the floor. The lumbar spine showed 88.3% in neutral lumbar values. In other study, Muyor et al. (2011b) reported that elite cyclists showed a statistically higher thoracic hyperkyphosis than non-athlete subjects. These authors justified their findings with specific sport adaptations. In this sense, Grabara and Hadzik (2009) found that a kyphotic posture tended to be more frequent and the lordotic one less frequent in volleyball players than in untrained subjects. The authors attributed that finding to the typical volleyball posture consisting of forward bending with rounded back, as well as, the arms and shoulders protruding. Wojtys et al. (2000) reported that a high intensity training increases the risk of developing adolescent hyperkyphosis. In this sense, Alricsson and Werner (2006) found that after 5 years of intensive training the skiers increased their thoracic kyphosis but no change in lumbar lordosis. However, in the current study, where the tennis players had an average experience around 6 year of training, they showed a low percentage of thoracic hyperkyphosis.

When the spinal values were compared between male and female tennis players, the female tennis players showed a higher percentage in neutral thoracic kyphosis and lumbar lordosis (93.8% and 93.8%, respectively) than male tennis players (62.5% and 83.3%, respectively). These differences in the percentages of spinal references in the relaxed standing posture may be because the female tennis players showed statistical differences in a greater anterior pelvic tilt. These results are in agreement with Widhe (2001) who reported similar results in adolescent girls (15-16 years, the same ages that the average age in the current study). However, this author did not evaluate the pelvic tilt.

The pelvis is considered the base of the spine. An anterior pelvic tilt increases the lumbar lordosis and a posterior pelvic tilt decreases the lumbar lordosis. In this sense, a person properly trained in a pelvic tilt maneuver can voluntarily rotate his pelvis a sufficient amount to alter the lumbar lordotic curve (Day et al., 1984). Moreover, the lumbar spine and pelvis work together in order to maintain lumbopelvic balance (Chanplakorn et al., 2010). An asymptomatic population tends to stand with a relatively stable sagittal global balance (Mac-Thiong et al., 2010). For these reasons, the female tennis players who showed a greater anterior pelvic tilt and lumbar lordosis could adopt a lower thoracic kyphosis to find the best balance.

On the other hand, Chow et al. (2009) reported high lumbar spinal loads expected during the phase of acceleration because of the hyperextension posture and profound front-back and bilateral co-activations in lower trunk muscles. In the current study, the spinal curvatures and pelvic tilt in the specific sport posture as in the serve were not evaluated. This might be an important issue for future research to quantify the spinal angular values in specific tennis postures and their relationships with possible spine injuries. It might also be interesting to compare the sagittal spinal curvature between elite tennis players and non-athlete population and to evaluate the spinal curvatures in frontal plane to identify possible scoliosis in tennis players. Moreover, future studies should be done to analyse the spinal curvatures in tennis players according to their specific hand grip.

**Conclusion**

In conclusion, tennis does not alter sagittal spinal morphology in the relaxed standing posture in adolescent highly trained tennis players. The thoracic hyperkyphotic posture in relaxed standing in male tennis players may be more related to factors other as a lack of postural scheme than the specific training in tennis. Due to the differences found in the spinal curvatures and pelvic tilt between male and female tennis players, it is recommended to separately analyse both groups and to develop the specific postural strategies in each group.

**Acknowledgments**

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**References**


**Key points**

- This study evaluated thoracic and lumbar spinal curvatures and pelvic tilt during several postures in young highly trained tennis players.
- Female tennis players showed statistically significantly greater anterior pelvic tilt, lumbar lordosis and lower thoracic kyphosis than male tennis players.
- The high percentage of neutral thoracic kyphosis and lumbar lordosis posture in both groups of young tennis players in relaxed standing might affirm that tennis does not negatively affect sagittal spinal posture at these ages.
- A specific postural program could be recommended to improve the slumped sitting and maximal trunk flexion in knees extended postures.

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