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ORIGINAL RESEARCH

The comparison of the psoas muscle thickness and strength, and sagittal lumbopelvic alignment in female gymnasts with sway-back posture and normal posture

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Abstract

Background: Sway-back posture (SBP) is a common type of posture among gymnastic athletes that can cause muscle imbalances and pain in the neck and low back regions. The psoas muscle is an important postural muscle that may be involved in this posture. However, the thickness of the psoas muscle and lumbopelvic alignment in gymnasts with SBP has not been studied. **Objective:** This study aims to investigate the thickness and strength of the psoas muscle, lordosis, and pelvic tilt in female gymnasts with SBP and normal posture. **Methods:** This cross-sectional study involved 17 female elite artistic gymnasts, aged 22.1 ± 5.01 years. Among them, ten had SBP, while seven exhibited a normal posture. Ultrasonography, a manual dynamometer, a flexible ruler, and a manual inclinometer were used to measure muscle thickness, strength, lumbar lordosis, and pelvic tilt, respectively. **Results:** The thickness of the psoas muscle at the levels L2-L3 and L3-L4 in female gymnasts with SBP was significantly less than in those with normal posture (L2-L3: p = .021, η_p^2 = .327; L3-L4: p = .035, η_p^2 = .281). However, the strength (p = .732, η_p^2 = .009) and strength-to-thickness ratio of the psoas muscle (p = .356, η_p^2 = .061), degrees of lordosis (p = .414, d = 0.41), and pelvic tilt (p = .323, d = 0.52) did not significantly differ between the two groups. **Conclusions:** The present study revealed the thickness of the psoas muscle was significantly decreased in gymnasts with SBP while its strength was not different from the controls. This may be considered as a prelude for possible changes in bony alignments in the future. Future studies could potentially explore the implications of these findings for training and injury prevention strategies among gymnasts.

Keywords: female gymnasts, lordosis, pelvic tilt, sway-back posture, psoas, ultrasound imaging

Introduction

Posture plays a significant role in the functioning of the human body (Carini et al., 2017). General body posture (Pezolato et al., 2012), as opposed to specific lumbopelvic positions (Dolphens, Cagnie, Coorevits, et al., 2013), has a greater impact on the relationship with spine pain. Deviations from normal posture can lead to changes in torque and biomechanical properties of structures such as the spine (Singla & Veqar, 2017). Such deviations can cause changes in muscle length, muscle stiffness (Mehta, 2005), inappropriate loads on joints and soft tissues, and long-term pain in different parts of the body.

Among different parts of the body, the back could be affected more than the other regions by poor posture. Gymnastics is one of the sports that needs a lot of different ballistic-stretching exercises. There is evidence that shows normal posture may change due to competition or training programs (Purcell & Micheli, 2009). It is not surprising to find that sway-back posture (SBP) is a common abnormal posture in gymnasts (Mulhearn & George, 1999) and low back pain is a common complaint among them (Pimentel et al., 2020).

The prevalence of neck and low back pain is higher in SBP than in other postural abnormalities (Lewis & Sahrmann, 2015). The low back pain in this group of athletes may result from the spinal muscle variations that have occurred due to the SBP. Literature has indicated people with SBP experience forward displacement of the pelvis and backward displacement of the thoracic region (Dolphens, Cagnie, Coorevits, et al., 2013; Dolphens et al., 2014; Kendall et al., 2005; Varangaonkar et al., 2015).

According to Kendall et al. (2005), in SBP, the normal curvature of the lumbar spine disappears, and the pelvis rotates to the back while the hip joints extend. Atrophy of the lumbar erector spinae (Pezolato et al., 2012), atrophy in addition to decreased activity of the multifidus (Mahdavie et al., 2017; O'Sullivan et al., 2002; Pezolato et al., 2012), and increased activity in the rectus abdominis (O'Sullivan et al., 2002) have been reported in SBP.

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The psoas muscle is a close muscle to all lumbar spine, attached to the lumbar spine, pelvis (through the iliacus muscle), and lesser trochanter of the femur, responsible for primary hip flexion and dynamic stabilization of the lumbar during the hip flexion. However, a review of the available literature showed us that psoas has not been studied yet in people with SBP, while changes in this particular muscle could lead to loss of proper biomechanics of the lumbar spine and may play a role in low back and hip pain (Aspinall, 1993; Lewis & Sahrmann, 2015).

This muscle has been understudied probably because it is an in-depth muscle and difficult to assess easily. Thus, the studies might have focused on other important muscles in people with SBP (multifidus, rectus abdominis, and so on (O'Sullivan et al., 2002; Pezolato et al., 2012).

The present study, considering the paucity of the literature, was designed to evaluate the thickness and strength of the psoas muscle in addition to changes in lumbar lordosis and pelvis tilt in gymnasts with SBP. The later variables were added since the function of spinal muscles can vary depending on posture and there is no comprehensive and uniform definition for identifying SBP in the lumbar and pelvic segments in terms of lordosis and tilt respectively.

However, recent studies have attempted to classify SBP in the sagittal plane for a large juvenile population (Dolphens, Cagnie, Coorevits, et al., 2013; Dolphens et al., 2014). According to the Dolphens et al.' procedure, the vertical line through C7 passes well from the posterior of the lateral malleolus in SBP. In people with SBP, the pelvis shifts forward compared with lateral malleolus and the thoracic region shifts backward compared with pelvic.

Muscle thickness can be an index of muscle efficacy, tension, and contractibility (Hodges et al., 2003). Muscle size has been reported to correlate significantly with electromyography activities of the same muscle (Hodges et al., 2003).

We hypothesized that the thickness and strength of the psoas muscle, as well as lordosis and pelvic tilt in female gymnasts with SBP, would be lower than in those with a normal posture.

Methods

Participants

To recruit the participants, the research team attended a national competition in Shiroodi stadium. All female gymnasts from different parts of Iran competed in artistic gymnastics. These gymnasts came through a set of competitions at different levels (in their gym, city, and province) to reach the national competition which had been among different provinces (16 teams and 32 gymnasts in total).

We used the purposive sampling method and only included gymnasts who met the inclusion criteria: Age, willingness to participate in the study, normal body mass index (BMI), and having normal posture or SBP posture. All gymnasts in the age range of 17–25 years were invited to participate in the study. Those who, or whose legal guardians (for the 17-year-old gymnasts), signed the consent form underwent the first examination, which involved checking their BMI. Participants who had a BMI in the normal range (18–25) filled out a self-report questionnaire that included a wide range of information.

The research team designed the questionnaire based on available literature such as Pezolato et al. (2012). This questionnaire included demographic information, such as gender, age, educational level, height, and weight, as well as information about athlete dominant limbs, their sports major/s from the beginning, when they started gymnastics, how often they practice, what other sports major was their focus and concentration, and finally, their medical history with an emphasis on low back pain, hip problems, any surgery in specific parts of the body, and any disease or disorder that physician/s put them on medication for.

The researchers declined the participation of those gymnasts who had any previous history of intervention to correct their posture, received any therapeutic procedure for their spine, lower extremities, and pelvis, and anyone with musculoskeletal complaints such as spasm, tendonitis, sprain, and strain, or fractures or dislocations of the spine or pelvis.

The research team, comprising a master's student in physiotherapy and an assistant professor in the department of physiotherapy, evaluated and recorded each participant's postural type. Seventeen gymnasts with either normal posture or SBP qualified for the last step, which included measuring the psoas muscle, and other relevant variables.

The study was conducted in accordance with the principles of the Helsinki Declaration of 2013, and all procedures were approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences (code number IR.SBMU.RETECH.REC.1395.290).

Procedures

The postures

To start the examination, the grid line was attached to the wall. One line in the grid paper was highlighted and extended on the ground about two meters. At the 50 cm of the grid line paper, the plumb line was aligned. The examiner stood 150 cm away from the plumb line still on the extended line that came from the grid paper. The examiner's dominant eye checked two lines (the highlighted grid line and the plumb line) to be matched and overlapped and perceived as one line (Simorgh et al., 2006).

The participant stood between the grid paper and the plumb line for three minutes to reach their habitual posture. Then the examiner marked her C7 spinous process, greater trochanter, and lateral malleolus. The plumb line passed through the lateral malleolus (Simorgh et al., 2006).

We used the definition presented by Dolphens, Cagnie, Vleeming, et al. (2013) to diagnose the postural type. In SBP, the pelvis (or vertical line passing through the greater trochanter) shifts forward relative to the lateral malleolus, and the vertical line passing through the spinous process of C7 shifts backward relative to the pelvis (or greater trochanter) and lateral malleolus.

In normal posture, the pelvis (or vertical line passing through the greater trochanter) only slightly shifts forward relative to the lateral malleolus, and the vertical line passing through C7 slightly shifts backward relative to the greater trochanter and coincides with the lateral malleolus or very close to it (Dolphens, Cagnie, Vleeming, et al., 2013).

Lordosis and pelvic tilt measurements

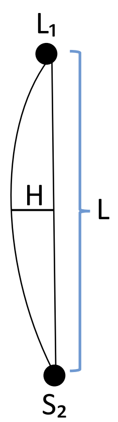
The angle of lumbar lordosis was determined by measuring the angle between the spinous processes of L1 to S2 using a flexible ruler (Mahdavie et al., 2017). The lumbar lordosis angle was calculated using the formula D = 4*arctan(2H/L), where "L" represents the distance of the line connecting the spinous process of L1 to the spinous process of S2, and "H" is the length of a perpendicular line drawn from the midpoint of line "L" to the curve (Figure 1). This method has been reported to have high reliability (ICC = .97; Hart & Rose, 1986).

To measure pelvic tilt in the sagittal plane, a pelvic inclinometer with two movable arms has been used. The base of the inclinometer was 23 cm, and each arm was 15 cm that moved freely in 360 degrees in the horizontal plane. A protractor was inserted in the middle of the base, with a plumb line hanging. This tool was invented by Eftekhar Hosseini and Khalkhali (1994). This tool is a common lab-made tool in Iran. Before the study, the reliability of the pelvic tilt measurement was assessed in five participants, and the results revealed high relative and low absolute reliabilities (ICC = .97, *SEM* = 0.51 degrees). when the reliability of our lab-made tool was confirmed, the arms were placed at the end of anterior superior iliac spine and posterior superior iliac spine, and a plumb line connected to the device showed the angle of pelvic tilt in degrees as described by Nourbakhsh and Arab (2002).

Thickness and strength measurements of iliopsoas muscle

To visualize the psoas muscle between L1 and L4, an ultrasound scanner (Honda HS-2100, Honda, Tokyo, Japan) with a frequency of 7.5 MHz, gain of 100, and depth of 8 cm was used. However, getting a clear image of the muscle outline between the L4 and S1 segments was challenging due to the depth and intra-abdominal structures.

Figure 1 Schematic diagram for calculating the lumbar lordosis angle



Note. L_1 = spinous process of L_1 vertebra; S_2 = spinous process of S_2 vertebra; L = connector line from the L_1 to S_2; H = perpendicular line from the midpoint of line L to the curve.

Therefore, with the participant in a prone position (Rivers et al., 2014), the spinous processes of the lumbar spine were identified by touch and marked with a pen. To obtain a high-quality image, the probe was placed longitudinally on the spinous process at the L1-L2 level with uniform pressure on the skin. Moving the probe from the middle line of the body to the outside revealed the lamina and articular process. Further movement of the probe outward identified the transverse processes of L1 and L2, as well as the psoas muscle between them, which was captured in an image (Figures 2 and 3).

In this place, the ultrasound probe was almost 3–5 cm outside the midline. The best imaging was obtained during hold of breath (Takai et al., 2011). To ensure viewing the psoas muscle, we asked the subjects to flex their hip against an external resistance and looked at the fiber responses on the monitor. The same process was repeated at the lower segments at L2-L3 and L3-L4 levels.

Before the beginning of the study, the reliability of test-retest for measurements of the thickness of the psoas muscle between L1 to L4 was calculated in random order by one examiner with a 15-minute interval between tests in five participants. The results indicated high reliability of measurements (ICC = .97–.98, *SEM* = 0.57–0.80 mm).

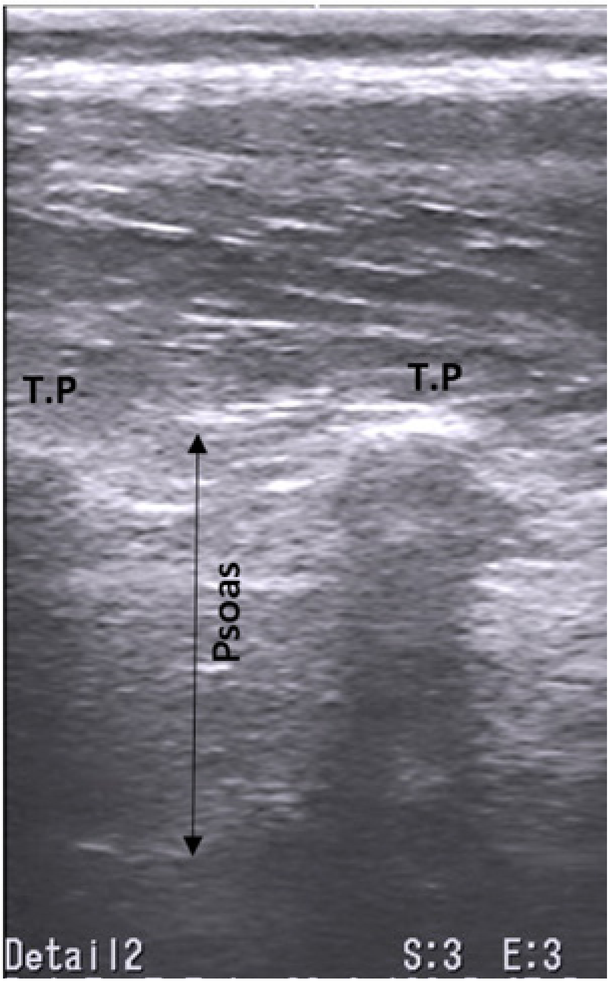
A hand-held dynamometer (Model 01160, Lafayette Instrument Company, Lafayette, IN, USA) was used to measure the strength of the iliopsoas muscle by maximal voluntary isometric contraction of the hip flexion in 90–100° of flexion (Thorborg et al., 2010). The intra-rater reliability of this method was good to excellent (ICC= .77–.94; Mentiplay et al., 2015). The trunk of the participant was fixed to the chair and the upper limbs were crossed in front of the chest while the dynamometer was placed 10 cm above the knee at the distal end of the thigh. All measurements were repeated twice with a 60-s separation, and the mean of the two was used in the statistical analysis.

Statistical analysis

We used the Shapiro-Wilk test to assess the normality of variables. To determine the difference in demographic characteristics of the participants, we employed independent

Figure 2 Sonographic image of the psoas muscle on a participant

Figure 3 An example of ultrasound imaging of psoas muscle between levels of L1-L2



Note. T.P = transverse process.

sample *t*-tests for variables that had normal distribution and Mann-Whitney *U* test for those that did not.

The postural type was considered an independent variable, and the thickness and strength of the psoas muscle, lordosis, and pelvic tilt were considered dependent variables. We also calculated the quality of the muscle, which is the ratio of strength to muscle mass (Ackland et al., 2003; Salmela, 1979). Therefore, we normalized the maximal voluntary isometric contraction (MVIC) of the psoas muscle to the total thickness (TotalTH: sum of muscle thickness at levels of L1-2, L2-3, L3-4 divided by three) of muscle as a dependent variable according to the formula:

$$\text{Quality of muscle} = \text{MVIC}/\text{TotalTH}$$

To assess thickness, strength, and quality of the psoas muscle, we employed analysis of covariance to control for the effects of BMI. We used partial eta-squared (η_p^2) as the measure of effect size, with .01 considered a small effect, .06 a moderate effect, and .14 a large effect (Cohen, 1988).

To compare the mean values of lordosis, and pelvic tilt between the groups, we conducted independent sample *t*-tests. We used Cohen's *d* as an indication of the magnitude of the difference between the two groups, with 0.2 considered a small effect, 0.5 a moderate effect, and 0.8 a large effect (Cohen, 1988).

The level of statistical significance was set at $\alpha = .05$ for all tests. All statistical analyses were done using SPSS software (Version 21 for Windows; IBM, Armonk, NY, USA).

Results

All of the variables had normal distribution, except for the training time in the SBP group.

Table 1 shows the basic sample characteristics. There was no statistically significant difference between the two groups in any of the observed variables.

The results of analysis of thickness, strength, and quality of the psoas muscle are presented in Table 2. The female gymnasts with SBP had significantly lower muscle thickness at L2-L3 and L3-L4 levels as well the total thickness. The strength and muscle quality were higher in the gymnasts with SBP, but this difference was not statistically significant.

The results of analysis of lumbar lordosis and pelvic tilt are shown in Table 3. The values in the SBP group were lower than in the normal posture group; however, the differences were not statistically significant.

Discussion

The present study aimed to assess the thickness and strength of the psoas muscle, lumbar lordosis, and pelvic tilt in elite-female gymnasts who had normal posture or SBP. Among the 32 gymnasts, about thirty percent had SBP. This finding was in agreement with the previous findings that showed abnormal postures such as SBP are quite common among gymnasts (Mulhearn & George, 1999).

The main finding of the present study was that the SBP group compared to the controls had significantly lower total thickness of the psoas muscle, due to lower thickness at L2-L3 and L3-L4 levels.

We found no experimental study that evaluates the psoas muscle specifically depending on general standing postures. However, a study (Shaikh et al., 2020) that examined the effect of seated, standing, and supine postures on the morphometry of the lumbar muscles using MRI showed the effect of the vertebral level on the cross-sectional area (CSA) of the psoas muscle was posture-dependent. Moreover, in each specific posture, the change in the CSA of the psoas muscle at each vertebral level was different from each other. In such a way that transitioning from a standing posture to a seated posture, where the lumbar lordosis becomes flat, the percentage of CSA expansion of the muscle from the vertebral level L3 towards L5 became greater. This increase in muscle thickness with the reduction of lumbar lordosis in the seated posture contradicts the results of our study.

The results of our study showed that the overall thickness of the psoas muscle decreased in the SBP. In this posture, although not significantly, lumbar lordosis decreased. Perhaps one reason for this discrepancy could be found in differences in the methodologies. They examined the immediate changes in the CSA of the erector spinae muscle from standing posture to sitting posture. However, what

Table 1 Means, *SD*s, ranges, and *p* values for basic sample characteristics and training time

Variable	Sway-back posture (n = 10)		Normal posture (n = 7)		p
	Mean ± *SD*	Range	Mean ± *SD*	Range	
Age (years)	21.60 ± 4.69	18.24–24.95	22.85 ± 5.72	17.56–28.15	.626
Height (m)	1.60 ± 0.04	1.57–1.63	1.61 ± 0.05	1.56–1.65	.759
Weight (kg)	53.01 ± 3.23	50.69–55.33	55.97 ± 2.59	53.57–58.37	.055
Body mass index (kg/m^2)	20.74 ± 1.59	19.60–21.88	21.74 ± 1.89	19.98–23.49	.258
Training time (hours/week)	27.80 ± 1.75	26.54–29.05	25.28 ± 2.43	23.04–27.53	.055

Note. The Mann-Whitney *U* test was used for the training time and the *t*-test for the rest of the variables.

Table 2 Means, *SD*s, ranges, *p* values, and effect sizes for thickness and strength of psoas muscle

Variable	Sway-back posture (n = 10)		Normal posture (n = 7)		p	η_p^2
	Mean ± *SD*	Range	Mean ± *SD*	Range		
THL1-2 (mm)	33.83 ± 3.41	31.39–36.27	37.56 ± 2.97	34.81–0.30	.055	.238
THL2-3 (mm)	34.36 ± 2.78	32.37–36.35	38.14 ± 2.46	35.86–0.42	.021	.327
THL3-4 (mm)	34.71 ± 3.56	32.16–37.25	38.89 ± 2.93	36.18–1.60	.035	.281
TotalTH (mm)	34.30 ± 2.87	32.24–36.35	38.19 ± 2.16	36.20–0.19	.016	.350
MVIC (kg)	13.90 ± 5.24	10.15–17.66	12.03 ± 2.66	9.56–14.49	.732	.009
Quality of muscle (kg/mm)	0.41 ± 0.16	0.29–0.52	0.32 ± 0.08	0.24–0.39	.356	.061

Note. THL1-2 = thickness of psoas muscle at L1-L2 level; THL2-3 = thickness of psoas muscle at L2-L3 level; THL3-4 = thickness of psoas muscle at L3-L4 level; TotalTH = total thickness: sum of thicknesses at L1-L2, L2-L3, and L3-L4 divided by three; MVIC = maximal voluntary isometric contraction; quality of muscle = normalized value of MVIC to TotalTH.

Table 3 Means, *SD*s, ranges, *p* values, and effect sizes for lumbar lordosis and pelvic tilt

Variable	Sway-back posture (n = 10)		Normal posture (n = 7)		p	Cohen's *d*
	Mean ± *SD*	Range	Mean ± *SD*	Range		
Lumbar lordosis (deg)	38.18 ± 7.02	33.15–43.20	41.36 ± 8.60	33.40–49.32	.414	0.41
Pelvic tilt (deg)	7.65 ± 3.40	5.22–10.08	9.14 ± 2.15	7.15–11.13	.323	0.52

we observed in the thickness of the psoas muscle resulted from the static general standing SBP, induced by changes and adaptations that may have occurred over a long period of time.

Furthermore, our findings in this section might be partly explained by the lengthening of this muscle due to the SBP or the effect of stretching exercises and/or certain activities used in gymnastics. This mechanical behavior can be expected for any tissue that is thinned by stretching and thickened by shortening (Shaikh et al., 2020).

It may be inferred from this study that the lower the thickness of the psoas muscle, the lower its strength. However, despite the lower thickness of psoas in SBP in this study, the maximal strength of hip flexion at an angle of more than 90 degrees involving psoas muscle was not significantly different than those of female gymnasts with normal postures. Also, the muscle quality, which is the ratio of strength to muscle thickness, did not differ significantly between the two postural types. This finding is consistent with those of another study that examined the correlation between the CSA of the psoas and back extensor muscles and strength parameters in two groups of athletes (including gymnasts, figure skaters, and ballet dancers) and non-athletes.

The CSA of the muscles was examined using MRI, and the maximum strength of trunk extension and flexion in a standing position was measured using a dynamometer. The results indicated that although the CSA of the muscles was larger in athletes than in non-athletes; the comparison of force per muscle CSA did not differ significantly between athletes and non-athletes (Peltonen et al., 1997).

This expands on the concept of the previous study (Trexler et al., 2015) which was based on the lack of a significant relationship between muscle CSA and performance in gymnasts. Moreover, it has been shown that the relationship between muscle mass (volume) and strength (Rolland et al., 2007) may not be linear (Cruz-Jentoft et al., 2014; Wu et al., 2014), and some studies show muscle mass and strength may also be affected independently (Andersson, 2014). Therefore, a firm conclusion on this case requires further studies.

Additionally, during maximal voluntary isometric contraction of psoas achieved during hip flexion at an angle of more than 90 degrees of hip flexion, synergistic muscles like Iliacus and some other muscles may have been contracted with a higher capacity which compensated the force generation during hip flexion. Consequently, the recorded force may be higher than the actual value in which the actual strength of the psoas muscle is obscured by synergistic muscles. However, the separation of the contribution of each muscle in force generation is not possible by the method of muscle strength measurement used in this study.

Although not statistically significant, this study showed a decrease in lumbar lordosis and pelvic tilt in the SBP group. This finding was in agreement with the results presented by previous studies (Mahdavie et al., 2017; Meziat-Filho et al., 2016). They showed angles of lumbar lordosis or pelvic tilt were lower in the SBP than in normal posture. This is interesting because, in some of the available studies, there is no consensus on the direction of changes in lumbar lordosis and pelvic tilt in SBP (Andersson, 2014; Mahdavie et al., 2017; Meziat-Filho et al., 2016). It has been reported that during a study involving 17 healthy male adults, when asked to replicate three different postural conditions (neutral, SBP, and lordosis) in a random order; in SBP, lumbar lordosis increased significantly, while anterior pelvic tilt decreased (Fujitani et al., 2017).

The lack of a statistically significant difference in lumbar lordosis between the two groups in this study could be due to at least two reasons. First, the high variance in the means of each group could be related to the small sample size.

Second, a recent study evaluated the effect of SBP on global and regional sagittal spinal angles in 30 asymptomatic young adults in the standing position. Interestingly, their results showed that while there was no difference in the global lumbar angle between the two groups of SBP and the normal thoracic group (without posterior shift), there was a difference in regional lumbar angles between the two groups. The normal thoracic group had balanced lumbar lordosis between the upper and lower lordotic arcs, whereas the SBP group tended to have a flat upper lumbar angle and increased lower lumbar angle. (Shin et al., 2023).

In the present study, we only measured global lumbar lordosis. Therefore, given the results of the aforementioned study and our study it is suggested that in future studies, the lumbar lordosis angle in SBP should be measured both globally and regionally. In this way, we can probably obtain a more accurate insight into the differences in lumbar lordosis changes between different postural groups. In addition, more accurate results can be obtained regarding the relationship between segmental changes in the psoas muscle and regional lumbar lordosis changes.

Limitations

The present study had access to a limited number of elite gymnasts with unclear backgrounds about their nutrition, family history, and lifestyles. Therefore, future studies with larger sample sizes considering more confounding factors may present a different picture.

Moreover, only female gymnasts were evaluated, so the generalization of the findings to all gymnasts must be done with caution. The extension of our findings to other levels of gymnasts should be done with restraints since our participants were elite ones. Further research could investigate whether similar trends are observed in male gymnasts or athletes from other sports.

Lastly, the sampling method used in this study was purposive sampling, which, while justified given the specific population of interest, may limit the external validity of the findings and may not fully represent the broader gymnast population. Despite these limitations, this study provides a valuable contribution to our understanding of elite female gymnasts and sets the stage for future research in this area.

Conclusions

The present study revealed the thickness of the psoas muscle is significantly decreased in gymnasts with SBP while its strength was not different from the controls. This may be considered a prelude to possible changes in bony alignments in the future. Future studies could potentially explore the implications of these findings for training and injury prevention strategies among gymnasts.

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Conflict of interest

The authors report no conflict of interest.

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