ANALYSIS OF THE SPINAL CURVATURE IN RHYTHMIC GYMNASTICS ATHLETES OF DIFFERENT COMPETITIVE LEVELS AND WITH DIFFERENT POSTURES

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Original article *DOI: 10.52165/sgj.16.3.423-433*

Abstract

Rhythmic gymnastics is characterized by high mobility demands on the spine, which can lead to structural changes and associated injuries or pain. The aim of this study is to assess and compare spinal posture in different positions, mobility, and pain perception among RG athletes. The sample consisted of 34 gymnasts (age: 14.18 ± 2.17) of grassroots and federation levels. Spinal posture and mobility were analyzed using the Spinal Mouse® system, along with pain perception (location and intensity) and body composition. Most gymnasts exhibited normal spinal curvature in both standing and sitting positions. Significant differences (p<0.05) were only found in the sacral curve during extension. Regarding lumbar mobility, differences in sacral mobility from standing to extension were noted, with the federation-level gymnasts showing a greater tendency for hyperlordosis in extension. In terms of pain, the lumbar region was the most affected, with 32.4% of cases reporting pain. It was observed that gymnasts experiencing pain displayed more pronounced lumbar hyperlordosis in the standing position. A low but significant correlation was found between lumbar pain and its intensity (p=0.045), and a moderate correlation was observed between hip pain and pelvic tilt. The gymnasts demonstrated a greater tendency for lumbar hyperlordosis in the standing position and during the transition from standing to extension, which was more pronounced among federation-level gymnasts. Furthermore, there appears to be a stronger correlation between hyperlordosis and the occurrence of lumbar pain, as well as the intensity of pain.

Keywords: *Spinal Mouse®, anthropometry, spinal curvature, pain, rhythmic gymnastics.*

INTRODUCTION

Analyzing the components of training load, particularly the volume of repetitive work in specific postures unique to the sport, can lead to musculoskeletal and spinal deterioration (López-Miñarro et al., 2011; Mahdavie et al., 2017; Muyor et al., 2011; Sainz de Baranda et al., 2010; Zemková et al., 2020). The analysis of the spine and its integrity has been addressed by various disciplines, including the study of dorsal and lumbar sagittal curves. Assessing spinal curvature is important due to its influence on the mechanical properties of intervertebral tissues under load, which increases forces and the potential for injury in young athletes (López-Miñarro et al., 2011; Muyor et al., 2011; Smith et al., 2008; Steinberg et al., 2021). Keller et al. (2005) studied the impact of the angular arrangement of lumbar and thoracic curves on the shearing and compression of intervertebral structures.

It is therefore essential to examine the correlation between repetitive sport practice and spinal alignment to understand its effect on spinal morphotype. Rhythmic gymnastics (RG) is among the sports that involve repeated actions of vertebral flexion, bending, and rotation, with forced movements at maximum intensity and improper loading postures (Maroon & Bailes, 1996). To assess RG's impact on spinal alignment, it is necessary to identify common modifications in the sagittal plane and determine whether they contribute to pathologies or improve spinal curvature (Vaquero et al., 2015).

Some studies have found that ballet dancers suffer from spinal hypermobility, hyperlaxity, or generalized hypermobility, which is associated with lumbar pain (Armstrong, 2018a, 2018b; Bukva et al., 2019; Sands et al., 2016; Steinberg et al., 2021). Additionally, it has been observed that dance training is associated with increased lumbar kyphosis during maximum trunk flexion with the knees extended (Esparza-Ros et al., 2014). In RG, studies have analyzed the posture and common spinal alterations among gymnasts, with lumbar hyperlordosis being the most characteristic postural change in the sagittal plane (Ambegaonkar et al., 2014; Bosso & Golias, 2012).

Differences in competitive levels result in varying physical demands and training loads, which can lead to different physiological responses. Conversely, other authors have highlighted the postural benefits of RG, emphasizing postural education, strength, endurance, and flexibility in the lumbar and hamstring regions, all of which are crucial for proper spinal alignment (Conesa Ros & Martínez-Gallego, 2017; Jaime-Gil et al., 2021; Martínez-Gallego, 2004; Piazza et al., 2009; Sands et al., 2016).

The aim of this study is to assess and compare the postural alignment of the spine in standing, sitting, maximum flexion, and maximum extension positions, as well as to evaluate mobility and the perception of musculoskeletal pain, in grassroots- and federation-level rhythmic gymnasts. aim of this study is to assess and compare the postural alignment of the spine in standing, sitting, maximum flexion, and maximum extension positions, as well as to evaluate mobility and the perception of musculoskeletal pain, in grassroots- and federation-level rhythmic gymnasts.

METHODS

The sample consisted of 34 grassroots- and federation-level rhythmic gymnastics (RG) athletes, aged 12 to 18 years. The mean age ($\bar{X}$) was 14.18 ± 2.17 years. The grassroots-level group included 20 gymnasts (mean age: 13.75 ± 2.24), while the federation-level group included 14 gymnasts (mean age: 14.79 ± 1.97). The grassroots and federation categories have different requirements: the grassroots level involves a lower degree of difficulty, with a scoring code adapted to national regulations, whereas the federation level applies the highest degree of difficulty, following the International Gymnastics Federation scoring code.

The inclusion criteria were: being female, having at least 3 years of experience in rhythmic gymnastics, and participating in grassroots or federation competitions. The exclusion criteria were: having a current pathology or muscle/joint injuries (within the past 6 months), having a spinal pathology, or having undergone surgery on the spine or hamstring muscles.

All participants were informed about the study procedures and provided signed informed consent. The research complies with the principles of the Declaration of Helsinki and relevant local and national legislation. The gymnasts are members of two of the largest clubs in the province of Pontevedra (Spain).

Height, weight, fat-free mass, fat mass, body fat percentage, and fat-free percentage were measured. Waist and hip circumferences were also recorded, from which the waist-hip ratio [waist (cm)/hip (cm)] was calculated. Another proportionality index determined was the Body Mass Index (BMI) [weight/height² (kg/m²)].

Postural assessment was based on the angular alignment of spinal curves and pelvic tilt. The Spinal Mouse® system (Idiag, Fehraltdorf, Switzerland) was used, applied from the seventh cervical vertebra (C7) to the third sacral vertebra (S3), both of which were previously located and marked. The variables measured included the joint angles between the sacrum and hip bone, thoracic curve, lumbar curve, and pelvic tilt in each position (standing, flexion, extension, and sitting). Additionally, the mobility of the thoracic, lumbar, and sacral regions, as well as tilt changes between standing-flexion, standing-extension, and flexion-extension positions, were analyzed.

The Spinal Mouse® system has been validated and proven reliable for assessing spinal curves and pelvic tilt (Demir, 2020; Guermazi et al., 2006; Mannion et al., 2004; Post & Leferink, 2004; Zanguie et al., 2023). Standing measurements were conducted according to the protocol developed by Muyor et al. (2011), while the other postures followed techniques described by Martínez-Gallego (2004), Vaquero et al. (2015), and García Vélez (2019). Normal values for relaxed standing were based on those defined by López-Miñarro et al. (2007), for asthenic sitting and maximum trunk flexion on those defined by Martínez-Gallego (2004), and for maximum spinal extension in the standing position on the parameters preset in the Spinal Mouse software.

To assess pain perception, a numerical scale from 0 to 10 was used to identify the body areas where gymnasts regularly experience pain, with 0 corresponding to no pain/interference and 10 representing the worst imaginable pain/interference. Scores from 0 to 3 indicated light pain, 4 to 7 moderate pain, and 8 to 10 severe pain. The body regions analyzed were grouped into the hip, lumbar, and dorsal areas.

A descriptive and comparative analysis of the studied variables was conducted, using the mean ($\bar{X}$) as a measure of central tendency and the standard deviation (SD) as a measure of data dispersion for numerical variables, while frequencies and percentages (%) were used for categorical variables. A comparative analysis between groups was also performed. To test the normality of the data, the Shapiro-Wilk test was applied, and homogeneity of variance was assessed using Levene's test. The Student's t-test was used to compare numerical variables between two groups or categories, while the Mann-Whitney U test was employed for variables with a non-normal distribution. Additionally, the Student's t-test for related samples was used to compare spinal curves in the standing and sitting positions, with the Wilcoxon test used for non-normal variables.

Spearman's correlation coefficient was employed to analyze the correlation between pain intensity and various postural and mobility variables. Data were analyzed using SPSS 22.0 statistical software, with a significance level of $p<0.05$ for all tests.

RESULTS

The values obtained for anthropometric variables, years of training, and weekly training hours showed no significant differences between the grassroots and federation levels, allowing us to conclude that both groups were homogeneous (Table 1).

The categorization of the spinal curves in standing and seated position is mostly normal (Figure 1 and 2).

Table 1
Descriptive study of anthropometric variables, years of sport practice, weekly training hours and comparison between grassroots- and federation-level gymnasts.

	Total (n=34)		Grassroots-level (n=20)		Federation-level (n=14)		
	X	SD	X	SD	X	SD	Sig. (bilateral)
Height	1.5537	.09085	1.5396	.09314	1.5739	.08677	.290†
Weight	48.3824	10.58236	47.5900	11.07068	49.5143	10.13910	.609
BMI	19.8076	2.63141	19.8293	2.83465	19.7767	2.41488	.955
Waist circumference (cm)	61.7118	5.34358	61.0700	5.20891	62.6286	5.59360	.411
Hip circumference (cm)	84.9618	9.52305	84.5650	10.08993	85.5286	8.99037	.776
WHR	.7295	.04440	.7259	.04548	.7346	.04397	.583
% body fat	16.9735	8.85600	16.6400	9.43863	17.4500	8.27450	.904†
% fat free	83.0265	8.85600	83.3600	9.43863	82.5500	8.27450	.904†
Years of training	8.62	2.257	8.25	1.773	9.14	2.797	.304
Training hours per week	13.79	3.109	13.65	3.628	14.00	2.287	.931†

[Mean (X); Standar Deviation (SD); Body Mass Index (BMI); Waist-hip ratio (WHR)] †U de Mann-Whitney *p<0.05

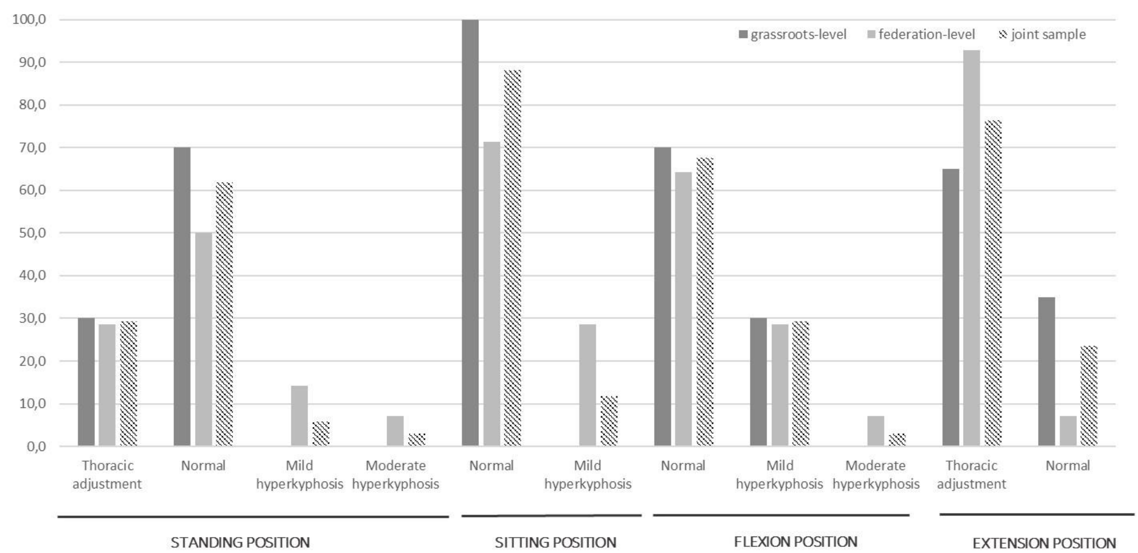

Figure 1. Categorization of thoracic spine curves

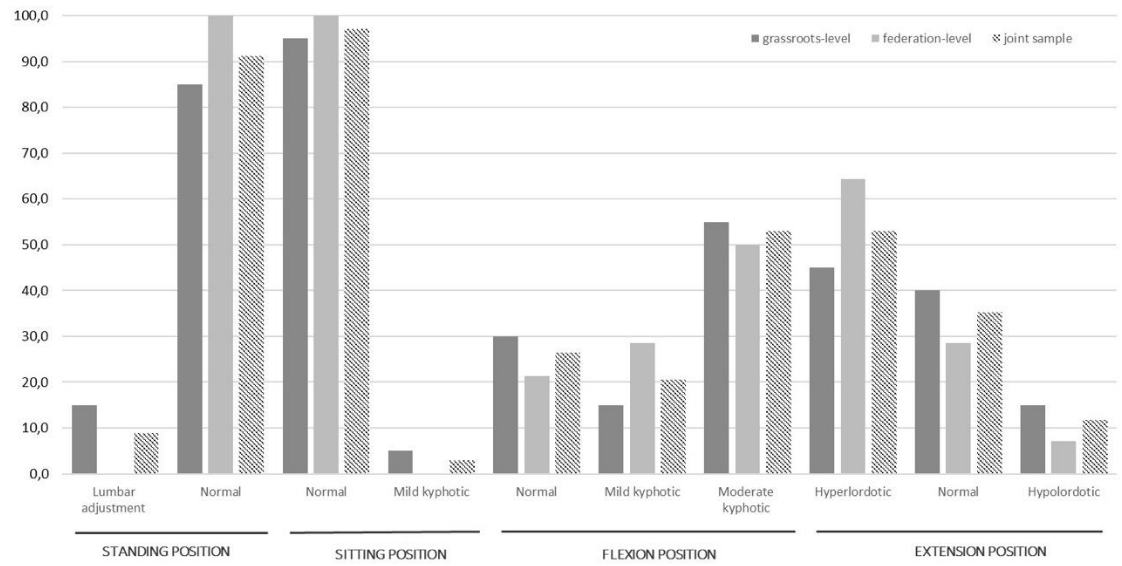

Figure 2. Categorization of the curves of the lumbar spine

Table 2
The sacral, thoracic, and lumbar spinal curves and pelvic tilt in each position and comparative analysis between the grassroots-level and federation-level groups.

	Total (n=34)		Grassroots-level (n=20)		Federation-level (n=14)		
	X	SD	X	SD	X	SD	Sig. (bilateral)
Sacrum hip in standing position	19.50º	6.316	19.90º	7.476	18.93º	4.358	.637
Sacrum hip in flexion position	105.15º	14.722	106.15º	15.882	103.71º	13.333	.642
Sacro hip in extension position	21.91º	97.839	19.45º	105.334	25.43º	89.780	.030†*
Sacro hip in sitting position	14.59º	7.488	13.05º	7.681	16.79º	6.874	.155
Thoracic curve in standing position	20.88º	26.369	17.35º	26.615	25.93º	26.137	.500†
Thoracic curve in flexion position	45.26º	10.632	44.50º	10.435	46.36º	11.209	.691†
Thoracic curve in extension position	-.09º	24.667	6.75º	25.786	-9.86º	19.949	.052
Thoracic curve in sitting position	18.74º	19.300	17.65º	14.957	20.29º	24.783	.457†
Lumbar curve in standing position	-28.56º	6.268	-28.80º	7.302	-28.21º	4.644	.793
Lumbar curve in flexion position	28.62º	10.566	28.95º	11.941	28.14º	8.637	.830
Lumbar curve in extension position	-65.76º	18.159	-62.50º	19.435	-70.43º	15.658	.215
Lumbar curve in sitting position	-8.29º	12.717	-5.85º	14.199	-11.79º	9.673	.184
Pelvic tilt in standing position	3.32º	4.117	3.35º	4.804	3.29º	3.049	.743†
Pelvic tilt in flexion position	136.82º	12.677	138.30º	12.482	134.71º	13.117	.425
Pelvic tilt in extension position	-63.47º	10.880	-65.15º	11.824	-61,07º	9.253	.289
Pelvic tilt in sitting position	12.44º	5.971	11.85º	5.842	13.29º	6.269	.499

[Mean (X); Standar Deviation (SD)] †U de Mann-Whitney *$p<0.05$

Table 2 shows the degrees of spinal curvature in the different positions (standing, sitting, flexion, and extension). In the comparative analysis between grassroots-level and federation-level gymnasts, significant differences ($p<0.05$) were observed only in the curvature formed by the sacrum and hip bones during extension. Federation-level gymnasts displayed a greater curvature, indicating a higher tendency for hyperlordosis (Table 2).

In the comparative analysis, significant differences ($p<0.001$) were found in the spinal curvatures between the standing and sitting postures. There was a greater tendency for hyperlordosis in the sacral curve ($p=0.003$) and an increased lumbar curvature ($p=0.000$) in the standing position, along with a greater pelvic tilt (p=0.000) in the sitting position. Similar differences were observed among grassroots-level gymnasts, with significant variations in the sacral (p=0.005) and lumbar curves (p=0.000), and in pelvic tilt (p=0.000). Federation-level gymnasts showed significant differences only in the lumbar curve (p=0.000) and pelvic tilt (p=0.000), with more pronounced lordosis in the standing posture.

Table 3 presents the mobility analysis of different spinal regions. The comparative study between gymnast levels revealed significant differences (p<0.05) in the sacral region concerning mobility from standing to extension. Federation-level gymnasts showed an increased degree of curvature in the extension posture compared to standing, indicating a greater tendency for hyperlordosis in extension. Conversely, grassroots-level gymnasts exhibited a decrease in curvature, suggesting a lesser tendency for hyperlordosis in extension compared to the standing posture.

Significant differences (p<0.05) were also found in the extension-to-flexion motion for the sacrum and the thoracic curve. The sacral region showed a greater increase in curvature for grassroots-level gymnasts compared to federation-level gymnasts, indicating a higher tendency for hyperlordosis in flexion among grassroots-level gymnasts. In the thoracic region, federation-level gymnasts demonstrated a higher degree of curvature than grassroots-level gymnasts, reflecting a greater tendency for kyphosis in flexion among federation-level gymnasts.

35.3% of gymnasts experience some degree of pain, with 40% of grassroots-level gymnasts and 28.6% of federation-level gymnasts reporting pain. The most common pain location across the pooled sample was the lumbar region, followed by the hip, and then the dorsal region. In federation-level gymnasts, although the lumbar region remained the most common area of pain, the second most common location was the dorsal region, with no cases of hip pain.

When analyzing hip pain separately, it was found that 14.7% of the total participants experienced this type of pain, including 25% of grassroots-level gymnasts. Dorsal pain was reported by 5.9% of participants, with 5% of grassroots-level and 7.1% of federation-level gymnasts affected. The highest incidence of pain was observed in the lumbar region, affecting 32.4% of the cases, including 35% of grassroots-level and 28.6% of federation-level gymnasts.

Table 3 shows the distribution of pain intensity by spinal region for those gymnasts who experienced pain. Lumbar pain was the most common in both groups, with the highest pain scores recorded. The intensity of pain was similar across both competitive levels (Table 3).

To analyze the relationship between experiencing pain and postural patterns, gymnasts were first divided into two groups: those who experienced pain in any region and those who did not. They were then further categorized into two groups based on whether they experienced lumbar pain or not. The analysis revealed significant differences in lumbar curvature in the standing posture, with those who experienced any type of pain showing greater lumbar hyperlordosis (Table 4).

Table 3

Intensity of pain perception in the pooled sample and in the grassroots- and federation-level groups.

	Total				Grassroots-level				Federation-level			
	n	X(SD)	Mín	Máx	n	X(SD)	Mín	Máx	n	X(SD)	Mín	Máx
Perception of hip pain	5	6.8(0.46)	6	7	5	6.80(0.45)	6	7	0			
Perception of thoracic pain	2	6.5(0.71)	6	7	1	7	7	7	1	6	6	6
Perception of lumbar pain	11	7.18(1.25)	5	9	7	7.14(1.57)	5	9	4	7.25(0.50)	7	8

[Mean (X); Standar Deviation (SD)]

Table 4
Comparison of spinal morphology between gymnasts with and without pain, and between gymnasts with and without lumbar pain.

	No pain (n=22)		Pain (n=12)			No lumbar pain (n=23)		Lumbar pain (n=11)		
	X	SD	X	SD	Sig	X	SD	X	SD	Sig
Sacrum hip in standing position	19.27º	6.833	19.92º	5.501	.781	19.26º	6.676	20.00º	5.762	.755
Sacrum hip in flexion position	102.23º	14.155	110.50º	14.811	.119	102.96º	14.265	109.73º	15.278	.215
Sacro hip in extension position	7.86º	74.135	47.67º	130.792	.657†	7.48º	72.454	52.09º	136.231	.800†
Sacro hip in sitting position	13.55º	7.614	16.50º	7.167	.278	13.61º	7.445	16.64º	7.500	.277
Thoracic curve in standing position	18.32º	29.325	25.58º	20.174	.557†	19.09º	28.887	24.64º	20.877	.717†
Thoracic curve in flexion position	48.18º	9.200	39.92º	11.373	.058†	47.96º	9.053	39.64º	11.885	.084†
Thoracic curve in extension position	1.14º	22.710	-2.33º	28.849	.701	2.30º	22.884	-5.09º	28.550	.422
Thoracic curve in sitting position	15.73º	22.224	24.25º	11.104	.204†	16.00º	21.753	24.45º	11.622	.188†
Lumbar curve in standing position	-26.86º	5,955	-31.67º	5,821	**.030***	-27.13º	5.957	-31.55º	6.089	.053
Lumbar curve in flexion position	29.95º	11,408	26.17º	8,737	.325	29.70º	11.215	26.36º	9.135	.398
Lumbar curve in extension position	-66.77º	17,320	-63.92º	20,268	.668	-67.39º	17.180	-62.36º	20.495	.459
Lumbar curve in sitting position	-5.77º	13,402	-12.92º	10,308	.119	-6.13º	13.206	-12.82º	10.806	.154
Pelvic tilt in standing position	4.18º	4,159	1.75º	3,696	.094†	4.04º	4.117	1.82º	3.868	.143†
Pelvic tilt in flexion position	135.50º	12,301	139.25º	13,539	.418	135.96º	12.216	138.64º	14.023	.572
Pelvic tilt in extension position	-62.41º	11,492	-65.42º	9,830	.450	-62.04º	11.364	-66.45º	9.595	.275
Pelvic tilt in sitting position	13.18º	5,885	11.08º	6,142	.335	12.87º	5.941	11.55º	6.219	.553

[Mean (X); Standar Deviation (SD)] † U de Mann-Whitney *p<0.05

When comparing mobility between groups with or without pain, and those with or without lumbar pain, none of the variables showed significant differences between the groups experiencing general or lumbar pain. However, a notable difference, though not significant, was observed in sacral mobility from standing to extension. Gymnasts with pain exhibited a greater tendency for hyperlordosis in extension, while those without pain showed a reduced tendency for hyperlordosis.

To explore the relationship between the intensity of lumbar, thoracic, and hip pain and various spinal curves, inclinations, and mobility, a correlation study was conducted. For lumbar pain, lumbar curvature in the standing position was the only variable with a significant relationship (p=0.045), with a Spearman's Rho coefficient of -0.346, indicating a low correlation. This suggests that greater lumbar lordosis in the standing position is associated with higher pain levels. For hip pain, a significant correlation was found with thoracic curvature in extension (p=0.04), with a correlation coefficient of 0.354, showing a low correlation. Additionally, a significant correlation was observed with pelvic tilt in the standing position (p=0.01), with a Spearman's Rho coefficient of -0.434, indicating a moderate correlation; greater pain was associated with a lesser pelvic tilt. No significant correlation was found between dorsal pain intensity and any of the analyzed variables.

DISCUSSION

The primary objective of this study was to compare normality ranges in various basic and sport-specific postures, and to determine if deviations from normality were more pronounced in forced versus relaxed postures. Additionally, the study aimed to compare mobility ranges and pain perception across different competitive levels (grassroots and federation-level). Research on this topic is limited, but protocols for ballet dancers—a discipline with requirements thought to be comparable to rhythmic gymnastics (RG)—are available (Vaquero et al., 2015).

The first finding was that gymnasts generally displayed normal thoracic values in standing and sitting postures. However, during maximum extension, most gymnasts, particularly those at the federation level, showed a tendency for thoracic adjustment. Ballet dancers also exhibited a tendency for thoracic adjustment, with values of 18.51±10.71º, falling within <20º (Vaquero et al., 2015). In contrast, RG athletes in the standing posture were within normal standards, with a mean of 20.88º, indicating that this posture did not align with the analyzed sample (Vaquero et al., 2015). Notably, grassroots gymnasts had greater thoracic adjustment values (17.35º±26.615º) compared to federation-level gymnasts (25.93º±26.137º). This suggests that competitive level differences influenced this aspect in the opposite direction from what was initially predicted.

In standing posture, ballet dancers had a lumbar curve of -24.74±8.53º, which falls within the intermediate range of -20º to -40º (Vaquero et al., 2015). Gymnasts in our study had a similar mean lumbar curve of -28.56º±6.268, also within the range of -20º to -40º, indicating a tendency towards hyperlordosis in rhythmic gymnastics.

At maximum trunk flexion, the thoracic region showed similar results between our study and that of Vaquero et al. (2015). Ballet dancers had a mean thoracic curve of 42.61±11.14º, while gymnasts had a mean of 45.36±10.632º. This similarity suggests that both disciplines impose similar demands on thoracic curvature in this posture. For the lumbar curve, gymnasts exhibited a pattern of kyphosis at maximum trunk flexion, similar to ballet dancers (Esparza-Ros et al., 2014).

In the sitting posture, ballet dancers had a thoracic curve value of 6.32±9.84º (Vaquero et al., 2015). In contrast, rhythmic gymnasts had a mean of 18.74º±19.30º, reflecting a normal thoracic curve. The lower values in ballet dancers could be attributed to scapular retraction. The postural reeducation associated with these disciplines likely helps avoid the hyperkyphotic tendency typical in the general population. The flexibility of the ischiosural muscles in gymnasts might reduce the kyphotic curve, minimizing the load on the thoracic area. However, our study found that most gymnasts exhibited greater thoracic adjustment without a tendency towards kyphosis in relaxed postures.

It should be noted that mobility from standing to extension was greater in federation-level gymnasts compared to grassroots-level gymnasts. Federation-level gymnasts demonstrated a larger range of movement in the sacral region, which may indicate a tendency towards hyperlordosis in this posture and could be associated with an increase in lumbar pain.

In fact, 34.5% of gymnasts experienced lumbar pain, with federation-level gymnasts exhibiting the highest prevalence in this region. In contrast, grassroots-level gymnasts reported more distributed pain across other sections. These findings are consistent with other research studies (Armstrong, 2018a, 2018b; Bukva et al., 2019; Deighton, 2005; Sands et al., 2016; Steinberg et al., 2021). It is crucial to seek preventive measures to ensure that increased mobility does not negatively impact high-level competitive gymnasts, particularly in the lumbar region.

It is important to acknowledge several limitations of this study. Firstly, the sample size for federation-level gymnasts was smaller compared to that of grassroots-level gymnasts. Although the hours and types of training are relatively similar at both levels, with only minor adjustments to federation standards, differences might be more pronounced if other levels of competition, such as pre-grassroots, were included. These lower-level gymnasts generally have fewer training hours and less demand. Additionally, gymnasts experiencing pain, particularly those with specific organic conditions like spondylolysis or Bertolotti syndrome secondary to sacralisation, were not assessed using imaging methods, which could provide more detailed insights into their conditions.

CONCLUSIONS

Rhythmic gymnasts exhibit specific alterations in spinal curvature, notably a greater tendency towards lumbar hyperlordosis, particularly evident in federation-level gymnasts. There appears to be a stronger correlation between hyperlordosis and the occurrence of lumbar pain, as well as with the intensity of training.

Federation-level gymnasts have a higher prevalence of low back pain. Despite this, rhythmic gymnastics provides postural control benefits in positions such as sitting, leading to a reduced kyphotic tendency in the thoracic region during relaxed standing and asthenic sitting.

These findings underscore the need for further research into sports that involve hypermobility and laxity. Such studies could provide a scientific basis for physical trainers and sports rehabilitators to develop strategies aimed at reducing injury rates. Increasing strength training for the abdominal and lumbar muscles may be particularly beneficial, as it could help alleviate localized or distributed pain.

Declaration of competing interest:
The authors have no relevant financial or non-financial interests to disclose.

Acknowledgements:
The authors thank all the coaches and gymnasts for their participation and cooperation. The authors also wish to thank all the participating clubs for their permission to set up the study and for their collaboration during the investigation.

Ethical statement:
The study was approved by the Autonomous Ethics Committee of Research of Xunta de Galicia (Spain) (Reference Number 2023/020).

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Article received: 29.5.2024
Article accepted: 16.8.2024