FACTA UNIVERSITATIS
Series: **Physical Education and Sport**, Vol. 21, No 2, 2023, pp. 73 - 87
https://doi.org/10.22190/FUPES211213006P

Research article

DIFFERENCES IN THE REPRESENTATION OF SPINAL COLUMN DEFORMITIES IN RELATION TO THE SPORTS EXPERIENCE OF YOUNG GYMNASTS

UDC 615.82/.84:796.41

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Abstract. *This study has two aims, to determine the possible existence of spinal deformities in young gymnasts, and then to determine whether there are differences in the prevalence of spinal deformities in relation to their age and training experience. A total of 87 participants were included in the study, as competitors in the International tournament "Laza Krstić and Marica Dželatović" held in Novi Sad. According to age (8-10; 11-12; 13-14; 15-17), the participants were divided into 4 categories (subsamples). The "Spinal Mouse" was used to determine postural status at training, one day before competition. For each applied variable (kyphosis, lordosis, and scoliosis), the basic descriptive statistics parameters were calculated, while in order to determine the differences between the groups, the Mann–Whitney U test was applied. No statistically significant differences were determined between the groups in terms of almost all the deformities, which can be justified by the approximately equal prevalence of deformities at all ages. Out of the total number of participants, as many as 69% (60 gymnasts) have deviations from the normal values of spinal column curves. The results also indicate that the trend of potential deformities first increases at approximately 11 and 12 years of age (when puberty begins) and only at this transition were statistically significant differences found (only in the case of scoliosis). The results should promote a much more serious approach to the training process of young gymnasts, which should be reflected in regular-periodic control of the spinal column with modern measuring instruments.*

Key words: *artistic gymnastics, children, adolescents, spinal column, Spinal Mouse*

Received December 13, 2021 / Accepted June 20, 2023
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INTRODUCTION

Due to high-load training and repetitive one-sided workouts, asymmetric sports (kayaking, rowing, weightlifting, skating, volleyball, basketball, and handball) can lead to the development of an asymmetrical posture or the formation of functional degrees of deformity of the spinal column (Baranto et al., 2009; Đurić et al., 2015; Hawrylak et al., 2001). In that regard, poor posture does not consist of just one, but several disorders, whereby they disappear by tightening the muscles. It leads to the body weakness, especially joints and muscles, which further leads to spine static weakness (or spinal column weakness), as well as to weakness of the rest of the locomotor system (Živković, 2009; Živković & Karaleić, 2014).

As a heterogenous spectrum of abnormalities which can significantly affect health-related quality of life (Diebo et al., 2019; Naresh-Babu et al., 2019), posture is mainly innate and can be influenced by various external factors (age, illness, growth, sports, diet, living conditions, etc.). External influences and the force of the earth's gravity are constantly opposed by the active forces of the body – muscles, ligaments, bones and joints that maintain an upright position. Hence, there should be a balance between systems that disrupt proper body position and systems that maintain proper body position while maintaining proper posture, certain movements or rest (Bogdanović et al., 2015).

Since artistic gymnastics consists of acrobatic skills, it demands spine mobility and real stretching, which are realized as early as the age of 4 or 5 (Bompa & Haff, 2009). Likewise, gymnasts frequently begin their training in childhood and specialize shortly after (Baker et al., 2014; Norris, 2010). Hence, the realization of various exercises on apparatuses leads to the proper formation of the body and reduces the possibility of body deformities. These exercises play a big role in shaping the body and the proper growth and development of the body. Exercising on the apparatus engages the muscles of the arms and the muscles of the torso, which leads to the proper functioning of internal organs. Abdominal wall and chest strength are also an important prerequisite for proper body functioning as well (Petković et al., 2013).

Grabara (2010) did a comparison between female gymnasts and their untrained mates. They discovered that the spine is better shaped among the youngest gymnasts ($p<0.01$), who also have good overall posture rating ($p<0.01$), whereas lumbar lordosis was less expressed in gymnasts ($p<0.05$). Ambegaonkar et al. (2014) identified that female collegiate gymnasts have either marked (62.1%; N-18) or moderate (34.5%; N-10) lumbar lordosis deviations, based on an extreme range of motions in exercising. On the other hand, Sanz-Mengibar et al. (2017) identified increased thoracic kyphosis in male gymnasts (-0.445; $p<0.001$), whereas a non-significant correlation were found between training hours per year (0.264), training volume (0.192), and any spine measurements on the sagittal plane (thoracic kyphosis, 0.192; lumbar lordosis, -0.054). A total of 62.5% of gymnasts had functional thoracic kyphosis and 39.6% had lumbar kyphosis.

Based on the fact that artistic gymnastics contains polystructural and acyclic movements, i.e. exercises are performed in all three movement planes and around all three axes of rotation (Petković et al., 2013), it is uncertain if the frequency of spinal column deformities are lower or higher among artistic gymnasts. Hence, this study has two aims, to determine the possible existence of spinal deformities in young gymnasts, and then to determine whether there are differences in the prevalence of spinal deformities in relation to their age and training experience.

METHODS

Participants

The total sample consisted of a total of 87 participants, i.e. competitors in the International tournament "Laza Krstić and Marica Dželatović" in Novi Sad. More precisely, the sample is divided into subsamples (categories), according to current age:

1. Category I – Aged 8-10 (19 gymnasts);
2. Category II – Aged 11 and 12 (29 gymnasts);
3. Category III – Aged 13 and 14 (24 gymnasts);
4. Category IV – Aged 15-17 (15 gymnasts).

Measurements

The "Spinal Mouse" was used to determine postural status, a valid and reliable measuring system specially developed for fast, non-contact static and dynamic measurement of the surface of the back and spine, without harmful radiation (Livanelioglu et al., 2016; Mannion et al., 2004; Post & Leferink, 2004). Likewise, the study was performed in accordance with ethical principles of human research of the World Medical Association's Declaration of Helsinki.

The participants were minimally dressed, more precisely, they wore only shorts, and the diagnosis of postural status was performed by experts. The participant being measured must assume a standing natural position with his hands next to his body and legs hip-width apart. The person performing the measurement on the cervical vertebra (S7) marks point 7 with a dermographic pencil and this point represents the beginning of the measurement. After that, the invigilator uses the same method to place point 3 on the lumbar vertebra (S3) and this point represents the end of the measurement. The moving part is placed at the point where the measurement is started, and after the sound, it is pulled over all the vertebrae all the way to the point that marks the end of the measurement. The obtained data are entered into the computer and the analysis is performed. Reference values were provided for:

1. Kyphosis
   - normal kyphosis – range from 30° to 45° in the sagittal thoracic part;
   - kyphotic bad posture of the 1st degree – from 45° to 55° in the thoracic part;
   - kyphotic bad posture of the 2nd degree – over 56° in the thoracic part;
   - flat back 1st degree in the thoracic part – from 29° to 20° thoracic part;
   - flat back 2nd degree in the thoracic part – 19° and less.
2. Lordosis
   - normal lordosis – range from 20° to 36° in the sagittal lumbar part;
   - lordotic bad posture of the 1st degree – from 37° to 45° in the lumbar part;
   - lordotic bad posture of the 2nd degree – over 45° in the lumbar part;
   - flat back 1st degree in the lumbar part – from 19° to 11° in the lumbar part;
   - flat back 2nd degree in the lumbar part – below 10° in the lumbar part.
3. Scoliosis
   - normal scoliosis – range from 0° to 5° in the frontal plane;
   - first degree scoliosis – range from 5° to 20° in the frontal plane;
   - second degree scoliosis – range from 21° to 30° in the frontal plane.

If the results are in normal range, then a grade of 5 is given, if the results indicate a 1st degree deformity, they are evaluated with a grade of 3, and if the results indicate a 2nd

degree deformity, they are evaluated with a grade of 1. Grade 5 indicates that there is no deformity, i.e. that there is normal physiological kyphosis and lordosis, as well as that there is no scoliosis. Grade 3 indicates that there is a postural disorder in the form of kyphosis, lordosis or scoliosis of the 1st degree, and grade 1 indicates the presence of deformity of the spinal column of the 2nd degree and more.

Statistical Data Processing

For the purpose of this study, mathematical-statistical procedures were selected that corresponded to the nature of the research, and which served to obtain relevant data. For the processing and analysis of raw data, the statistical package for data processing SPSS v.20 was used. For each applied variable, the basic parameters of descriptive statistics were calculated: arithmetic means (AM), minimum value (MIN), maximum value (MAX), range (R), standard deviation (SD), and coefficient of variation (CV%). A non-parametric procedure was used to determine the differences between the groups in the postural status of the spinal column – the Mann–Whitney U test.

RESULTS

Representation of deformities in the age range of 8-10

From Table 1, an overview of the arithmetic means of the estimates suggests the presence of a smaller number of deformities in a larger number of deformities in the sagittal plane (Kyphosis and Lordosis), as well as a higher percentage of scattering of the results.

Table 1 Parameters of the central tendency and variance

	AS	MIN	MAX	R	SD	CV%
Scoliosis	4.89	3.00	5.00	2.00	0.46	9%
Kyphosis	4.05	1.00	5.00	4.00	1.39	34%
Lordosis	4.16	1.00	5.00	4.00	1.21	29%

Legend: AS – mean score, MIN – minimum value, MAX – maximum value, R – range, SD – standard deviation, CV% – coefficient of variation in %.

Table 2 shows the presence of deformities in 10 of 19 gymnasts, 47% of 1st degree deformities (six of 19) and 21% 2nd degree deformities (four of 19 gymnasts aged 8-10).

Of the observed deformities, these are mainly deformities in the sagittal plane (kyphosis and lordosis). In the case of kyphosis and lordosis, there is a 37% (seven of 19 gymnasts) rate of occurrence, mainly reduced chest and lumbar curvature (the so-called "flat back"). In order to analyze the possible impact of the training system, it is worth mentioning that the countries of origin of the gymnasts with a deformity was determined. Decreased kyphosis was found in gymnasts from Serbia (four of five gymnasts), Switzerland (one of one), and Bulgaria (two of two). Reduced lordosis was found in competitors from Croatia (two of two), South Africa (one of two), Romania (two of seven), and Serbia (two of five). Only one competitor has scoliosis, and was from Serbia.

Table 2 Percentage of deformities

	Normal	1st degree	2nd degree
Frontal plane – scoliosis	95%	0%	5%
Sagittal plane	32%	47%	21%
Kyphosis	63%	26%	11%
Lordosis	63%	32%	5%
Total deformities	32%	47%	21%

Representation of deformities in the age range of 11 and 12

From Table 3, high values of arithmetic means and a lower percentage of variation in the results of deformities in the frontal plane can be observed.

Table 3 Parameters of central tendency and variance

	AS	MIN	MAX	R	SD	CV%
Scoliosis	4.59	3.00	5.00	2.00	0.82	18%
Kyphosis	4.25	1.00	5.00	4.00	1.24	29%
Lordosis	4.24	1.00	5.00	4.00	1.35	32%

Legend: AS – mean score, MIN – minimum value, MAX – maximum value, R – range, SD – standard deviation, CV% – coefficient of variation in %.

Table 4 shows the presence of 28% of 1st degree deformities (eight of 29) and 38% of 2nd degree deformities (11 of 29). The range of deformities of the 1st degree is approximate values for all analyzed deformities. Deformities of the 2nd degree are present in a smaller percentage than deformities of the 1st degree.

In the case of kyphosis, it is 31% (six reduced and three larger chest curves from 29 gymnasts), in lordosis 27% (four with a larger and four with a smaller lumbar curve from 29 gymnasts), and in the case of scoliosis 31% of which thoracic 14% (four of 29), lumbar 10% (three of 29), and thoracolumbar 7% (two of 29). In order to analyze the possible impact of the training system, it is worth mentioning the countries of origin of the gymnasts where a deformity was determined. In the case of kyphosis, increased chest curvature was found in gymnasts from Croatia (one of three gymnasts), Romania (one of one) and Serbia (one of eight) and decreased chest curvature in gymnasts from Bulgaria (one of two), South Africa (one of seven), Slovenia (one of three), and Serbia (three of eight). In the case of lordosis, increased lumbar curvature was found in gymnasts from Bulgaria (one of three), Croatia (one of three), and Serbia (two of eight), and decreased lordosis was found in competitors from South Africa (three of eight) and Slovenia (one of three). Scoliosis was found in competitors from Bulgaria (two of three), South Africa (three of eight), and Serbia (three of eight).

Table 4 Percentage of deformities

	Normal	1st degree	2nd degree
Frontal plane – scoliosis	69%	21%	10%
Sagittal plane	48%	31%	21%
Kyphosis	69%	24%	7%
Lordosis	72%	17%	10%
Total deformities	34%	28%	38%

Representation of deformities in the age range of 13 and 14

Table 5 shows higher values of the arithmetic means and a lower percentage of variation in the results for scoliosis compared to deformities in the sagittal plane.

Table 5 Parameters of central tendency and variance

	AS	MIN	MAX	R	SD	CV%
Scoliosis	4.58	3.00	5.00	2.00	0.72	16%
Kyphosis	4.27	2.50	5.00	2.50	0.90	21%
Lordosis	4.02	1.00	5.00	4.00	1.33	33%

Legend: AS – mean score, MIN – minimum value, MAX – maximum value, R – range, SD – standard deviation, CV% – coefficient of variation in %.

Table 6 shows the presence of 21% of 1st degree deformities (seven of 24) and 50% of 2nd degree deformities (12 of 24 have one major deformity or two or more deformities of the spinal column). The percentage of 1st and 2nd degree deformities is more pronounced in the sagittal plane (especially 1st degree kyphosis and 2nd degree lordosis).

In the case of kyphosis, it is about 42% (six reduced and 4 larger chest curves from 24 gymnasts), in lordosis 46% (four with a larger and seven with a smaller lumbar curve from 24 gymnasts), and in the case of scoliosis 25% (two thoracic, three lumbar and one thoracolumbar). In order to analyze the possible impact of the training system, it is worth mentioning the countries of origin of the gymnasts with a deformity were determined. In the case of kyphosis, increased chest curvature was found in gymnasts from Austria (one in two), Bulgaria (one of four), Slovenia (one of two), Serbia (one of six), and decreased in gymnasts from Republika Srpska (one of two), Bulgaria (one of four), Croatia (one of one), South Africa (two of four), and Serbia (one of six). In the case of lordosis, increased lumbar curvature was found in gymnasts from South Africa (two of four), Slovenia (one of two), and Serbia (one of six), while decreased lordosis was found in competitors from Bulgaria (three of four), Croatia (one of one), South Africa (one of four), Slovenia (one of two), and Switzerland (one of three). Scoliosis in the thoracic part was found in competitors from Austria (one of one), Serbia (one of one), in the lumbar part in competitors from Bulgaria (one of four) and Serbia (two of six), and in the thoracic-lumbar in gymnasts from Denmark (one of one).

Table 6 Percentage of deformities

	Normal	1st degree	2nd degree
Frontal plane – scoliosis	75%	8%	17%
Sagittal plane	33%	38%	29%
Kyphosis	58%	38%	4%
Lordosis	54%	33%	13%
Total deformities	29%	21%	50%

Representation of deformities in the age range of 15-17

From Table 7, higher values of the arithmetic means of the deformity in the frontal plane and somewhat lower in the sagittal plane can be observed. The percentage of variation in the results is more pronounced with deformities in the sagittal plane.

Table 7 Parameters of central tendency and variance

	AS	MIN	MAX	R	SD	CV%
Scoliosis	4.73	3.00	5.00	2.00	0.70	15%
Kyphosis	3.93	1.00	5.00	4.00	1.28	33%
Lordosis	4.07	1.00	5.00	4.00	1.28	31%

Legend: AS – mean score, MIN – minimum value, MAX – maximum value, R – range, SD – standard deviation, CV% – coefficient of variation in %.

From Table 8, the presence of 40% of 1st degree deformities and 33% of 2nd degree deformities can be seen. Deformities of both the 1st and 2nd degree are more pronounced in the sagittal plane.

In the case of kyphosis, it is 47% (three reduced and four times greater chest curvature from 15 gymnasts), and in lordosis 40% (two with a greater and four with a lower lumbar curvature from 15 gymnasts). In the case of scoliosis, it is 13% with only two cases of thoracic scoliosis out of 15 gymnasts. In order to analyze the possible impact of the training system, it is worth mentioning the countries of origin of gymnasts with a deformity. In the case of kyphosis, increased chest curvature was found in gymnasts from Austria (one of two), Bulgaria (two of four), and Serbia (one of two), and decreased in gymnasts from Bulgaria (one of four), Italy (one of four), and Slovenia (one of one). In the case of lordosis, increased lumbar curvature was found in gymnasts from Croatia (one of two) and Serbia (one of two), and decreased lordosis was found in competitors from Bulgaria (one of four), Denmark (one of one), South Africa (one of one), and Italy (one of one). Scoliosis in the thoracic part was found in competitors from Denmark (one of one) and Serbia (one of two).

Table 8 Percentage of deformities

	Normal	1st degree	2nd degree
Frontal plane – scoliosis	87%	13%	0%
Sagittal plane	27%	47%	27%
Kyphosis	53%	40%	7%
Lordosis	60%	33%	7%
Total deformities	27%	40%	33%

Representation of deformities cumulatively among all the gymnasts aged 8-17

From Table 9, high values of arithmetic means of deformities in the frontal plane and somewhat lower ones in the sagittal plane can be observed. The percentage of variation in the results is more pronounced with deformities in the sagittal plane.

Table 9 Parameters of central tendency and variance

	AS	MIN	MAX	R	SD	CV%
Scoliosis	4.49	1.00	5.00	4.00	1.15	26%
Kyphosis	4.10	1.00	5.00	4.00	1.25	30%
Lordosis	4.08	1.00	5.00	4.00	1.32	32%

Legend: AS – mean score, MIN – minimum value, MAX – maximum value, R – range, SD – standard deviation, CV% – coefficient of variation in %.

Table 10 shows the presence of 69% of spinal deformities in 87 gymnasts/participants aged eight to 17. Of that, 33% is a 1st degree deformity and 36% 2nd degree deformity. Grade 1 deformities are more pronounced in the sagittal plane. In the case of grade 2 deformities, a minimal presence of all deformities was noted.

Table 10 Percentage of deformities

	Normal	1st degree	2nd degree
Frontal plane – scoliosis	79%	11%	9%
Sagittal plane	38%	39%	23%
Kyphosis	62%	31%	7%
Lordosis	63%	28%	9%
Total deformities	31%	33%	36%

Deformities in the sagittal plane

Tables 11, 12, and 13 shows that the most common deformities include flat backs (36 gymnasts) of which 11% (10) have a more pronounced occurrence. This deformity occurs equally in the chest and back, but the occurrence of this deformity is less common on the entire spinal column (7%). After a flat back, the next most common deformities are lordosis and kyphosis, but there are not many values that can indicate a higher degree, i.e. structural deformity.

Table 11 Percentage of deformities collectively in the sagittal plane

	Normal	1st degree	2nd degree
Normal values	38%	0	0
Flat back	40%	29%	11%
Increased curvature values in the sagittal plane	22%	18%	4%

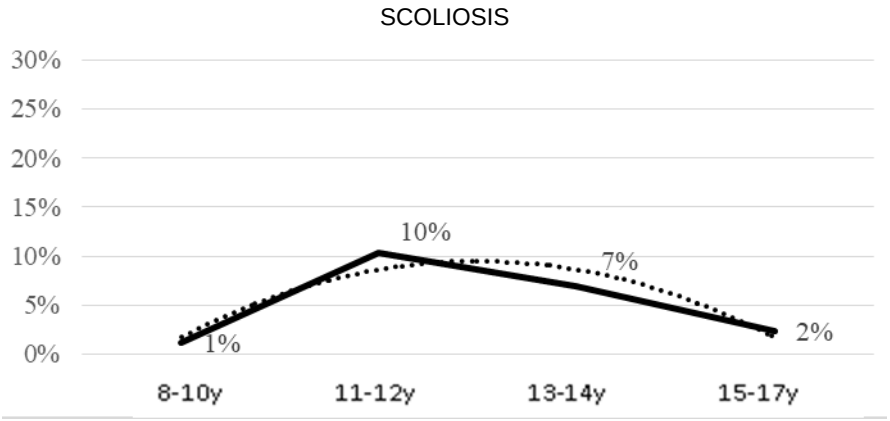
Table 12 Percentage of deformities – reduced curvature

	In total	1st degree	2nd degree
Flat back in the chest part	18%	14%	4%
Flat back in the lower part	16%	10%	6%
Flat back in both regions	6%	5%	1%

Table 13 Percentage of deformities increased curvature

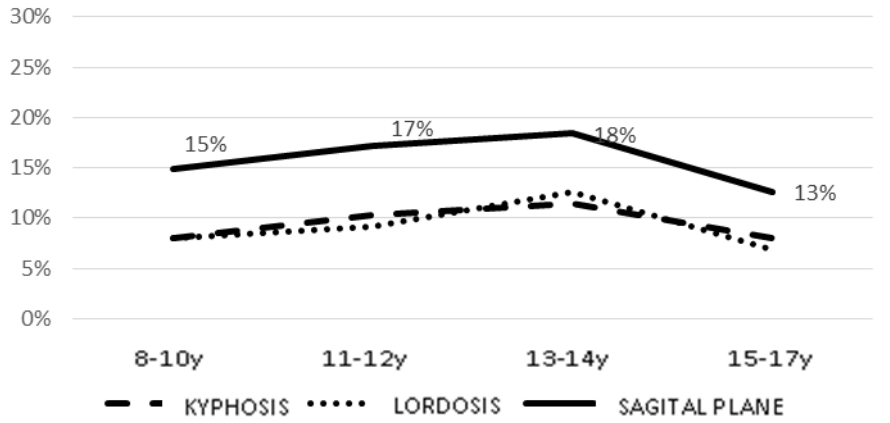
	In total	1st degree	2nd degree
Kyphosis	9%	8%	1%
Lordosis	11%	9%	2%
Kypho/lordosis	2%	1%	1%

Trend of deformities



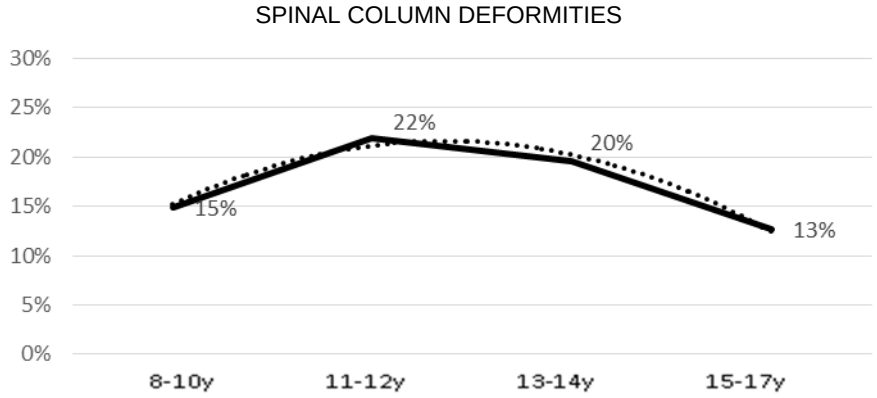
Graph 1 Trend of deformities in the frontal plane

The trend of deformities in the frontal plane, observing age, increases from 1% to 10% at 11 to 12 years, and decreases to 7% (13 to 14 years) and 2% in 15 to 17 years.



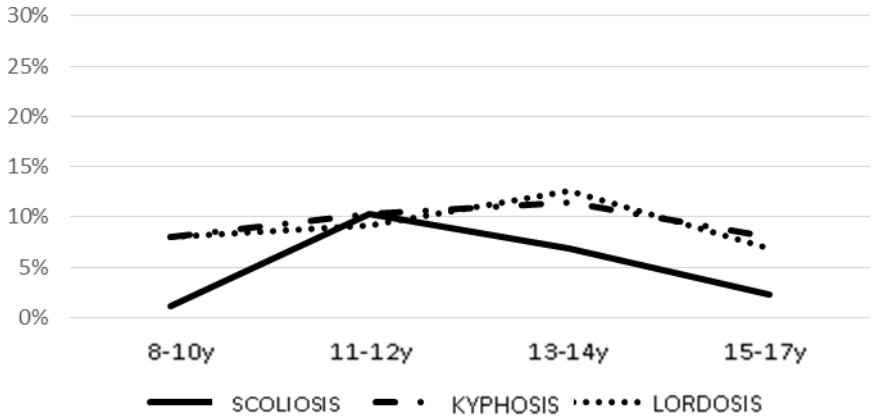
Graph 2 Trend of deformities in the sagittal plane

The trend of deformities in the sagittal plane is increasing. Looking at age, it increases slightly from 15% (8 to 10 years) to 18% in 13 to 14 years, after which it decreases to 13% at the age of 15 to 17.



Graph 3 Trend of all deformities

The trend of deformities observed in gymnasts/participates in relation to age, increases from 15% to 22% in 11 to 12 years, and then decreases to 13% in 15 to 17 years.



Graph 4 Ratio of spinal column deformities in the frontal and sagittal plane

A review of Graph 4 shows that deformities in the sagittal plane are dominant.

Differences in deformities between age groups

Based on the obtained results of the Mann-Whitney U test (Table 14), it can be concluded that in almost all cases of comparing the values of spinal column deformities, there are no statistically significant differences between the groups. The only recorded statistical significance of the differences between the groups is between groups one and two, in terms of scoliosis. Namely, here is the difference in favor of a larger number of observed cases of scoliosis in the older group (11 to 12 years).

Table 14 Differences in deformities between age groups

		Scoliosis	Kyphosis	Lordosis	Fropla	Defall
Difference 1st and 2nd group	M-W U	207.50	257.50	256.50	238.50	271.50
	Z	-2.02	-.46	-.49	-.84	-.09
	Sig.	.04	.65	.62	.40	.93
	AS diff	.62	-.19	-.08	-.34	.07
Difference 1st and 3rd group	M-W U	203.00	223.50	202.50	218.50	191.50
	Z	-1.10	-.13	-.71	-.25	-.95
	Sig.	.27	.90	.48	.80	.34
	AS diff	.29	-.03	.32	.13	.46
Difference 1st and 4th group	M-W U	132.00	132.00	137.50	131.50	97.00
	Z	-.74	-.42	-.20	-.41	-1.69
	Sig.	.46	.68	.84	.68	.09
	AS diff	.19	-.01	.22	.21	.92
Difference 2nd and 3rd group	M-W U	301.00	316.50	289.00	291.50	305.50
	Z	-1.12	-.67	-1.24	-1.08	-.81
	Sig.	.26	.50	.21	.28	.42
	AS diff	-.33	.16	.41	.47	.39
Difference 2nd and 4th group	M-W U	176.00	186.00	195.50	173.50	162.00
	Z	-1.36	-.92	-.67	-1.17	-1.46
	Sig.	.17	.36	.51	.24	.14
	AS diff	-.43	.17	.31	.55	.85
Difference 3rd and 4th group	M-W U	172.00	169.50	166.00	174.50	157.00
	Z	-.37	-.35	-.46	-.17	-.71
	Sig.	.71	.73	.65	.87	.48
	AS diff	-.10	.02	-.10	.08	.46

Legend: M-W U – Mann–Whitney U test, Z – value Z, Sig. – significance level Z,
AS diff – arithmetic mean differences expressed in %,
FROPLA – deformities in the frontal plane, DEFALL – the sum of all deformities.

DISCUSSION

This study had two aims, to determine the possible existence of spinal deformities in young gymnasts, and then to determine whether there are differences in the prevalence of spinal deformities in relation to their age and training experience. According to the main study findings, there are no statistically significant differences between groups in terms of almost all deformities, which can be justified by the approximately equal prevalence of deformities at all ages. Namely, these values range between 13% and 22%, i.e. between 13 and 19 gymnasts per group have spinal column deformities. Looking at the total number of participants (87), it is a low percentage, but looking at the group it is a mediocre percentage. However, the overall balance of spinal column deformities is worrying. Out of the total number of participants (87), as many as 69% (60 gymnasts) have deviations from the normal values of spinal column curves. Of this number, as many as 37% of gymnasts (32) have one more pronounced deviation from normal values or deviations from normal values for two or more monitored parameters. What mitigates the previously mentioned statement is the trend of recorded values. The results also indicate that the trend of potential

deformities first increases towards 11 and 12 years (when puberty begins) and only at this transition statistically significant differences were found (only in the case of scoliosis). However, after this period, the trend of deformity gradually decreases as the maturation period progresses.

The simplest scoliosis definition is a lateral spine curvature of at least 10 degrees (the Cobb angle) (Choudhry et al., 2016; Grivas et al., 2010; Kuznia et al., 2020; Lizak et al., 2014). In that regard, our study results show increases from 1-10% at 11 and 12 years, and decreases to 7% (13 and 14 years) and 2% in 15-17 years. There has been a rise in the occurrence of scoliosis among rhythmic gymnasts (10-16 years old), and potential causes include persistent asymmetric forces across the spine's development cartilage, particularly in prepubertal and pubertal athletes (Tanchev et al., 2000). Likewise, Jeon and Kim (2021) revealed that low body weight is closely associated with spinal deformity and scoliosis (idiopathic) in 10-year-old children, this may be related to our study, in terms of low body weight compared to the population mean values (Georgopoulos et al., 2012). But contrary to previously stated results, Meyer et al. (2006) have claimed that gymnastics has minimal impact on scoliosis; nonetheless, due to high important joint laxity, adolescents appear to select and prefer to continue gymnastics exercises. Gymnastics exercises, when practiced on a regular basis, strengthen the deep muscles of the spine and involve proprioceptive work. Although scoliosis is not often a deformity in the analyzed participant sample, this may indicate that the movements in artistic gymnastics are primarily symmetrical, i.e. require equal participation of both the left and right side of the body. This statement is also confirmed by Trexler et al. (2015). Thus, the results of this study indicate the positive side of exercising on apparatuses. However, Kenanidis et al. (2010) concluded that the relationship between scoliosis and sport is rather vague. In that case, we can assume that sport can be seen as both a causative factor and a means of treatment. Although the actual causes are still unclear (Kenanidis et al., 2008), the genetic factor should not be neglected (Lowe et al., 2000), or gender and curve pattern according to curve direction (Soucacos et al., 2000), as well as the family history and hereditary diseases (Bettany-Saltikov et al., 2016; Lizak et al., 2014). Hence, according to everything previously mentioned, there is a great need for conducting more studies on this topic with samples of gymnasts, in order to completely understand the eventual progression/regression mechanisms.

Particular critical periods taken in the deformity development (in this case kiphosis and lordosis) are ages 6 and 7, starting school, and puberty (Ghanem & Rizkallah, 2020). In that regard, we have identified that the trend of deformities in sagittal plane is increasing. By looking from the age perspective, it increases slightly from 15% (8-10 years) to 18% in 13 and-14 year-olds, after which it decreases to 13% at the age of 15-17. Likewise, deformities in the sagittal plane dominate (63%), i.e. 55 gymnasts have deviations in the thoracic and lumbar curvature. On the positive side, these values are, in most cases, in a group of values that deviate slightly from normal values. It is interesting to note that in the case of kyphosis and lordosis, increasingly lower values of the angles of these curves were found in relation to normal values (40% of all analyzed competitors). This indicates the appearance of a "flat back", which may be, in part, the impact of an improperly balanced training process. For example, while training handstands, which is a basic exercise, gymnasts are often required to have a whole body "straight line", which is better provided by conscious reduction of the chest and back curvature. Excessive training of these movements and positions can lead to the appearance of a flat back. In order to prevent this, it is necessary to perform regular periodic checks of the spine and enrich the training process with exercises of a compensatory nature.

However, our results are not in accordance with those of Sanz-Mengibar et al. (2017) who identified increased thoracic kyphosis in male compared to female gymnasts (-0.445; $p<0.001$). Likewise, the same study also revealed hyperkyphosis (12.5% male vs. 2.1% female gymnasts) and hypokyphosis (2.1% in female gymnasts). But regardless of the incongruity, comparisons must be made with caution based on the fact that the mentioned study did not present the participants' age. Furthermore, higher values of the chest and back curvature occur less in the examined group of female gymnasts, which differs from some studies (Ambegaonkar et al., 2014; Grabara, 2010). The mentioned research indicates that the main problem with female gymnasts is the increase of the lordotic curve, which is also partly caused by poor balanced training (too much hyperextension elements such as bridge, etc.). As in the previous case, the recommendation is regular periodic control of the spinal column and enrichment of training with compensatory exercises.

As far as the study limitations are concerned, the study involved participants in training, a day before competition itself, who were difficult to gain access to. Likewise, according to recent literature, there are better and modern ways of examining the spinal column deformity than the Spinal Mouse, such as Diers 4D Motion. This further means that our results could be taken with caution. Likewise, we can only say that based on the study scarcity on this topic, some conclusions must be taken with caution as well. Consequently, this is also a call for future studies.

CONCLUSION

The results of the study should promote a much more serious approach to the training process of young gymnasts, which should be reflected in regular-periodic control of the spinal column with modern measuring instruments. This further means that in order to detect possible disorders of the spine in time, an increased presence of exercises that will prevent some of the negative effects of the training process from the perspective of top gymnasts is necessary.

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RAZLIKE U ZASTUPLJENOSTI DEFORMITETA KIČME U ODNOSU NA SPORTSKO ISKUSTVO MLADIH GIMNASTIČARKI

Cilj ovog istraživanja bio je dvostruk, da utvrdi moguće postojanje deformiteta kičmenog stuba kod mladih gimnastičarki, a zatim da utvrdi da li postoje razlike u učestalosti kičmenih deformiteta u odnosu na njihov uzrast i iskustvo u treningu. Istraživanjem je obuhvaćeno ukupno 87 učesnica, kao takmičari na Međunarodnom turniru „Laza Krstić i Marica Dželatović" održanom u Novom Sadu. Prema uzrastu (8-10; 11-12; 13-14; 15-17), učesnice su podeljene u 4 kategorije (poduzorke). „Spinalni miš" korišćen je za određivanje posturalnog statusa na treningu, jedan dan pre takmičenja. Za svaku primenjenu varijablu (kifozu, lordozu i skoliozu) izračunati su parametri osnovne deskriptivne statistike, dok je za utvrđivanje razlika između grupa primenjen Mann–Whitney U test. Među grupama nisu utvrđene statistički značajne razlike u pogledu skoro svih deformiteta, što se može opravdati približno jednakom prevalencijom deformiteta u svim uzrastima. Od ukupnog broja učesnika, čak 69% (60 gimnastičarki) ima odstupanja od normalnih vrednosti krivine kičmenog stuba. Rezultati takođe ukazuju da se trend potencijalnih deformiteta najpre povećava sa približno 11. i 12. godinom (kada počinje pubertet) i tek na ovom prelazu utvrđene su statistički značajne razlike (samo u slučaju skolioze). Rezultati bi trebalo da promovišu mnogo ozbiljniji pristup trenažnom procesu mladih gimnastičarki, što bi trebalo da se ogleda u redovno-periodičnoj kontroli kičmenog stuba savremenim mernim instrumentima.

Ključne reči: *umetnička gimnastika, deca, adolescenti, kičmeni stub, Spinal Mouse*