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Shape of the Sagittal Curvatures of the Spine in Young Female Volleyball Players

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Abstract: Background: The issue of the relation betweeen training loads on the shape of the spine of young players is of significant importance, as with the advancement of training seniority, unfavorable changes may be perpetuated resulting in possible consequences in the next stages of ontogenesis. The aim of this study was to assess the formation of the sagittal curvatures of the spine in girls practicing volleyball versus their nonpractising peers. Methods: We examined 60 girls aged 10–13 years, including 30 volleyball players and 30 untrained peers. The Baseline Bubble inclinometer was applied as a research. The data were analyzed based on Mann–Whitney U test and Pearson Chi-square test. Results. There were statistically significant intergroup differences in lumbar lordosis curvature values ($Z = -2.67$; $p = 0.007$). The prevalence of correctness values of the thoracic kyphosis curvature, was group-dependent ($\chi^2(1) = 4.34$; $p = 0.037$). Group also determined the prevalence of lumbar lordosis normalities ($\chi^2(1) = 5.41$; $p = 0.020$). Conclusions. Volleyball has a beneficial effect on the formation of the thoracic kyphosis, while the lumbar lordosis is shallowed under the influence of training. This indicates the need for a holistic approach to player training and the need to supplement the technique and tactics training with exercises to strengthen the muscles that stabilize the lumbar spine, improve spinal mobility, learn how to control the anterior tilt of the pelvis and train the fascia.

Keywords: sport; training; measurements; thoracic kyphosis; lumbar lordosis; health

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1. Introduction

There are many scientific reports in the literature on the impact of systematic physical activity on human psychomotor development. Most authors focus on the positive aspect of practicing sports as a recipe for longevity. People with higher physical fitness have better cardiorespiratory capacity and, therefore, higher VO_2max levels, which lead to a longer life expectancy and a better quality of life [1–4]. According to other authors, physical activity is a prerequisite for a correct posture [5]. Noteworthy, in addition to the benefits of an active lifestyle, there is a risk of disorders, including posture, especially in the case of high-intensity efforts and competitive sports requiring repetition of sport-specific body positions. Therefore, sports training can be a variable affecting posture, including the curvature of the spine [6–8], and in turn, abnormalities in the shape of the spine can increase the risk of injury and overload of the musculoskeletal system, resulting in back pain in the future [9–12].

Every sport is characterized by a certain specificity, which is particularly evident in training plans. Playing volleyball involves the need to perfect the ability to change direction of movement and combinations of multi-directional movements. It requires fast reaction time and neuromuscular coordination [13]. The game requires moderate physical effort, interspersed with high-intensity activities [14,15]. Flexed positions prevail during defense, while upright positions prevail during attack and play. In addition, the game forces the player to perform dynamic unilateral movements [16]. The analysis of the available literature indicates that studies of volleyball players focus mainly on measurements of muscle strength [17] and postural stability [18,19], while there are no papers on the impact of volleyball training on posture, especially of those in the developmental period. Meanwhile, the problem of the influence of training and training loads on the shape of the spine of young players is of significant importance, as with the advancement of training seniority, unfavorable changes may be perpetuated, which may have consequences in the next stages of ontogenesis. Wilczyński et al. [20] and Wilczyński et al. [21] pointed out that postural defects constitute a significant health problem. Therefore, it is very important to pay attention to all the conditions that play a significant role in postural development. The above considerations became the reason for taking up the topic of the study, which aimed to assess the formation of the sagittal curvatures of the spine in girls practicing volleyball versus their untrained peers.

2. Materials and Methods

2.1. Participants

We examined 60 girls aged 10–13 years, including 30 volleyball players (eight 10-year-olds, six 11-year-olds, nine 12-year-olds, and seven 13-year-olds) attending Inter-school Sports Club “GALA” in Skarżysko-Kamienna, Świętokrzyskie Voivodeship, Poland. The control group included 30 health peers (eleven 10-year-olds, six 11-year-olds, six 12-year-olds, and seven 13-year-olds) who did not train any sports and did not regularly participate in any physical exercises apart from attending obligatory PE classes at Primary School No 13 in Skarżysko-Kamienna, Świętokrzyskie Voivodeship, Poland. The average age of girls from the study group was $\overline{x}$ = 11.50 ± 1.14 years, and the average age of girls from the control group was $\overline{x}$ = 11.30 ± 1.21 years. In the case of the study group, the training plan included drills to improve playing technique, i.e., receiving, passing, and playing the ball with the upper and lower ways, perfecting jumping, and practicing tactical skills, including field settings and attack and defense combinations.

Adopted criteria for inclusion were as follows: 10–13 yrs, right hand and right leg dominating according to Waterloo Handedness and Footedness Questionnaire—Revised [22], as well as an informed consent. The girls practicing volleyball trained for two years on a regular basis, three times a week.

The criteria for exclusion were symptoms of disease and/or musculoskeletal injuries, pathology of the limbs, previous orthopedic surgery, neurological disorders, being active in other sports groups, and refusal to participate in the study.

Basic descriptive statistics and comparison of select bodily characteristics of the study subjects are presented in Table 1. These data indicate that girls practicing volleyball had higher body weight (p = 0.007) and height (p = 0.002) values compared to their nonpractising peers, while the Body Mass Index values did not differentiate both groups.

Table 1. Comparison of select bodily characteristics of the study subjects.

Group	$\overline{x}$ ± SD	Max–Min	Q_{25}	Me	Q_{75}	Z	p
Body mass [kg]							
Study	47.73 ± 5.50	61.00–38.00	44.00	47.50	51.00	2.70	0.007 *
Control	44.10 ± 14.12	102.00–29.00	35.00	42.00	47.00		
Body height [cm]							
Study	159.27 ± 7.09	174.00–146.00	154.00	160.00	163.00	3.05	0.002 *
Control	152.27 ± 9.38	172.00–135.00	146.00	151.00	158.00		

Table 1. *Cont.*

Group	$\bar{x} \pm$ SD	Max–Min	Q_{25}	Me	Q_{75}	Z	p
			Body Mass Index				
Study	18.84 ± 1.99	22.90–15.10	17.90	18.45	20.60	0.99	0.321
Control	18.74 ± 4.18	36.10–13.20	16.40	18.10	19.60		

Abbreviations: $\bar{x}$ —arithmetical mean value; SD—standard deviation; Max—maximum value; Min—minimum value; Q_{25}—lower quartile; Me—median; Q_{75}—upper quartile; Z—value of the Mann–Whitney U test statistic; p—probability value. * $p < 0.05$.

2.2. Examination Protocol

The gravity-dependent (analog) Baseline Bubble inclinometer, model 12-1056 (Fabrication Enterprises, Inc., White Plains, NY, USA), was applied as the research tool of choice. The reliability of this measuring tool is excellent: Intraclass Correlation Co-efficient for interrater reliability ICC = 0.81–0.97, and Intraclass Correlation Coefficient for intrareader reliability ICC = 0.83–0.96 [23].

The study protocol entailed the measuring of the sagittal curvatures of the spine in a relaxed stance, with the upper limbs hanging down freely along the body. The feet were hip-width apart, and the toes were in one line. In order to avoid measuring errors, before starting the tests, landmarks were marked on the skin surface of each examined subject by means of a dermograph: C7 spinous process, thoracolumbar transition, a line connecting the lower aspects of the upper posterior iliac spines [24]. Palpation techniques employed in this research were adapted from those described by Palastanga et al. [25]. Before every test, the inclinometer was in the base position (zeroed to the vertical line), and the results were taken perpendicularly to the tool.

Measurements were made with an accuracy of 2° in the following landmarks:

- The sacral midpoint (α angle),
- Th12-L1 intervertebral space (β angle),
- C7-Th1 intervertebral space (γ angle) [24].

Measurements were compared to general Saunders guidelines [26]:

- Lumbosacral angle, LA (α angle), where the reference values are within the range of 15° to 30°;
- Thoracic kyphosis curvature, TKC (β angle + γ angle), where the reference values are within the range of 30° to 40°;
- Lumbar lordosis curvature, LLC (α angle + β angle), where the reference values are within the range of 30° to 40°.

Based on the measurement data, the compensation ratio (μ), was taken by subtraction of lumbar lordosis curvature value from the thoracic kyphosis curvature value [27]:

$$\mu = \text{TKC} - \text{LLC}.$$

The type of body posture as well as its subtypes were found based on Wolański's typology [28]. Balanced posture (B) was adopted as having the angle variance between the curvature of the thorax and lumbar spine between 0 and 5°. Such subtypes were noted:

- B I—with 0° to 2° difference between Th and L,
- B II—with 0° to 2° difference between Th and L,
- B III—with 5°difference between Th and L.

The kyphotic posture (K) was diagnosed when the thoracic curvature angle was big-ger than the angle of lumbar curvature by more than 5°. Such subtypes were noted:

- K I—normal (6–10°),
- K II—slight kyphosis (11–15°),
- K III—significant kyphosis (16–20° or more).

The lordotic posture (L) was determined in case the angle of lumbar curvature was bigger than the one of thoracic curvature by more than 5°. Such subtypes were noted as:

- L I—the norm (6–10°),
- L II—slight lordosis (11–15°),
- L III—significant lordosis (16–20° and above) [28].

Anthropometric measurements of the body mass and height were taken. The body mass was measured with OMRON BF500635 medical scale (Omron Ltd., Muko, Japan), determined to the nearest 0.1 kg. The body height was measured with GPM anthropometer (Vitako Ltd., Zurich, Switzerland), to the nearest 0.1 cm. Based on collected data, Body Mass Index was calculated which define height weight proportions for each study participant.

All measurements were carried out in the morning, in a warm, well-lit room, using the same measuring instruments operated by the Authors. Study participants wore their underwear, and barefoot. All study protocol procedures were pursued in full compliance with the ethical standards of the Helsinki Declaration as revised in 2013. All participants, their parents or legal guardians received detailed information concerning the aim and methodology used in the research and signed written informed consent. The study protocol was approved by the Bioethics Review Committee, University of Rzeszów (Approval Ref. No. 3/12/2015).

2.3. Statistical Analysis

The consistency of the values with the normal distribution was verified by means of the Shapiro–Wilk test. The data did not meet the assumptions of parametric tests, therefore non-parametric Mann–Whitney U test was used to evaluate differences in average level of tested variables between girls practicing volleyball and the controls. The analysis of qualitative data was carried out using the Pearson Chi-square test. The statistical significance was set at $p < 0.05$. The Statistica application, ver. 13.3 PL (StatSoft Inc., Tulsa, OK, USA; StatSoft, Krakow, Poland) was used to process the test results.

3. Results

Data in Table 2 indicate statistically significant intergroup differences in lumbar lordosis curvature values ($p = 0.007$). These values were lower in the study group.

Table 2. Comparison of values of angles determining the shape of the sagittal curvatures of the spine and the compensation ratio in the study subjects.

Group	$\bar{x} \pm$ SD	Max–Min	Q_{25}	Me	Q_{75}	Z	p
Inclination of the lumbosacral section of the spine: α angle [°]							
Study	13.80 ± 4.57	20.00–2.00	10.00	15.00	16.00	−1.83	0.066
Control	16.27 ± 5.17	26.00–5.00	12.00	15.00	20.00		
Inclination of the thoracolumbar section of the spine: β angle [°]							
Study	13.40 ± 5.63	30.00–5.00	10.00	14.10	16.80	−1.55	0.118
Control	15.77 ± 5.26	25.00–5.00	12.00	14.20	17.15		
Inclination of the upper thoracic section of the spine: γ angle [°]							
Study	22.90 ± 7.12	35.00–5.00	18.00	21.50	30.00	−0.57	0.564
Control	24.20 ± 6.60	40.00–15.00	19.00	25.00	30.00		
Thoracic kyphosis curvature: TKC [°]							
Study	36.30 ± 8.21	45.50–12.00	31.00	35.50	40.00	−1.45	0.145
Control	39.97 ± 9.34	41.50–8.10	31.00	40.00	45.00		

Table 2. *Cont.*

Group	$\bar{x} \pm SD$	Max–Min	Q_{25}	Me	Q_{75}	Z	p
Lumbar lordosis curvature: LLC [°]							
Study	27.20 ± 7.36	45.00–15.00	22.00	27.00	31.00	−2.67	0.007 *
Control	32.03 ± 6.39	50.00–22.00	28.00	31.00	33.00		
Compensation ratio: µ [°]							
Study	9.10 ± 6.64	22.00–(−4.00)	5.00	10.00	13.00	0.85	0.391
Control	7.93 ± 8.06	25.00–(−4.00)	1.00	5.50	12.00		

$\bar{x}$—arithmetical mean value; SD—standard deviation; Max—maximum value; Min—minimum value; Q_{25}—lower quartile; Me—median; Q_{75}—upper quartile; Z—value of the Mann–Whitney U test statistic; p—probability value. * $p < 0.05$.

The prevalence of correctness values of the thoracic kyphosis curvature was group-dependent ($p = 0.037$). In the study group, normal values of this variable were found more often. Group also determined the prevalence of lumbar lordosis normalities ($p = 0.020$). Girls from the study group less often have normal lumbar lordosis (Table 3).

Table 3. Frequency of abnormalities in lumbosacral inclination, curvature of thoracic kyphosis, and lumbar lordosis depending on group.

Formation of Spinal Curvatures	Study Group	Control Group
	***n* (%)**	***n* (%)**
Inclination of the lumbosacral section of the spine (α angle)		
Correct	10 (33.0)	8 (27.0)
Incorrect	20 (67.0)	22 (73.00)
Chi-square test	$\chi^2(1) = 0.32$; $p = 0.573$	
Thoracic kyphosis curvature		
Correct	21 (70.00)	13 (43.00)
Incorrect	9 (30.00)	17 (57.00)
Chi-square test	$\chi^2(1) = 4.34$; $p = 0.037$ *	
Lumbar lordosis curvature		
Correct	10 (33.00)	19 (63.00)
Incorrect	20 (67.00)	11 (37.00)
Chi-square test	$\chi^2(1) = 5.41$; $p = 0.020$ *	

n—number of subjects; %—percent of subjects; χ^2—value of the Chi-square test statistic; p—probability value. * $p < 0.05$.

The data in Table 4 indicate that lordotic type of body posture was not recorded in any of the groups. The prevalence of body posture types and individual subtypes of body posture was not group-dependent.

Table 4. Prevalence of body posture types and subtypes depending on group.

Type of Body Posture		**Study Group**	**Control Group**
		***n* (%)**	***n* (%)**
Balanced		9 (30.00)	15 (50.00)
Kyphotic		21 (70.00)	15 (50.00)
Lordotic		0 (0.00)	0 (0.00)
Chi-square test		$\chi^2(1) = 2.50$; $p = 0.114$	
Balanced	B I	5 (56.00)	9 (60.00)
	B II	1 (11.00)	4 (27.00)
	B III	3 (33.00)	2 (13.00)
Chi-square test		$\chi^2(2) = 1.75$; $p = 0.416$	
Kyphotic	K I	9 (43.00)	4 (27.00)
	K II	10 (48.00)	6 (40.00)
	K III	2 (9.00)	5 (33.00)
Chi-square test		$\chi^2(2) = 3.30$; $p = 0.192$	

n—number of subjects; %—percent of subjects; χ^2—value of the Chi-square test statistic; *p*—probability value.

4. Discussion

In our study, in terms of values of angle determining the lumbar lordosis, there are differences between girls practicing volleyball and their nonpractising peers. Volleyball players are characterized by smaller lumbar lordosis curvature. Moreover, practicing volleyball determined the prevalence of lumbar lordosis normalities. Volleyball players less often have correct lumbar lordosis. Similar results were obtained by Grabara [7], who analyzed the shape of anteroposterior spine curvatures in 14–16-year-old boys practicing volleyball compared to their non-training peers. In terms of volleyball, adolescent males demonstrated a lower degree of lordosis than those not training. The compensation coefficient showed that thoracic kyphosis was bigger than lumbar lordosis. No significant differences were observed regarding the angle of thoracic kyphosis in the volleyball players and non-training subjects. Authors suggest that flattened lumbar lordosis may also be connected with retroversion of the pelvis because of enhanced trained abdomen and gluteus muscle activation. In turn, Muyor et al. [29] and Yang et al. [30] mentioned that the stiffness of the lower lumbar segments and limitations of spinal joint mobility may influence the depth of the lumbar lordosis.

The outcomes of our study and analysis of the available literature are thought-provoking. A shallowing of the lumbar lordosis reduces the cushioning function of the spine. This is a cause for concern, as training and match play include elements such as attacking, playing, and blocking the ball thrown by the opponent, which require multiple repetitive jumps, which, with the limited cushioning capacity of the spine, may predispose to overloading of the lower part of the spine. These abnormalities can contribute to disturbances in the entire kinematic chain and be a risk factor for injury during training or play. Wasser et al. [13] also pointed out that playing volleyball poses a risk of musculoskeletal strain. The authors pointed out that postural abnormalities in athletes are often a consequence of mistakes at the initial stage of training, with the most common being a warm-up that is too short and inadequate for the effort involved and a lack of exercises to form the habit of correct posture. Therefore, it is necessary to pay attention to a holistic approach to player training. Exercises that strengthen the muscles that stabilize the lumbar spine, fascial training, pelvic anterior tilt training, and spinal mobility facilitation in the volleyball training course can be an important part of the prophylaxis of musculoskeletal abnormalities.

Results of our research indicate that practicing volleyball determines the frequency of correctness in the thoracic kyphosis curvature. For volleyball players, normal values of this variable were found more often. On this basis, it can be concluded that playing volleyball has a positive effect on the shape of the thoracic kyphosis. It seems that one of the factors shaping the thoracic kyphosis are ball passes from above the head, which do not require a lot of physical effort, but are repeated many times during training and match play. The stabilizing muscles of the shoulder girdle have their attachments on the vertebral column, so movements of the shoulder girdle, especially those requiring the elevation of the upper limbs over the head, are linked to, i.e., movements of the thoracic spine. Therefore, they can be a factor in shaping the spine.

Our results showed that the prevalence of body posture types and subtypes is not de-pendent on practicing volleyball. There is a lack of reports in the literature on posture types and subtypes in adolescent female volleyball players. Few include the study by Chromik et al. [31] in a group of 13- and 14-year-old adolescents. The authors found no variation in the frequency of individual posture types and subtypes in girls, while the kyphotic type predominated in the male sex.

It is worth noting that girls practicing volleyball had higher body weight and height values compared to their nonpractising peers. We do not recognize these differences as potential confounders affecting the results, especially that the Body Mass Index values did not differentiate both groups.

In conclusion, it should be emphasized that the development of short- and long-term training programs aimed at improving the performance of volleyball players requires the use of theoretical foundations in physiology and sports medicine, as well as knowledge of the biomechanics of movements typical of the sport. Training plans, especially in the case of children and adolescents at the developmental age, in addition to exercises to improve technique and movement dynamics, should include general development exercises, strengthening muscle strength, coordination exercises, postural stabilization, as well as stretching and rolling exercises to improve muscle and tendon mobility. In addition, training plans should include activities aimed at athlete recovery, which will minimize the risk of deterioration in health and performance, thereby reducing sports performance.

Limitations and Future Research

This study has several limitations. Firstly, we limited our study to analyzing selected features that determine the shape of the anteroposterior curvatures of the spine, including its lumbosacral, lumbar, and thoracic parts. Therefore, future research projects should also consider analyzing the shape of the cervical part of the spine. Secondly, we focused on a cross-sectional study of adolescent female volleyball players, and the results encourage longitudinal studies. It would be interesting to see whether the demonstrated differences in spinal curvature also occur in the same individuals in adulthood. In addition, future research projects should also contain male athletes, including those representing various sports. Third, only the gravity-dependent Baseline Bubble inclinometer was applied as the research tool of choice. Therefore, future research protocols should be supplemented with measurements by optoelectronic methods, enabling photogrammetric video recording of the tested surface using the raster stereography process.

5. Conclusions

1. Only in terms of values of angle determining the lumbar lordosis are there differences between girls practicing volleyball and their untrained peers. Volleyball players characterized by less lumbar lordosis curvature.
2. Practicing volleyball determines the frequency of correctness in the thoracic kyphosis curvature. For volleyball players, normal values of this variable were found more often. The group also determined the prevalence of lumbar lordosis normalities. Volleyball players less often have normal lumbar lordosis.
3. The prevalence of body posture types and subtypes is not dependent on practicing volleyball.

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