Physical activity and the shape of anterior-posterior spinal curves in primary school children

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

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Abstract

Background & Study Aim: The children and youth should engage in an average of at least 60 minutes of moderate-to-vigorous physical activity every day of the week, as well as muscle and bone-strengthening activities at least three days a week. The data indicate that 27.5% of adults and 81% of adolescents do not meet the 2020 WHO recommendations for physical activity with almost no improvements seen during the past decade. The goal of the research was knowledge about the influence of physical activity on the shape of anterior-posterior spinal curves in children in primary school age.

Material & Methods: The study included 103 pupils, divided into a research group (48 children) with additional physical activities (6 h/week), and a control group (55 children) who participated only in PE classes at school. The study included an interview, clinical examinations and assessment of the back surface using the photogrammetric method. The three indicators were analysed: alpha, beta, and gamma angles. Measurements were taken in June 2022.

Results: The results of alpha and beta measurements showed significantly higher values for girls and boys in the control group. Gamma angle values differed in boys, with higher angle values recorded in boys in the control group. Among the girls, the gamma angle was bigger in the control group but the differences between the groups were not statistically significant.

Conclusions: The research group (more intense physical activity) showed lower values of spinal curves in the sagittal plane than the control group. In both groups, gender did not differentiate the values of the indicators in question. The results obtained in both groups suggest that more frequent physical activity may contribute to a greater awareness of the correct posture habit.

Keywords: body posture • moiré topography • posture defects

Conflict of interest: Authors have declared that no competing interest exists

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Moiré topography – a method of three-dimensional morphometry in which contour maps are produced from the overlapping interference fringes created when an object is illuminated by beams of coherent light issuing from two different point sources.

PE – *abbreviation* physical education [36].

Obesity – *noun* the condition of being seriously overweight [36].

Cardiovascular – *adjective* relating to the heart and the blood circulation system [36].

Kyphosis – *noun* an excessive backward curvature of the top part of the spine (NOTE: The plural is **kyphoses**) [36].

INTRODUCTION

According to the World Health Organization (WHO), physical activity is any bodily movement produced by skeletal muscles that requires energy expenditure. In 2020, WHO set some recommendations for physical activity and sedentary behaviour in different age groups. They state that children and youth should engage in an average of at least 60 minutes of moderate-to-vigorous physical activity every day of the week, as well as muscle and bone-strengthening activities at least three days a week. The data indicate that 27.5% of adults and 81% of adolescents do not meet the 2020 WHO recommendations for physical activity with almost no improvements seen during the past decade. There are also notable inequalities regarding physical activity and gender (in most countries girls and women are less active than boys and men) and significant differences in levels of physical activity between higher and lower economic groups, and between countries and regions [1-3]. The quality of life of children and youth is determined, among others, by the amount of physical activity. If insufficient, it may lead to the decline in physical fitness, excessive weight/obesity, cardio-vascular and psychophysical disorders, and development of negative posture-forming processes [4-10]. A sedentary lifestyle, which is, among other things, a consequence of the excessive use of devices emitting blue light, can become one of the main causes of reduced psychophysical fitness and, consequently, contribute to the development of postural defects [8].

It should be borne in mind that in 25-60% of children and adolescents, body posture disorders occur in the form of a rounded back, hanging arms or too much front-crushed pelvis. In a properly forming child's spine, ensuring on the one hand mobility on the other, stability, spine arches in a sagittal plane should be harmonious, but also change in a characteristic way in individual periods of posture genesis. Because body posture develops especially during childhood and maturation, it seems reasonable to monitor body posture in children, also in the anterior-posterior plane, because, for example, increased spinal curvature of the spine (thoracic kyphosis or lumbar lordosis) in combination with increased tilt of the chest and head protraction is observed in children with weak postural muscles. Thus, the assessment of the impact of physical activity on the child's body posture seems to be the most justified, e.g. in terms of the selection of a dedicated form of improvement, considering the form of sports activities in which the child participates [11-14].

Observing today's lifestyle, it can be seen that on the one hand there is a lack of diverse physical activity, and on the other hand, asymmetrical, static activities and overloads dominate, which can lead to overloading of the musculoskeletal system. These negative changes cause a lower level of physical fitness and can also lead to changes in body posture as early as preschool. The situation deteriorates when children go to school. With the start of school education, the spontaneous physical activity of children is even more limited. They are exposed to stress resulting from school duties, remain in a sitting position for a long time, and in addition, there is often a lack of ergonomic workplace in schools. All these factors affect the musculoskeletal system, which can cause changes in body posture. As the body increases, some of these changes are improved, however, some of the permanent changes in body posture may turn. An important fact is that an adequate level of physical activity also has a significant impact not only on body posture parameters, but also involves improving cardiopulmonary efficiency, muscle efficiency and healthy bones [15-17].

So far, there is no clear response in the literature on the relationship between physical activity and the formation of the anterior-posterior curves of the spine in children. Bearing in mind the occurrence of disorders in body posture in a sagittal plane and negligible information about the relationship between the influence of physical activity and these changes, it is important to undertake the analysis of this topic. Thus, introducing early diagnostics of posture defects in children and an ongoing promotion of physical activity should be one of the priority elements of prevention of postural defects. Diagnostics of the anterior-posterior spinal curvatures in children in primary school age is an important element of early detection of such deformities and can be performed using simple or more complex measuring methods [16].

Thus, the early assessment of changes arising in the spinal plane among children, in the context of their prevention and treatment, seems reasonable. According to the authors, the use of the photogrammetric method and the effect of the mory projection, corresponds to the assumption that the test is simple and quick to perform, non-invasive, also possible to perform in a mobile version (mobile device), which gives the opportunity to assess in schools or facilities located in terms of peripheral to specialist diagnostic centres. Archiving of the projection mory research ensures easy storage and reproduction of images while respecting the patient's anonymity. The use of this technique allows the child to better understand posture defects, which improves his cooperation during exercise or physical activity.

The authors assumed that in children who participate in additional classes related to physical activity, it may have a corrective effect on the formation of anterior-posterior curvatures of the spine.

The goal of the research was knowledge about the influence of physical activity on the shape of anterior-posterior spinal curves in children in primary school age.

MATERIAL AND METHODS

Participants

Initially, the first author chosen 120 children aged 7-10 years to participate the study. Due to written withdrawals of parent/guardian's consent (n = 6), coexisting diseases preventing from participating in the tests (n = 7) or inability to communicate with the respondent in order to perform the examination (n = 4), 103 children were eventually qualified and then divided into a research group (48 children engaged in additional physical activities) and a control group (55 children not engaged in additional physical activities) (Figure 1).

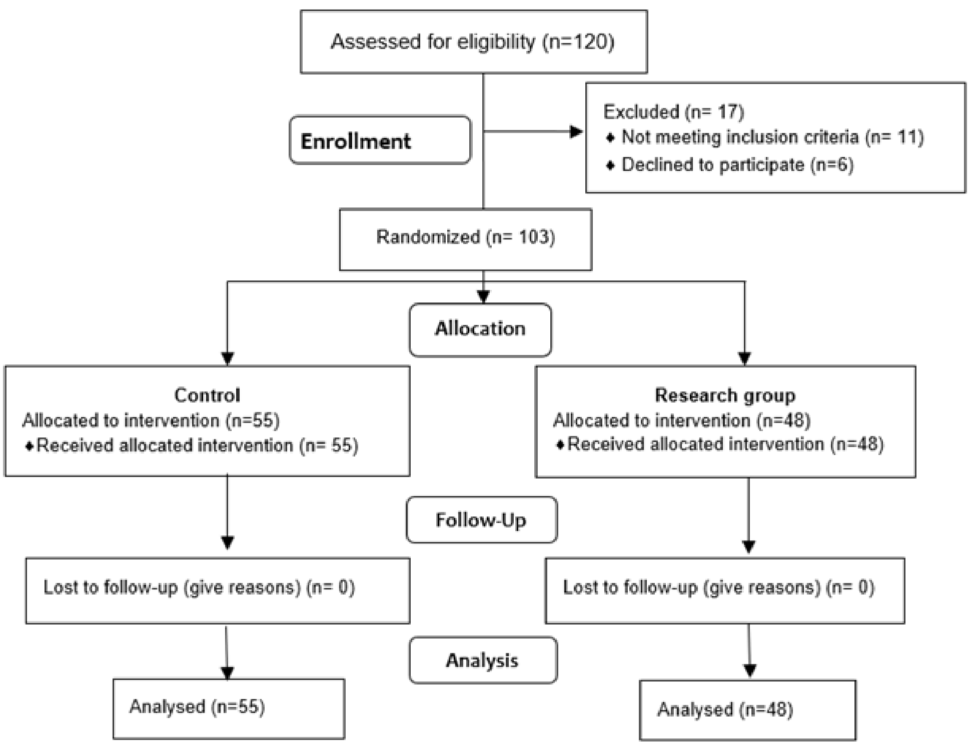

Figure 1. Flow diagram.

The study was conducted among children in early primary school age, the average age for girls was 8.2 years (min 7.2; max 9.8) and for boys 8.4 years (min 7.2; max 9.8). The results of the anthropometric tests showed lack of differences in the weight between girls and boys in both analysed groups. Some significant differences were only found between boys, in the weight in the research and control group (Table 1). Boys in the research group had a higher average body weight. The assessment of the height showed differences between boys and girls in the research group and between girls in the research and control group (Table 1).

Study design

The observation cross-sectional study was conducted in compliance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies [11].

The research was conducted in eight primary schools in Malopolskie region, between November and December of 2019.

The first author recruited 120 pupils the study. On the day of the assessment, 17 people did not take the test, the final sample consisted of 103 students. The respondents were then divided into two groups: research and control. The research group consisted of 48 students (22 girls and 26 boys) who were engaged in an additional physical activity organized after school 3 times a week (average 6 hours a week), for a year. These additional activities included skiing, team sports, swimming, cross-country running, cycling for at least 10 months. The other group was a control group of 55 children (26 girls and 29 boys) who participated only in PE lessons at school.

The eligibility criteria for both groups were: age 7-9 years, no coexisting diseases which could affect the test results, normal body weight according to the Cole index.

Excluding criteria: medical contraindications to participate in physical activity (including PE lessons), visible body deformations (differences in limb length, visible spine curvature), vision and hearing defects.

In addition, respondents had to have consent of the school directors for the examinations to be performed; good communication, necessary to perform the examinations (a child willing to undress and prepare for the examination).

Intervention

At the outset, the age in years and months was estimated based on the date of birth. The next step was:

1. Clinical examination involving: (a) anthropometrics tests: weight and height measurement while standing using a verified medical column scale C315.60/150.OW-3 – a 100-200 cm height measuring device (UNIWAG – Professional electronic scales, Krakow, Poland); (b) assessment

Table 1. Body weight (kg) and body height (cm) research group (boys 26, girls 22) and control group (boys 29, girls 26).

Group	Boys		Girls		p
	M	SD	M	SD	
		body weight [kg]			
Research	28.04	5.46	29.7	6.35	0.082
Control	32.3	8.37	29.0	4.41	0.334
p	**0.039***		0.644		
		body height [cm]			
Research	132.1	8.53	127.4	4.44	**0.018***
Control	132.1	8.53	132.1	7.69	0.428
p	0.459		**0.011***		

*p<0.05

of the course of the spinous processes of thoracic and lumbar vertebrae, assessment of the set of selected anatomical trunk points: shoulder processes and bottom angle of the shoulder-blades, waist triangles, anterior superior and posterior superior iliac spines, greater trochanter of the femurs. A medical skin marker from Covidien was used to mark the characteristic anthropometric points on the skin (Medtronic, Minneapolis, MN, USA).

2. Physical examination using a device to study the back surface with photogram metrical method and projection moiré (MORA 4G system, Computer Postural Assessment Device, Wroclaw, Poland).

During the observation, the room must have been darkened and artificial light was switched off during the recording of the image. The examined person was dressed only in underwear and barefoot. First, selected anatomical points were marked on the patient's skin with the washable skin marker. The participant was standing, their posterior superior iliac spines were positioned in the same proximity from the measuring device (the rotation angle of the pelvis was 0°). PSISs were palpated by the attending physiotherapist. Several to several dozens of images were recorded in this position. Out of them, one was selected, which met the criterion of proper positioning of the pelvis and reflected the most typical posture of the patient. Examination of one child took about 5 minutes, including preparation. The research was always carried out by the same person.

The following 3 indicators showing changes in sagittal plane of the spine were analysed: alpha angle [α] – the inclination of the lumbosacral section; beta angle [β] – the inclination of the thoracic-lumbar section; gamma angle [γ] – the slope of the thoracic-upper segment (Figure 2).

Outcome measure

The moiré patterns method, sometimes called the projection moiré, is one of the spatial photograms metrical (photo topographic) methods used to reflect the shape and position, and to measure spatial objects based on the so-called photograms (special photographs). The moiré method uses deflections of the light beam between a screen with a network of lines and its shadow which is cast on the patient standing in front of the screen. The light waves interfere once they travel through the raster. The result is the image with layers, the so-called moiré patterns. The course of the topographic lines depends on the shape of the surface lit, usually the back, and the distance between the patient and the screen.

MORA 4G system Computer Postural Assessment Device is a modern measuring instrument that combines the advantages of MORA/ISIS spatial analysis systems and marker-based motion/walk analysis laboratories. At the same time, it enables simple and quick examinations [18].

Thanks to a second built-in camera, the whole body of the patient can be captured. This helps to identify major errors in posture setting such as turned head, moving the body weight in one leg, bent knee etc. [18].

Statistical analysis

The statistical analysis was conducted using MedCalc ver.20.210 package. Distributions of the variables were determined by means of Shapiro-Wilk test. Due to normal distributions, the results of the descriptive analysis are presented as mean values (M) and standard deviations (SD or ±). The analysis of differences was performed using Student parametric t-tests for independent groups. In the studies, the level of at least $p<0.05$ and higher was shown as statistically significant differences; significance level, probability (*p*).

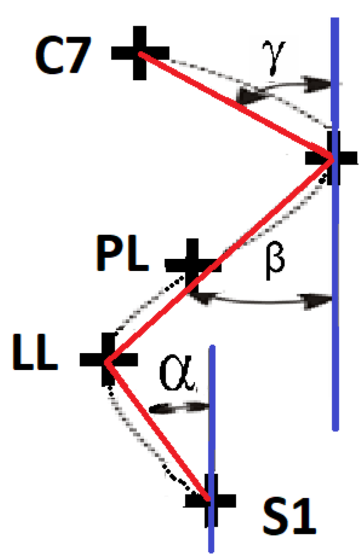

Figure 2. Alfa, beta, gamma angles [based on the figure from the article 18].

RESULTS

Results of spine curve measurements

Alpha angle

The results of alpha measurements show that significantly higher results were obtained for girls in the control group (research group M = 8.6 ±1.04, control group M = 9.3 ±1.04) Test t = 2.383, p = 0.021 (Figure 3). Similar situation was observed among the boys. The significantly higher results were noted in the control group (research group M = 8.6 ±1.56, control group M = 9.37 ±0.97). Test t = 2.148, p = 0.037 (Figure 4).

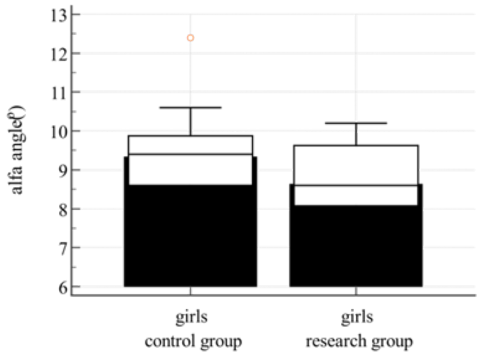

Figure 3. Alfa angle in girls.

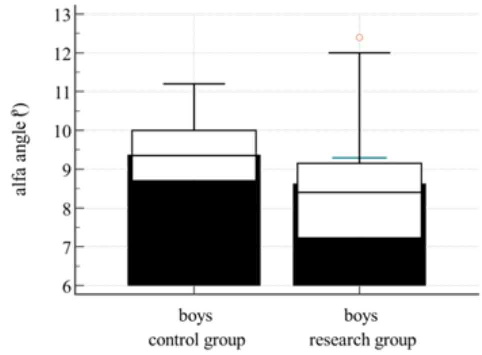

Figure 4. Alfa angle in boys.

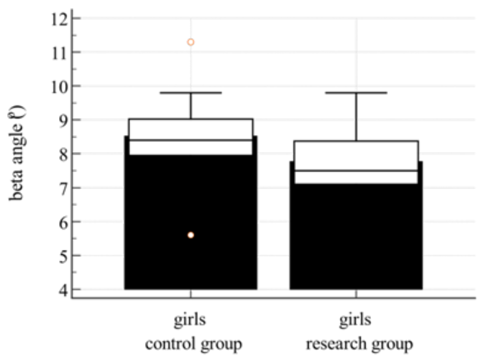

Figure 5. Alfa angle in girls.

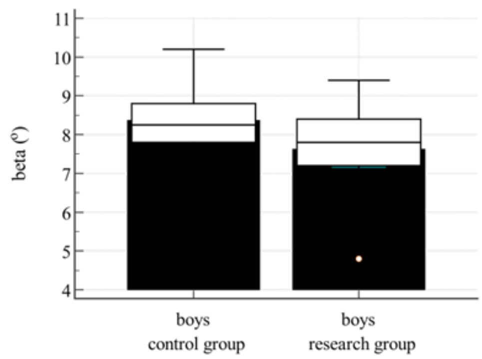

Figure 6. Alfa angle in boys.

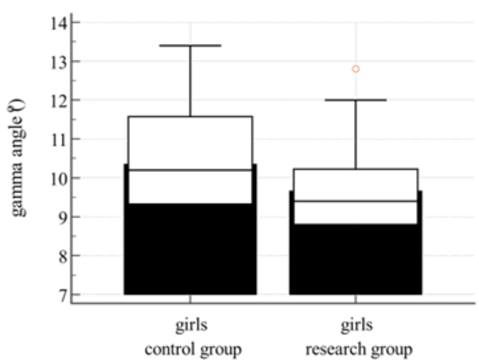

Figure 7. Gamma angle in girls.

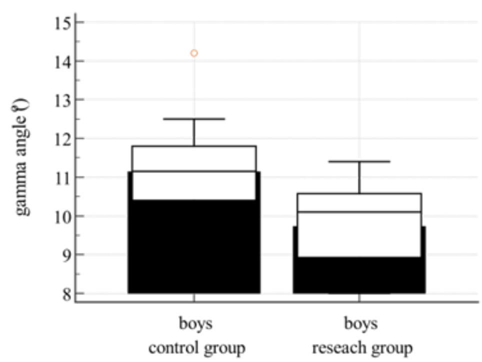

Figure 8. Gamma angle in boys.

Beta angle

The beta angle analysis also indicates higher values for girls in the control group (research group = 7.8 ±0.98, control group M = 8.5 ±1.04). Test t = 2.635, p = 0.011 (Figure 5). As for boys, the significantly higher beta angle values were also observed in the control group (research group M = 7.6 ±1.06, control group M = 8.4 ±0.92), Test t = 2.723, p =0.009 (Figure 6).

Gamma angle

As for the gamma angle, the higher values were also recorded among the girls, but they were not statistically significant (research group M = 9.7 ±1.24, control group M = 10.4 ±1.44). Test t = 1.800, p = 0.078 (Figure 7). In the boy group, in turn, the differences were clear (research group M = 9.7 ±1.06, control group M = 11.1 ±1.21). Test t = 4.653, p<0.0001 (Figure 8).

DISCUSSION

The results of the examinations indicate that the mean values of the indicators used to analyse changes in the sagittal plane (alpha, beta, and gamma angles) differ in both groups, depending on gender. The alpha and beta measurements show that significantly higher results were obtained for girls and boys in the control group. The gamma angle was statistically different for boys, the greater angle values were observed for boys in the control group. Among the girls, the gamma angle was bigger in the control group but the differences between the groups were not statistically significant.

According to the subject matter literature, primary school age is challenging in terms of posture genesis. In this period, children's bodies are the most vulnerable to posture alterations [19]. About 50% of children show postural changes in the frontal plane and 2-3% have idiopathic scoliosis [20-23]. Modern electronic devices offer children and adolescents various forms of spending free time while reducing the need for natural movement which is a necessary element of correct psychomotor development. Such lifestyle can contribute to increasing the body weight and, consequently, developing postural defects. Posture defects are one of the major health issues in today's society. The percentage of people with incorrect body posture has been growing. According to Janiszewska et al. [20], in Poland, the rate of children and adolescents aged 7-15 years with diagnosed postural defects ranges from 65% to over 90% [20].

The influence of physical activity on the development of anterior-posterior spinal curves in children in primary school age has not been widely discussed in the literature.

Kurzeja et al. [23] studied 189 children in average age 8.3 ±0.7 (7-10 years) using surface topography and measured their body imbalance tolerance. They concluded that the development of lumbar lordosis leads to a decrease in imbalance tolerance. The greater weight, the lower tolerance of imbalance.

Kozinoga et al. [22] used digital photographs to assess the body posture in 400 children selected randomly from a cohort of 9,300 kids participating in screening for scoliosis. 167 children were engaged in regular sport activities in school (control group), whereas 233 were engaged in both school sport classes and a dedicated physical activity program (intervention group). The authors showed that, compared to the children who were active only during school classes, those who participated in the dedicated physical activities tended to improve their posture – what is indirectly consistent with the results of the research presented herein.

Using photogram metrics, Barczyk et al. [24] evaluated spinal anterior-posterior curves in 94 children aged 8-13, with mild scoliosis, who participated in a 6-month program of swimming and improvement exercises in water. The analysis of their results revealed, among others, a significant increase in the total length of the spine and thoracic kyphosis in the examined sample. In addition, a decrease in the torso bending angle, thoracic kyphosis angle and lumbar lordosis angle was observed. The research described in this paper also showed lower values for thoracic kyphosis and lumbar lordosis in the group engaged in more intense physical activity which included swimming.

Greater anterior-posterior curves of the spine (thoracic kyphosis or lumbar lordosis) with accompanying increased thorax bending and head protraction has been observed in children with weak postural muscles as well as adults suffering from myofascial back pain [25]. In their study among children aged 4-12 years, Lafond et al. [26]

described the differences in the sagittal plane, resulting from the lifestyle. One of the factors that determined postural defects in the sagittal plane was the amount of time spent sitting. Marin et al. [27] stated that hyper kyphosis – as typical deformation in the sagittal plane – can be corrected only through introducing exercises focusing on the spinal erector muscle into one's daily physical activity. The original research confirms the tendencies observed regarding the positive influence of physical activity on the shape of the anterior-posterior spinal curves.

Zećirović et al. [28] analysed 17 articles about the body posture and thoracic kyphosis among school children and concluded that incorrect posture and kyphosis are significantly more often diagnosed in boys than in girls. Moreover, kyphosis is more advanced in individuals with an increased BMI and those who live sedentary lifestyle. The research presented herein showed higher values of the parameters measured for thoracic kyphosis for both girls and boys in the control group, and significantly lower values for both genders in the research group.

It can be assumed that the posture defects in question result from neuromuscular imbalance [29]. Thanks to muscular balance, individual body segments assume specific positions. It is assumed that weak stomach and buttock muscles as well as hip flexors spasm can lead to excessive anterior pelvic tilt, which in turn, results in lumbar hyperlordosis [30, 31]. Increased physical activity could have contributed to the normalization of the muscles of the tonic and phasic system, leading to the decrease in spinal curves in the sagittal plane. Thus, it can be assumed that more intense physical activity in the research group could have improved proprioception and the mechanism regulating postural stability.

This positive influence on the posture is not the only advantage of regular physical activity of children. In their 2008 report titled Physical Activity Guidelines Advisory Committee Report [32], the U.S. Department of Health and Human Services stated that children and adolescents involved in regular physical activity show a higher level of physical fitness (cardio-respiratory endurance and muscular strength), less adipose tissue, favourable risk profiles regarding cardio-vascular and metabolic diseases, improved bone health and less frequent symptoms like depression or anxiety. The positive impact of physical activity on the bone mass has been observed by Welten et al. [33], Sundberg et al. [34] and Bielemann et al. [35]. Thus, based on the study results, it can be assumed that children from the research group would show a higher level of physical fitness. This will lead to a better neuromotor control in the future, which can reduce the risk of spinal deformations.

Study limitations

The authors are aware of some limitations in the study. Examinations in a bigger population and by different forms of physical activity should be made. This would enable precise identification of the type and strength of influence of specific activities on the shape of the anterior-posterior spinal curves.

It can be observed that, despite being very beneficial for children's physical development, sport classes at school can be insufficient to ensure the correct postural development due to the prevailing model of sedentary lifestyle. A vital practical challenge is the question whether it can be enriched with additional out-of-school sport activities. There are numerous initiatives supporting physical development of children on the local, municipal, or regional levels. Advocating for additional activities for children, the authors wish to emphasize the benefits from using objective tools (such as moiré topography) in evaluating different programs introduced country wide, especially those based on the public funds.

CONCLUSIONS

The research group (more intense physical activity) showed lower values of spinal curves in the sagittal plane than the control group. In both groups, gender did not differentiate the values of the indicators in question. The results obtained in both groups suggest that more frequent physical activity may contribute to a greater awareness of the correct posture habit.

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