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Correlation between the functional state of the spinal column and the amount of movement among adolescents

Abstract

The aim of our research is to determine whether there is a correlation between the physiological condition of the spine, careless posture, and poor posture in the sample we examined in athletes and non-athletes. The questionnaire used during the research was adapted from the Global Physical Activity Questionnaire (GPAQ), to examine children's time spent exercising and sports habits. The assessment of the physiological state of the spinal column was carried out with the Idiag M360pro Spinal Mouse device. Negligence and playing sports show a statistically significant relationship ($\chi 2(1,N=61) =6.036$, $p =0.018$). A smaller proportion of sports children have careless posture (39.1%, 9 people) compared to non-athletes (71.7%, 27 people). Overall, postural weakness and playing sports also show a statistically significant relationship ($\chi 2(1,N=61) =7.878$, $p =0.008$). A smaller proportion of sports children have poor posture (26.1%, 6 people), compared to non-athletes (63.2%, 24 people). We can say that in the sample we examined, sports children have a smaller proportion of sloppy posture and poor posture, but half of the entire sample is affected by the problem. The primary task of physical education teachers and the coaches should be prevention through movement activities, the development of the need for sports, which promotes the development of proper muscle balance and, at the same time, correct posture.

Keywords: posture, poor posture, movement, spinal column, adolescents

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Introduction

Latalski et al.[1] posture is a motor habit formed at a specific morphological and functional level. From this point of view, posture is an indicator of the mechanical efficiency of the kinetic sense, which requires muscle balance and neuromuscular coordination. Others define posture as the optimal body position in which we achieve the best possible biomechanical efficiency with the least possible energy expenditure during our daily activities. In this case, the tension of the joint capsules and ligaments corresponds to the physiological level and the load on the taste surfaces is uniform.[2,3] Nowadays, correct posture is increasingly rare among children, thanks to prolonged incorrect sitting, ergonomically inappropriate desks, poorly carried school bags and lack of physical activity.[4–6] As a result, muscle balance is upset and posture disorders occur.[5,7] Adolescence is a critical period for the development of posture disorders. In this case, the hormonal balance of children changes, the rate of growth accelerates[6] as a result of the different rate of development of bones and muscles, disfunctions in posture may occur.[1]

Posture represents physical and mental health.[8,9] Optimum posture depends on many factors, but one of the most important of these is physical activity of the right intensity and reducing a sedentary lifestyle.[10,11,12] Risk factors for the development of increased back kyphosis include incorrect posture habits of adolescents, such as incorrect sitting position or prolonged use of electronic devices.[9,13] In most cases, spinal disorders and vertebral disorders that develop in adulthood are caused by poor posture, primarily the consequences of poor posture in childhood, and can be prevented with adequate exercises.[14,15] The World Health Organization[16] recommends that children and adolescents should do at least 60minutes of moderate to vigorous intensity physical activity per day. Based on research conducted among school-age children in Hungary, the proportion of non-athletes in boys between the ages of 9 and 15 rose continuously from 15.3% to 31.0%, and in girls of the same age, this proportion rose from 21.0% to 53.8 %.[17] The aim of the research is to present the relationship between the physiological condition of the spine, posture, and poor posture in the sample of children who are athletes and non-athletes.

Material and methods

In our research, we included seventh-grade students in an elementary school in Western Hungary in the 2020/2021 academic year (N=61, 31 boys, 30 girls; 12.67±0.6 years). We performed our study with the Idiag M360pro Spinal Mouse. Using its rollers, the examiner pulls the device along the spinous processes of the C7-S1 vertebrae along the spine. The software belonging to the instrument contains the necessary parameters to perform the Matthiass test, which can be used to measure the strength of the back muscles.[18] During the measurement, we examined the spine of the children in the sagittal plane while standing, bending forward, and after performing the Matthiass test, also while standing. The examination was carried out in the school's medical room, where only the people performing the examination and the examined student were present. The examined person exposed his upper body. The person conducting the examination marked the course of the vertebrae with the help of a felt-tip pen, then guided the instrument along the spinal column of the examined person, starting from the seventh cervical vertebra. The results measured by the Spinal Mouse device are sent to the computer via Bluetooth, and the software records them immediately. The reference values typical for the age group are recorded in the program, and we coded the results based on them. The questionnaire used during the research was adapted from the Global Physical Activity Questionnaire (GPAQ), to examine children's time spent exercising and sports habits.

Research ethics permit number for the study: 2020/136, issued by the Research Ethics Committee of ELTE (Hungary).

Statistical analysis

The sample selected based on the category variables (characteristics of the spinal sections measured in prominent body positions, gender, and physical activity) was analyzed using Pearson's chi-square (χ^2) test. In the scale variables (characteristics within, below, and above the reference value in each measured position, considering the different distinguished sections of the spine, were analyzed using the factorial ANOVA method, where $p<0.05$.

Results

Sample characterization

Children aged 12-14 took part in the research (N=61, M=12.67, SD=0.6), average 12.67±0.6, almost half of the boys (31 people, 50.8%) and girls (30 people, 49.2%). Among the children, 23 (37.7%) play sports and 38 (62.3%) do not. We considered an athlete to be someone who, in addition to physical education at school, participates in at least 60 minutes of training at least twice a week (Table 1). Most student athletes go to training twice a week (15 people, 65.2%); seven people three times a week (30.4%), one person five times a week (4.3%). The length of the training session is one hour for six people (26.1%); 11 people (47.8%) spend an hour and a half, while six (26.1%) spend two hours occasionally training (Table 1).

Spinal mouse measurement results, standing position

Gender and playing sports did not show a statistically significant relationship ($\chi2(1,N=61) =3.062$, $p =0.114$). However, based on the frequency data, a higher proportion of girls do not play sports (73.3%, 22 persons), while the proportion of boys is 51.6% (16 people).

Looking at the results of the standing position measurement for the entire sample, the value of dorsal kyphosis was within the reference value in 52.2% of sports children and 57.9% of non-sports children. Dorsal kyphosis above the reference value was measured in 17.4% of sports children and 21.1% of non-athletes, and dorsal kyphosis below the reference value was measured in 30.4% of athletes and 21.1% of non-athletes. 33.3% of male athletes and 87.5% of female athletes have a back curvature within the reference value. The same can be said about 56.2% of non-athletic boys and 59.1% of non-athletic girls. 26.7% of the male athletes have back curvature above the reference value, none of the female athletes. On the other hand, 31.8% of non-athletic girls have more dorsal kyphosis than necessary, while this rate is only 6.2% of non-athletic boys. Values below the reference value were measured in 40.0% and 37.5% of athlete and non-athlete boys, respectively, while in the case of girls it was only 12.5% and 9.1% (Table 2).

Examining the lumbar lordosis, in the entire sample we examined, 60.9% of the sports children and 47.4% of the non-athletic children were within the reference value. A value above the reference range was obtained for 30.4% of the sports children, while for 44.7% of the non-athletes, a value below the reference range was obtained for 8.7% of the athletes and 7.9% of the non-athletes. Among boys, there is a much higher proportion of values within the reference range for both athletes and non-athletes (73.3% and 62.5%) than for girls (athletes: 37.5%, non-athletes: 36.4%). In the case of girls, the values above the reference value are the highest in both groups: 50.0% for female athletes, 54.5% for non-athletes. The values below the reference range uniformly have the smallest proportion (boys: 6.7%, 6.2%, girls: 12.5%, 9.1%) (Table 2).

Among the results measured in the standing position, the sacral angle (the angle enclosed by the vertical plane and the contour line running on the surface of the sacrum) was within the reference for 60.9% of the sports children and 52.6% of the non-athletes; while 34.8% of sports children and 36.8% of non-athletes are below the reference value. Examining the boys, the values were in the normal range in a higher proportion than in the sample (athletes: 66.7%, non-athletes: 68.8%). In the case of girls, 50.0% of athletes and 40.9% of non-athletes were in the normal range, while 50.0% of athletes and 54.4% of non-athletes produced results below the reference values. For boys, the values below the reference appear in a much smaller proportion, 26.7% for athletes, 12.5% for non-athletes (Table 2).

After the Matthiass test, in a standing position

After performing the Matthiass test, among the results measured with the spinal mouse, examining the entire sample in a standing position with regard to dorsal kyphosis, it can be said that 60.9% of the athletic students and 52.6% of the non-athletic students have results within the reference value. Only 4.3% of athletes and 10.5% of non-athletes have values above the reference value, while 34.8% of athletes and 36.8% of non-athletes have values below the reference value. 66.7% of athletic boys and 68.8% of their non-athletic peers have normal values for back kyphosis, while among girls, 50.0% of athletes and 40.9% of non-athletes can say this about themselves. There are relatively few in the range above the reference value, only 6.7% and 18.8% of the boys, and only one of the girls from the non-athletic group. Results below the reference value were achieved by 26.7% of athletic boys, 12.5% of non-athletic boys, 50.0% of athletic girls, and 54.5% of non-athletic girls (Table 3).

When examining the lumbar lordosis of our entire sample during the measurement performed after the Matthiass test, it can be said that 69.6% of the athletic students and 53.3% of the non-athletic students had results within the reference range. 8.7% of the student athletes and 26.3% of the non-athletes were above the reference, while 21.7% of the athletes and 18.4% of the non-athletes produced values below the reference. 73.3% of male athletes and 62.5% of female athletes have results within the reference value. This ratio is 68.8% for non-athletic boys and 45.5% for non-athletic girls. Regarding results above the reference value, I would highlight the group of non-athlete girls, where the rate is 36.4% (Table 3).

Examining the values of the sacral angle after the Matthiass test, in the case of the entire sample, it can be said that 56.5% of the sports children and 65.8% of the non-athletes have values within the reference range. 17.4% of athletes and only 2.6% of non-athletes have values above the reference, and 26.1% of sports students and 31.6% of non-athletes have scores below the reference. Based on the gender distribution, it can be said that the difference is large, as 87.5% of the non-athletic boys fell into the reference category, while only 37.5% of the athletic girls did. It is interesting that only boys produced values above the reference range, and in the case of values below the reference, one athlete and one non-athlete among the boys fell into this category, while among the girls 62.5% of the athletes and 50.0% of the non-athletes -a (Table 3).

Negligence and playing sports show a statistically significant relationship ($\chi2(1,N=61) = 6.036$, $p = 0.018$). In the sample we examined, the prevalence of careless posture was typical for 71.1% (27 people) of non-sporting adolescents and 39.1% (9 people) of sports children. A similar ratio is more common among girls. This is also true for boys, but the proportion is higher for the non-athletic group, almost 40%, who do not have sloppy posture (Table 4).

Postural weakness and playing sports show a statistically significant relationship ($\chi2(1,N=61) = 7.878$, $p = 0.008$). A smaller

proportion of athletic adolescents have poor posture (26.1%, 6 people) compared to non-athletes (63.2%, 24 people). In this case, only 13.3% of athletic boys are affected, while 62.5% of non-athletic boys are affected. Among girls, 50.0% of athletes and 63.6% of non-athletes have postural weakness. In girls, postural weakness and playing sports do not show a significant relationship (Table 4).

Table 1 Athletes, sports and training time

Sport	Number of people	Number of training sessions per week	Length of training session on occasion
Self-defense sports (judo, krawmaga)	2	2	1 hour in 1 case, 2 hours in 1 case
Dance (hip-hop, jazz ballet)	4	2	1 hour in 3 cases, 1.5 hours in 1 case
Athletics	5	in 2 cases 3, 2 in 3 cases	1.5 hours
Football	4	2 in 2 cases, 3 in 2 cases	1.5 hours in 2 cases, 2 hours in 2 cases
Basketball	1	5	1.5 hours
Handball	1	3	1.5 hours
Riding	3	2	1.5 hours in 1 case, 1 hour in 2 cases
Triathlon	1	3	2 hours
Water polo	1	3	2 hours
Swimming	1	2	2hours

Table 2 Spinal Mouse results, standing position

		Complete pattern		Boys		Girls	
		Athlete	non-Athlete	Athlete	non-Athlete	Athlete	non-Athlete
Sac/hip	within the reference value	14	20	10	11	4	9
		60.9%	52.6%	66.70%	68.80%	50.00%	40.90%
	above the reference value	1	4	1	3	0	1
		4,3%	10,5%	6,70%	18,80%	0,00%	4,50%
	below the reference value	8	14	4	2	4	12
		34,8%	36,8%	26,70%	12,50%	50,00%	54,50%
		Complete pattern		Boys		Girls	
		Athlete	non-Athlete	Athlete	non-Athlete	Athlete	non-Athlete
Dorsal Kyphosis	within the reference value	12	22	5	9	7	13
		52,2%	57,9%	33,30%	56,20%	87,50%	59,10%
	above the reference value	4	8	4	1	0	7
		17,4%	21,1%	26,70%	6,20%	0,00%	31,80%
	below the reference value	7	8	6	6	1	2
		30,4%	21,1%	40,00%	37,50%	12,50%	9,10%
		Complete pattern		Boys		Girls	
		Athlete	non-Athlete	Athlete	non-Athlete	Athlete	non-Athlete
Lumbar lordosis	within the reference value	14	18	11	10	3	8
		60,9%	47,4%	73,30%	62,50%	37,50%	36,40%
	above the reference value	7	17	3	5	4	12
		30,4%	44,7%	20,00%	31,20%	50,00%	54,50%
	below the reference value	2	3	1	1	1	2
		8,7%	7,9%	6,70%	6,20%	12,50%	9,10%

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Table 3 After the Matthiass test, in a standing position

		Complete pattern		Boys		Girls	
		Athlete	**non-Athlete**	**Athlete**	**non-Athlete**	**Athlete**	**non-Athlete**
Sac/ hip	within the reference value	13	25	10	14	3	11
		56,5%	65,8%	66,70%	87,50%	37,50%	50,00%
	above the reference value	4	1	4	1	0	0
		17,4%	2,6%	26,70%	6,20%	0 %	0 %
	below the reference value	6	12	1	1	5	11
		26,1%	31,6%	6,70%	6,20%	62,50%	50,00%
		Complete pattern		**Boys**		**Girls**	
		Athlete	**non-Athlete**	**Athlete**	**non-Athlete**	**Athlete**	**non-Athlete**
Dorsal kyphosis	within the reference value	14	20	10	11	4	9
		60,9%	52,6%	66,70%	68,80%	50,00%	40,90%
	above the reference value	1	4	1	3	0	1
		4,3%	10,5%	6,70%	18,80%	0,00%	4,50%
	below the reference value	8	14	4	2	4	12
		34,8%	36,8%	26,70%	12,50%	50,00%	54,50%
		Complete pattern		**Boys**		**Girls**	
		Athlete	**non-Athlete**	**Athlete**	**non-Athlete**	**Athlete**	**non-Athlete**
Lumbar lordosis	within the reference value	16	21	11	11	5	10
		69,6%	55,3%	73,30%	68,80%	62,50%	45,50%
	above the reference value	2	10	1	2	1	8
		8,7%	26,3%	6,70%	12,50%	12,50%	36,40%
	below the reference value	5	7	3	3	2	4
		21,7%	18,4%	20,00%	18,80%	25,00%	18,20%

Table 4 Careless posture, poor posture

		Complete pattern		Boys		Girls	
		Athlete	**non-Athlete**	**Athlete**	**non-Athlete**	**Athlete**	**non-Athlete**
Careless posture	yes	9	27	6	10	3	17
		39,1%	71,1%	40,00%	62,50%	37,50%	77,30%
	no	14	11	9	6	5	5
		60,9%	28,9%	60,00%	37,50%	62,50%	22,70%
		Complete pattern		**Boys**		**Girls**	
		Athlete	**non-Athlete**	**Athlete**	**non-Athlete**	**Athlete**	**non-Athlete**
poor posture	yes	6	24	2	10	4	14
		26,1%	63,2%	13,30%	62,50%	50,00%	63,60%
	no	17	14	13	6	4	8
		73,9%	36,8%	86,70%	37,50%	50,00%	36,40%

Conclusion

In a standing position, after measurement

Increased dorsal kyphosis occurs in a slightly lower proportion among athletes, and flatter dorsal curvature occurs in a slightly higher proportion than in non-athletes. In the case of female athletes, we can say that most of them (87.5%) have a normal level of dorsal kyphosis, while in the case of male athletes, this ratio is very low (33.3%) (Table 2). In the case of boys, there is no significant difference between the athlete and non-athlete groups, values below and above the reference value occur in the same proportion as values within the reference19. So, we cannot say that the values of athletes are clearly better, only in the case of girls.

In terms of lumbar lordosis, a higher proportion of athletes have values within the reference, but the proportion of results above the reference value is relatively high (athletes: 30.4%, non-athletes: 44.7%) for both groups. This indicates that the lumbar curve is flattened in many cases and does not correspond to physiological values. These relatively "straight" lumbar spine sections affect the structures above and below them, influencing their size. Relatively few students have blood vessels below the reference range, which corresponds to the current state of research, according to which the lumbar curve straightens and flattens due to a sedentary lifestyle and a lot of sitting.[20] Regarding lumbar lordosis, the results of boys and girls are not the same. Physiological lumbar curvature of a normal degree occurs most often among boys (Table 2), looking at both the athlete and non-athlete groups, while the flattened lumbar curvature

with a smaller than normal curve appears most often in girls for both groups. Increased lumbar lordosis affects few children.

Regarding the sacral angle, there is a significant difference between the values of boys and girls, as well as sportsmen and non-sportsmen. While nearly two-thirds of the boys fall within the normal range, less than half of the girls and the other half of the girls represent the category below the reference value (athletes and non-athletes alike). This can be related to the position of the pelvis, which affects the entire spinal column and with it the posture.[21] Values below the reference range indicate a forward-tilted pelvis. In this case, it is very necessary to change the posture of the pelvis to a normal range, because the lower part of the abdominal muscles stretches and the upper part shrinks, the deep back muscles become inactive as a result of the forward-tilted pelvis, and this part of the spine also loses its flexibility.[22]

After the Matthiass test, in a standing position

Based on the results of the Matthiass test, dorsal kyphosis is in the normal range for two-thirds of athletic and non-athletic boys. This is a higher proportion than in the case of girls, where the same characteristics can be said for half of the athletes and 40.9% of the non-athletes. It is a gratifying fact that only four of the examined sample (n=61) were in the range above the reference value indicating weakness of posture. It is an interesting observation that half of the athletic girls and more than half of the non-athletic girls fall into the category below the reference value, less than a third of the athletic boys, and only two of the non-athletic boys. In their case, we can speak of a straighter dorsal spine section, where the degree of kyphotic curvature is smaller than the physiological one. This is not good, because it creates muscle asymmetry, which, if left untreated, can lead to changes in bony structures later.

During the first standing measurement, the ratio of lumbar lordosis results below the reference value was 8.7% among student athletes and 7.9% among non-athletes. After performing the Matthiass test, this rate increased from 8.7% to 21.7%, and from 7.9% to 18.4%. This suggests that postural weakness does not occur everywhere on the back. These adolescents tried to compensate for the postural and spatial imbalances caused by the weakening of the muscles in the lumbar spine. This can be said for boys and girls, as well as athletes and non-athletes. In terms of results within the reference range, both boys and girls had a higher proportion of athletes (boys: 73.3%, girls: 62.5%) with a normal lumbar lordosis compared to non-athletes (boys: 68.8%, girls: 45.5%). 36.4% of non-sporting girls have a milder lumbar curve. For them, it would be important to regularly introduce mobilizing exercises to improve the segmental mobility of the spine in this section.

Regarding the sacral angle, a greater proportion of boys have values within the reference range, while a greater proportion of girls have values below the reference range. The results of the first measurement were similar to the results measured after the Matthiass test. In both groups, a much higher proportion of girls had values below the reference level. For the first measurement: 50.00% and 54.50%, for the second measurement: 62.50% and 50.00%. In the case of the second measurement, the decrease in the value of the sacral angle appears at an even higher rate in the group of female athletes, which indicates a forward tilt of the pelvis after the test. This value can also be associated with an increase in lumbar lordosis. The combined change of these two values indicates the local appearance of postural weakness in the lumbar region of the spine. Low sacral angle values indicate that the pelvis tilts forward, which affects the entire spine and posture. Therefore, it is particularly important that the pelvic position and lumbar lordosis values are in the normal range, as this improves posture and spinal problems. To prevent such problems, regular exercise and proper posture improvement programs are recommended.

Careless posture, poor posture

Athletic boys struggle with poor posture and poor posture to a lesser extent than their non-athletic peers. Athlete girls also have a smaller proportion of sloppy posture, but this is not true with regard to poor posture, 50% of both athletic and non-athletic girls struggle with poor posture. It is therefore particularly important to pay attention to posture among girls, where there is no demonstrable connection between postural weakness and playing sports.

Discussion

Among the children included in the research, 23 (37.7%) play sports and 38 (62.3%) do not. This is an unfavorable ratio, considering that in the study by De Assis et al.[6] 23.7% of the children did not play sports, which confirms Bergmann et al.[11] according to which the prevalence of not playing sports is 26.8%.

De Assis et al.[6] found that non-athletic students were at greater risk of scoliosis than athletes. Examining the relationship between sports and the quality of posture, Radaković et al.[5] found that most changes occur in the sagittal plane of the spine during adolescence. Based on their results, it can be said that posture disorders occurred in a similar proportion between athletes and non-athletes. In the sample we examined, a large percentage of male athletes (66.7%) in terms of dorsal kyphosis and female athletes (62.5%) in terms of lumbar lordosis fell outside the reference range, so when examining the physiological state of the spine, it cannot be said that the results of the athletes better than their non-athlete counterparts.

Sidlauskiene et al.[23] found a statistically significant, positive, weak relationship between the results of spinal posture and the time spent in high-intensity exercise ($r = 0.186$; $p < 0.001$). This indicates that the posture of adolescents among those they studied is better in the group of more physically active ones. This can also be said about the sample we studied. Sloppy posture ($p = 0.018$) and poor posture ($p = 0.008$) also showed a significant relationship with sports.

Mucha et al.[24] found that athletic adolescents had a higher proportion of lumbar lordosis and sacral angle in the normal range, and their spine had greater mobility in the sagittal and frontal planes, compared to their non-athletic peers. Regarding our own sample, this can be said among boys, the athletes produced significantly better results than their non-athlete peers. Opposite results characterize the girls, where the value of the sacral angle of half of the female athletes is outside the reference range during the first measurement, and after performing the Matthiass test, only 37.5% of them can be said to have a value within the reference range. Similar values characterize the lumbar lordosis, very few (37.5%) of the female athletes have a normal lumbar curvature.

In the case of athletes, we obtained significantly better results for careless posture and poor posture, yet we cannot say that overall, the condition of the spine of athletic adolescents is better. In terms of dorsal kyphosis, female athletes had better results, and in terms of lumbar lordosis, the results of male athletes were better, but there was no significant difference between the two groups in terms of the other examined parameters. Sudden growth during adolescence, incorrect lifestyle habits, excessive workload, and early selection of certain sports5 can all be the cause of posture disorders among children who

are athletes and non-athletes alike. Therefore, it is recommended to incorporate posture-improving and mobilizing exercises into your daily routine. Playing sports has many benefits, but excessive strain can also have harmful effects on the spine, especially during adolescence.[13,25] Accordingly, all exercise professionals must monitor proper posture and movement patterns to help develop and maintain a healthy spine.

Research limitations

The results can be distorted by the fact that we do not know who started from which category during the measurement with the spinal mouse. Because if the person started with a value below the reference in the case of dorsal kyphosis, and after the Matthiass test it was in the normal range, there was also a ROM change in the segmental movement of the spinal column, which could indicate postural weakness.

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Conflicts of interest

Author declares there are no conflicts of interest.

References

1. Latalski M, Bylina J, Fatyga M, et al. Riskfactors of postural defects in children at school age. *Ann Agric Environ Med*. 2013;20(3):583–587.
2. Iunes DH, Cecílio MB, Dozza MA, et al. Quantitative analysis of the treatment of idiopathic scoliosis with the klapp method using computerized biophotogrammetry. *Braz J Phys The R.* 2010;(14):133–140.
3. Somhegyi A, Lazáry Á, Feszthammer A, et al. Application of special exercises in physical education to develop, automatize and maintain the biomechanically correct posture. *Public Health*. 2014;92(1):11–19.
4. Skoffer B, Foldspang A. Physical activity and low–back pain in schoolchildren. *Eur Spine J*. 2008;(17):373–379.
5. Radaković M, Protić–Gava B, Radaković K, et al. Differences in postural status of primary school students who engage in different sports and their peers who do not engage in sports. Facta Universitatis, Series: *Physical Education and Sport*. 2017;15(1):63–71.
6. de Assis SJC, Sanchis GJB, de Souza CG, et al. Influence of physical activity and postural habits in schoolchildren with scoliosis. *Arch Public Health*. 2021;79(1):1–7.
7. Đokić Z, Stojanović M. Morphologic characteristics and postural status in children aged 9 to 12 years in Sremska Mitrovica municipality. *General Medicine*. 2010;16(1–2):41–49.
8. Edington DW, Schultz AB, Pitts JS, et al. The future of health promotion in the 21st century: a focus on the working population. *Am J Lifestyle Med*. 2016;10(4):242–252.
9. Dima C, Mitoiu B, Nartea R, et al. Hyperkyphotic posture among adolescents–still a public health problem. *Romanian Journal of Pediat Rics*. 2022;71(2):51–60.
10. O'Donovan G, Blazevich AJ, Boreham C, et al. The ABC of Physical Activity for Health: a consensus statement from the British Association of Sport and Exercise Sciences. *J Sports Sci*. 2010;28(6):573–591.
11. Bergmann GG, Bergmann MLA, Marques AC, et al. Prevalence of physical inactivity and associatedfactors among adolescents from public schools in Uruguaiana, Rio Grande do Sul state, Brazil. *Cad Saúde Pública*. 2013;29(11):2217–2229.
12. McMaster ME, Lee AJ, Burwell, R. G. Physical activities of patients with adolescent idiopathic scoliosis (AIS): preliminary longitudinal case–control study historical evaluation of possible risk factors. *Scoliosis*. 2015;10(1):1–10.
13. Kikuchi R, Hirano T, Watanabe K, et al. Gender differences in the prevalence of low back pain associated with sports activities in children and adolescents: a six–year annual survey of a birth cohort in Niigata City, Japan. *BMC Musculoskeletal Disorders*. 2019; 20(1): 1–6.
14. Pavlik G. The role of regular physical activity in disease prevention and health preservation. *Health Science*. 2015;59 (2):11–26.
15. Bezalel T, Carmeli E, Levi D, et al. The effect of Schroth therapy on thoracic kyphotic curve and quality of life in Scheuermann's patients: a randomized controlled trial. *Asian Spine J*. 2019;13(3):490–499.
16. World Health Organization. Global Recommendations on Physical Activity for Health. Geneva: World Health Organization; 2010.
17. Kovács VA, Gábor A, Fajcsák Zs, et al. Sport habits and sedentary lifestyle among elementary school children in Obuda, Hungary. *Orv Hetil*. 2010;151(16):652–658.
18. Mannion AF, Knecht K, Balaban G, et al. A new skin–surface device for measuring the curvature and global and segmental ranges of motion of the spine: Reliability of measurements and comparison with data reviewed from the literature. *Eur Spine J*. 2004;13(2):122–136.
19. Chertman C, Maldonado H, dos Santos C, et al. A comparative study of lumbar range of movement in healthy athlets and non–athlets. *Rev Bras Ortop*. 2015;45(4):389–394.
20. Grabara M, Bieniec A, Nawrocka A. Spinal curvatures of children and adolescents – a cross–sectional study. *Biomedical Human Kinetics*. 2017;9(1):69–74.
21. Yang L, Lu X, Yan B, et al. Prevalence of Incorrect Posture among Children and Adolescents: Finding from a Large Population–Based Study in China. *iScience*. 2020;23(5):1–10.
22. Somhegyi A, Gardi ZZ, Feszthammer A, et al. Posture correction – Exercises that promote the control and development of muscle strength and muscle extensibility necessary for the development of biomechanically correct posture. Budapest, Hungary: *Hungarian Society of Spine Medicine*; 2003.
23. Sidlauskiene A, Strukcinskiene B, Raistenskis J, et al. The association between the level of physical activity with spinal posture and physical fitness parameters in early adolescence. *Vojnosanit Pregl*. 2019;76(12):1209–1216.
24. Mucha D, Ambroży T, Ząbek M, et al. Physical activity as a condition for correct body posture for youth. *Science–Practice–Reflections.* 2015;(19):139–148.
25. Van Gent C, Dols JJ, Carolien M, et al. The weight of schoolbags and the occurrence of neck, shoulder, and back pain in young adolescents. *Spine*. 2003;28(9):916–921.