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CHANGES IN BODY POSTURE PARAMETERS: A FOUR-YEAR FOLLOW-UP STUDY

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Abstract Body posture is an alignment of its segments relative to each other in a certain way and the relations between them. Abnormalities in the alignment of body segments or the cooperation of systems may cause postural defects. Scientific evidence shows that children of school age are more exposed to abnormalities in body posture, thus posture should be monitored because it is a key aspect of their body's physical health. This study aimed to evaluate changes in body posture parameters in the frontal plane in the same children at 5 and then 9 years of age.

This four-year follow-up study included 67 children (29 girls and 38 boys) in the preschool-age and school-age phases (the first examination at 5 years of age and the second examination at 9 years of age). Measurements of body weight and height were recorded. A computerized assessment of body posture was performed using the photogrammetric method (MORA 4 Generation). The normality of the distribution of variables was assessed with the Shapiro-Wilk test. Analysis of qualitative data was carried out using Pearson's chi-squared test. The highest percentage of children exhibited a deterioration in the position of the lower corners of the scapulae, taking into account the division into sex (51.7% in girls and 50.0% in boys, respectively) and the analysis of the whole group (50.7%). There were statistically significant differences in the position of the lower corners of scapulae (UL) between the first and second examinations in all examined children ($p = 0.005$). The difference in the height of the waist and the position of the shoulders improved and deteriorated in a similar percentage in children (above 30–40%).

Generally, an improvement in body posture was observed. However, the abnormalities of body posture that occurred indicate the need for continuous monitoring of the children's posture and for preventive and corrective measures to be implemented.

Key words: frontal plane, posture, children, postural deviations, photogrammetric method

Introduction

According to the Posture Committee of the American Academy of Orthopedic Surgeons, posture is the relative positioning of parts of the body. Good posture is defined as musculoskeletal balance which protects the load-bearing structures of the body against injuries or progressive deformation regardless of the position (upright, lying, or bent over) (Takasaki, 1970). Abnormalities in body posture in the form of different positions of the shoulders or the lower corners of scapulae in the frontal plane are usually the first symptoms of worrying changes in body posture that are noticed by teachers and parents. These changes in the frontal plane indicate incorrect body posture. Therefore, body posture is a key aspect of our body's physical health. Posture is exposed to many factors that can cause negative changes in the position of its segments in relation to each other. One of these factors is age.

Abnormal changes in body posture occur in children in two difficult periods when body posture develops. The first difficult period, which is discussed in this report, affects children aged 6-7 years (Bubanj et al., 2012; Gavela-Pérez et al., 2015). This age is characterized by dynamic and rapid changes in growth. These changes are because the muscular apparatus cannot keep up with the rapid growth of bones (Cosma et al., 2015). Moreover, three years of school education are conducive to the deterioration of body posture because of new conditions (sitting for extended periods at the school desk, carrying a heavy school bag, negative experiences). They also disturb the stabilization of posture, and contribute to the uneven distribution of muscle and ligament tension, which in turn leads to overloads and worsening of the asymmetry of the musculoskeletal system (Hagner et al., 2011). The second period discussed in this report occurs at the age of 9. After the age of 10, developmental changes intensify and the next growth spurt occurs. Maintaining correct body posture often requires more concentrated effort due to muscle weakness (Gavela-Pérez et al., 2015).

All these changes are negative factors that lead to the development of posture disorders. Young children adapt to changes, though not always in an appropriate way (Kratenová et al., 2007). They very quickly develop adaptation strategies (Bjorklund & Beers, 2016), compensating for the alignment of individual body segments with each other, and these adjustments can lead to posture defects in three planes (frontal, sagittal, and transverse) (Oba et al., 2015; De Vasconcelos et al., 2010).

Scientific evidence indicates that most primary school children have some degree of posture abnormalities, while 18–50% of children and adolescents have normal body posture (Kratenová et al., 2007; Pokrywka et al., 2011). A large-scale population study showed that Chinese children and adolescents had severe postural problems (65.3%) (Yang et al., 2020). Observations conducted in previous years confirm a similar percentage range of changes (Lee et al., 2010).

It is extremely important to carry out research, especially in periods difficult for the development of body posture. Systematic monitoring of children's posture at every stage of their development and taking appropriate preventive measures at an early stage when abnormalities occur is considered appropriate. The consequences of passivity and inappropriate actions are significant deformations in all body systems, pain ailments, and serious health changes (Calvota-Fonseca et al., 2019; Calvo-Munoz et al., 2013). To prevent the consequences of such changes, screening should be carried out in schools, and research should be conducted in this direction. The development of modern diagnostic methods is an opportunity to reduce the percentage of children with incorrect body posture postures.

The arguments presented here prove the validity of this research was right. The topic is still relevant and important, as evidenced by numerous research studies on school-age children. The paper characterizes changes in body posture parameters in children in two difficult periods impacting body posture. Therefore, this study aims to evaluate changes in body posture parameters in the frontal plane in the same children at 5 and then 9 years of age.

Material and methods

Subjects

The study included a group of 67 children (29 girls and 38 boys). The study was conducted twice in one group of 5-year-old children (I examination), who received follow-up after 4 years (at the age of 9) (II examination).

The inclusion criteria for the first examination of these participants were: 1) the parent's or legal guardian's written consent for the child's participation in the study, 2) the year of birth of the child (2010), 3) body mass index up to the 85th percentile according to the standards of the World Health Organization (WHO standards, 2010).

The inclusion criteria for the second examination were: (1) participation in the first study for children, (2) general good health. Exclusion criteria applied to the group included: (1) lack of complete documentation. At this stage, no one was excluded.

The present study was performed by the Helsinki Declaration and was approved by the Ethics Committee of Jozef Pilsudski University of Physical Education in Warsaw (DM. 74–SKE 01-30/2018; DS. 246–SKE 01-01/2014). All parents or guardians of the children were informed of the procedures and voluntarily gave consent to perform the measurements and use the results for scientific purposes. The parents or guardians were informed of the possibility of withdrawal at any time during the study. The study was conducted in the Body Posture Laboratory at Jozef Pilsudski University of Physical Education in Warsaw, Biala Podlaska Branch (Poland). The first examination was conducted in 2015, and the second in 2019.

Measurements

All the anthropometric measurements (body weight and body height) were performed with a stadiometer RADWAG with an accuracy of 0.1 kg and 0.1 cm. The measurements were performed in standard conditions. Children were in underwear, and standing in an upright position, without bent knees, and barefoot. Body mass index (BMI) was calculated according to the formula and was then referred to the standards proposed by the World Health Organization (WHO standards, 2010).

For the assessment of body posture, the photogrammetric method was used based on the projection of the Moire Topography (MT) (MORA 4 Generation, CQ Electronic System, Poland). MT appears to be a viable and complementary alternative to a radiographic examination. MT is a method of imaging the body surface and is very sensitive in detecting asymmetry. Research shows the technique is a reliable and repeatable method (da Silva Filho et al., 2017; Chowanska et al., 2012). Historically, MT is based on assessing the symmetry of the moire fringes projected onto the subject's back (Takasaki, 1970; Porto et al., 2010). However, it is worth emphasizing that the method has been reported as being an invaluable screening tool (da Silva Filho et al., 2017; Watanabe et al., 2019; Silva et al., 2014). It has been proven to be a quick and cheap method, and as a technique for testing body posture, it is easy and non-invasive. The measurement time is only 0.03 seconds. MT provides parameters describing body posture with an accuracy of 1 mm and 1º (CQ Electronic System, 2007; Grabara et al., 2017).

The body posture was assessed in the morning hours by a qualified person (physiotherapist) with many years of experience. The device was calibrated and the height of the measuring station was adjusted to the child's height before the examination. The room in which the examination was performed was darkened. During the examination, the children stood without their outerwear, with their backs to the camera at a distance of 2.6 m. The body position should be relaxed with eyes looking forward, arms along the torso, feet shoulder-width apart, and legs straight (Labecka et al., 2021).

For the MT examination, it was necessary to expose the entire surface of the back and mark the following anatomical landmarks with a dermograph: the spinous process of C7 and S1, the acromial angle of the shoulders, the inferior and superior angle of the scapula, and the posterior superior iliac spine, as suggested by the Society on Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT) (Negrini et al., 2012).

In the frontal plane, the studies analyzed the following parameters presented in Figure 1:

– KNT [º]: the coronal inclination of the trunk
– KLB [mm]: the difference in the height of the shoulders
– UL [mm]: the difference in the height of the lower corners of the scapulae
– KNM [mm]: the difference in the height of the pelvis
– TT [mm]: the difference in the height of the waist ("waistlines").

To qualitatively assess the size of changes in somatic parameters in the children, the following division into groups was made:

Group 1 – improvement body posture: parameter values below 1 mm/1 º

Group 2 – unchanged body posture: values in the range 1 mm/1 º – -1 mm/-1 º. This range was adopted as the measurement error.

Group 3 – deterioration body posture: parameter values above -1 mm/-1

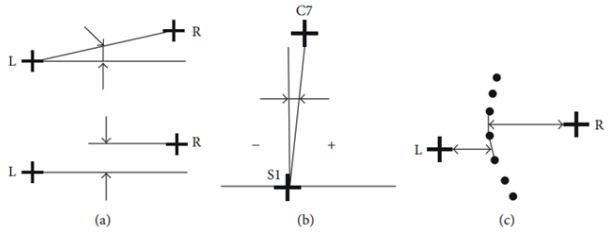

Figure 1. The method for determining parameters of body posture: (a) differences in the height of the shoulders, scapulae, and pelvis; (b) coronal inclination of the trunk; (c) difference in the distances from the lower corners of the scapulae to the spine.

Statistical analysis

The results were statistically analyzed using STATISTICA 13 (StatSoft, Poland). The normality of distribution was verified using the Shapiro-Wilk test. The analysis included a calculation of the mean, minimal and maximal values, and standard deviations of the variables, and a comparison of the results between groups using Student's t-test for dependent variables. The analysis of qualitative data was carried out using Pearson's chi-squared test. The accepted level of significance was $p < 0.05$.

Results

Anthropometric measures in group children of the I and II examinations are shown in Table 1.

Table 1. Anthropometric parameters in the children examined

Variables	I examination (n = 67)				II examination (n = 67)			
	M	SD	Min	Max	M	SD	Min	Max
Body weight [kg]	19.9	2.8	15.0	27.0	30.3	5.5	17.5	47.0
Body height [cm]	114.6	4.6	106.0	127.0	135.3	5.9	125.0	161.0
Body mass index [kg/m^2]	15.1	1.3	12.4	18.7	16.5	1.9	11.2	22.3

n – number of observations; M – mean values; SD – standard deviation; Min – minimal values; Max – maximum values

Over 4 years, the mean values in the coronal inclination of the trunk (KNT), the difference in the height of the pelvis (KNM), and the difference in the height of the waist (TT) decreased in all the children. Mean values in the position of the shoulders (KLB) and in the position of the lower corners of the scapulae (UL) increased. There were statistically significant differences in the position of the lower corners of scapulae (UL) between the first and second examinations in all the children (p = 0.005) (Table 2).

Table 2. Body posture parameters in all children examined

Variables	All (n = 67)		t	p
	I examination	II examination		
	M	M		
KNT [°]	1.2	0.9	1.457	0.153
KLB [mm]	5.2	5.3	–0.240	0.814
UL [mm]	3.8	5.2	–2.940	**0.005**
KNM [mm]	2.1	1.9	0.750	0.457
TT [mm]	5.8	5.2	0.890	0.377

n – number of observations; M – mean values; t – the result of Student's t-test for independent variables; p-level of probability (**p < 0.05**); KNT [°] – the coronal inclination of the trunk; KLB [mm] – the difference in the height of the shoulders; UL [mm] – the difference in the height of the lower corners of the scapulae; KNM [mm] – the difference in the height of the pelvis; TT [mm] – the difference in the height of the waist

In the group of girls, the parameters UL and TT decreased over 4 years. The parameters KLB increased slightly. In the group of boys, the parameters KLB and UL increased over 4 years, while the other parameters (KNT, KNM, TT) decreased. There were statistically significant differences in UL between the first and second examinations in the group of boys (p = 0.024) (Table 3).

Table 3. Body posture parameters in girls and boys

Variables	I examination	II examination	t	p
	M	M		
	Girls (n = 29)			
KNT [°]	1.1	1.1	–0.16	0.874
KLB [mm]	5.8	5.5	0.33	0.741
UL [mm]	3.5	4.5	–1.76	0.089
KNM [mm]	2.1	2.1	–0.06	0.950
TT [mm]	5.5	5.7	–0.19	0.854
	Boys (n = 38)			
KNT [°]	1.3	0.8	1.92	0.063
KLB [mm]	4.8	5.2	–0.71	0.481
UL [mm]	4.0	5.6	–2.35	**0.024**
KNM [mm]	2.1	1.7	1.32	0.196
TT [mm]	5.9	4.8	1.22	0.230

n – number of observations; M – mean values; t- the result of Student's t-test for independent variables; p- level of probability (**p < 0.05**); KNT [°] – the coronal inclination of the trunk; KLB [mm] – the difference in the height of the shoulders; UL [mm] – the difference in the height of the lower corners of the scapulae; KNM [mm] – the difference in the height of the pelvis; TT [mm] – the difference in the height of the waist

Also qualitative assessments of the size of changes in body posture parameters in the examined children have been made.

The highest percentage of children was characterized by the deterioration in the parameter UL, taking into account the division into sex (51.7% in girls and 50.0% in boys, respectively) and the analysis of the whole group (50.7%). The TT and KLB parameters improved and deteriorated by a similar percentage (about 30–40%) in all children, as well as broken down by gender. The parameters that did not change in more than half of the children were KNT and KNM. (Table 4, Table 5).

Table 4. Assessments of the size of changes in body posture parameters in all the children examined

All (n = 67)	Group 1	Group 2	Group 3
Variables	n (%)	n (%)	n (%)
KNT [º]	17 (25.4)	40 (59.7)	10 (14.9)
KLB [mm]	25 (37.3)	19 (28.4)	23 (34.3)
UL [mm]	20 (29.9)	13 (19.4)	34 (50.7)
KNM [mm]	20 (29.9)	35 (52.2)	12 (17.9)
TT [mm]	29 (43.3)	14 (20.9)	24 (35.8)

n – number of observations; % – percent; χ^2 – result of Pearson's chi-squared test; p-level of probability; Group 1 – improvement in body posture: parameter values below 1 mm/1 º; Group 2 – unchanged body posture: values in the range 1 mm/1 º – –1 mm/–1 º. This range was adopted as the measurement error; Group 3 – deterioration body posture: parameter values above –1 mm/–1; KNT [º] – the coronal inclination of the trunk; KLB [mm] – the difference in the height of the shoulders; UL [mm] – the difference in the height of the lower corners of the scapulae; KNM [mm] – the difference in the height of the pelvis; TT [mm] – the difference in the height of the waist

Table 5. Assessments of the size of changes in body posture parameters in the girls and boys examined

Variables	Girls (n = 29)			Boys (n = 38)			χ^2	p
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3		
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)		
KNT [º]	7 (24.1)	16 (55.2)	6 (20.7)	10 (26.32)	24 (63.16)	4 (10.52)	1.35	0.510
KLB [mm]	11 (37.9)	8 (27.6)	10 (34.5)	14 (36.84)	11 (28.95)	13 (34.21)	0.02	0.992
UL [mm]	6 (20.7)	8 (27.6)	15 (51.7)	14 (36.84)	5 (13.16)	19 (50.00)	3.22	0.201
KNM [mm]	10 (34.5)	11 (37.9)	8 (27.6)	10 (26.32)	24 (63.17)	4 (10.53)	5.05	0.081
TT [mm]	13 (44.8)	4 (13.8)	12 (41.4)	16 (42.11)	10 (26.32)	12 (31.57)	1.71	0.427

n – number of observations; % – percent; χ^2 – result of Pearson's chi-squared test; p – level of probability; Group 1 – improvement in body posture: parameter values below 1 mm/1 º; Group 2 – unchanged body posture: values in the range 1 mm/1 º – –1 mm/–1 º. This range was adopted as the measurement error; Group 3 – deterioration body posture: parameter values above –1 mm/–1; KNT [º] – the coronal inclination of the trunk; KLB [mm] – the difference in the height of the shoulders; UL [mm] – the difference in the height of the lower corners of the scapulae; KNM [mm] – the difference in the height of the pelvis; TT [mm] – the difference in the height of the waist

Discussion

This study aimed to evaluate the size of changes in body posture parameters in the frontal plane in children at 5 and then 9 years of age. This aim was achieved by observing abnormalities in body posture.

The present study revealed that over 4 years, the mean values in the position of the shoulder and the position of the lower corners of scapulae increased. Mean values in the coronal inclination of the trunk, the difference in the height of the pelvis, and the difference in the height of the waist decreased. There were statistically significant differences in the position of the lower corners of scapulae between the first and second examinations in the group

of boys (p = 0.024) and all the children examined (p = 0.005). The highest percentage of children was characterized by a deterioration in the position of the lower corners of scapulae, taking into account the division into sex (51.7% in girls and 50.0% in boys, respectively) and the analysis of the whole group (50.7%). The other parameters improved and deteriorated by a similar percentage (about 30–40 %).

The results of this study revealed differences in the position of the shoulders in the children examined between the first and second examinations. With increasing age, the difference in shoulder position slightly increased. Similar results were obtained by Radzevičienė & Kazlauskas (2016). The authors observed differences in the position of the shoulders in 163 children. Our previous research on children revealed a statistically significant decrease in the position of the shoulders (Labecka et al., 2021). Research by Rusek et al. (2018) analyzing the differences between girls and boys in body posture showed statistically significant differences in shoulder tilt. The boys had a greater angle of inclination (p = 0.018). This abnormality may be the result of different rates of growth of body segments. It should also be kept in mind that this change occurred during the growth phase. In addition, the differences in shoulder position may be due to an overload caused by external factors (asymmetric sitting position, school backpack, hypermobility) or internal factors (handedness) (Hu et al., 2020; Kendalet et al., 2019)

In the present study, there was an increase in the frontal plane in the position of the lower corners of the scapulae in both sexes, with statistically significant differences in boys. Scientific evidence points to the same phenomenon. Radzevičienė & Kazlauskas (2016) examined the body posture of 1268 pupils of school age. In 163 students, differences occurred in the position of the lower corners of the scapulae. Hagner et al. (2011) also observed a 6.25% deterioration in the position of the lower corners of the scapulae in the frontal plane in boys who were observed over 3 years. Kratenová et al. (2007) provided the data that the most frequently detected defects in the study group were protruding scapulae (50%).

The findings of the present study did not reveal significant differences in body posture parameters between girls and boys of a given age. However, in the literature on the subject, abnormalities in body posture appear more often in girls at a later age, which is associated with physical development (AlenCiric, 2015; Penha et al., 2017; Yang, 2020). Moreover, these differences may have been due to gender differences in muscle development. According to Marceau (2011), girls reach their maximum muscle force earlier than boys because in girls the sexual maturation process begins earlier than in boys. Due to earlier physiological development, girls are more likely to stretch their necks and chests to reduce the change in appearance (Kendall, 2007). In addition, girls may be less active than boys, which usually leads to a lack of muscle strength, making it more difficult for girls to control their posture than boys (Klassonheggebo & Anderssen, 2003). Therefore, based on these possible causes, girls may be a high-risk group with incorrect changes in posture.

Generally, over the 4 years, a decrease in the values of most parameters in the coronal plane was observed in the study group, thus improving body posture. The same conclusions were obtained by Hagner et al. (2011). The authors monitored the body posture of the children for 3 years and observed that posture improved overall. However, there was still a large percentage of children (more than half) who had incorrect postures (Hagner, 2011). Based on their analysis of a sample of 968 preschool children, Simov et al. (2011) determined that only 10.3% of the children had postural abnormalities. A study by Bicanin et al. (2017) showed that in the frontal plane, incorrect posture is less present in children in all segments of the spinal column (5.08% in boys and 9.42% in girls). Other studies show that poor body posture occurred in 38.3% of children, more frequently in boys. A significantly different occurrence of abnormal body posture was found between 7-year-old and 11-year-old children (33.0% and 40.8%,

respectively) (Kratenová, 2007). It is important to bear in mind that it is at this age that the first growth spurt occurs in children. Bones are still cartilaginous in some spots, the ligaments lack sufficient strength, and the muscles grow along with the bones (Lafond, 2007). Radzevičienė & Kazlauskas (2016) studied 1268 pupils in rural schools. Incorrect posture associated with the asymmetry of innervation tends to normalize during the child's development, and a posture defect resulting from damage to the musculoskeletal system may turn into a serious pathology of the skeletal system (Radzevičienė & Kazlauskas, 2016). Moreover, abnormal motor development may be a factor predisposing to abnormal values of the inclination of the trunk angle (Guzek et al., 2019).

Bearing in mind the prevention of various abnormalities in body posture and the prevention of three-dimensional changes (scoliosis), it is worth paying special attention to the parameters of body posture in which the greatest changes were observed (the position of the shoulders and the position of the lower corners of the scapulae in the frontal plane).

Research findings suggest that in children of younger school age, it is optimal for carrying out preventive measures that can help compensate for abnormalities in body posture and prevent posture problems through appropriate exercise programs. Children at this age tolerate more endurance exercise than expected. However, static muscle overload leads to a faster onset of fatigue in children (Kratenová, 2007). Therefore, younger school-age children should spend the same amount of time commuting to school. In addition, insufficient physical activity in free time constitutes a huge reserve of possibilities to influence the appropriate movement regime in the school environment, in which children spend a significant amount of time and are exposed to prolonged inactivity. The solution should be based on movement activities (physical education, exercises during school breaks, spontaneous movement at school and home), which may prevent future problems. It is important to monitor the attitudes of children at every stage of their development. Moreover, attention should be paid to the positions that children take during the day, especially with regard to the COVID-19 pandemic. Corrective actions are needed to prevent post-COVID syndrome. This study is the basis for further observation of body posture in the same group when children become adolescents. It is also worth analyzing the abnormalities in body posture in terms of other factors (genetics, hormones, nutritional status, etc.), and not only taking into account gender and age. The author will try to explain the variability of body posture in terms of physical activity in children in the future.

Conclusions

According to the results of our research, careful attention should be paid to the significant variability of some parameters in body posture (the position of the shoulders and the position of the lower corners of the scapulae in the frontal plane). Generally, an improvement in body posture was observed. However, the abnormalities of body posture which occurred indicate a need to monitor the children's posture continuously and to implement preventive and corrective measures.

Limitations

A limitation of the present study is the small study group. Only parameters in one plane (frontal plane) were used to assess body posture. However, these limitations did not significantly affect the value of the results. Further studies require consideration of body posture parameters in other planes (sagittal and transverse planes). Moreover, the influence of physical activity on children's body posture was not taken into account.

Study strengths

This study shows the differences in body posture parameters between the group of girls and boys. Periods that are difficult in terms of influencing body posture were taken into account. The children surveyed were from one social environment and were therefore subjected to a similar social and educational impact. The research used an objective measurement method (MT), which is both reliable and repeatable. Moreover, there is a lack of such studies showing changes in body posture without any intervention.

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