Acta of Bioengineering and Biomechanics
Vol. 23, No. 3, 2021

Original paper
DOI: 10.37190/ABB-01814-2021-04

The effects of the weight of school supplies carried on the right or left shoulder on postural features in the sagittal and transverse planes in seven-year-old pupils of both genders

MIROSŁAW MROZKOWIAK[1], MARTA STĘPIEŃ-SŁODKOWSKA[2]*

[1] Physiotherapy Practice AKTON, Warsaw, Poland.
[2] University of Szczecin, Institute of Physical Education Sciences, Faculty of Physical Education and Health, Szczecin, Poland.

Purpose: The aim of the study was to examine how the weight of a school backpack with school supplies carried on the right or left shoulder influences body posture in schoolchildren. *Methods*: The study of body posture was carried out on a group of 65 pupils aged 7, using the mora projection method in the following eight positions: (four positions for the diagonal loading of the right shoulder and four positions for the loading of the left shoulder) 1 – the habitual posture, 2 – the posture after a 10-minute asymmetric loading, 3 – the posture one minute after removing the load and 4 – the posture two minutes after removing the load. The fitness level was measured using the Sekita test. *Results*: Among the boys, the load on the left or right shoulder showed a statistically significant difference in the analyzed features, apart from the angle of inclination of the lumbosacral segment for the load on the right shoulder. In the girls, significant differences were observed in all of the analyzed features. *Conclusions*: The mode of carriage of school items may cause significant adaptation changes in the skeletal, muscular, and nervous system. Overall fitness affects the size of postural changes. The method of carriage of school supplies with asymmetric loading of the body trunk should not be practised among 7-year-old children of both sexes. The load should be smaller to affect the posture symmetrically.

Key words: *backpack, body posture, mora projection, fitness*

1. Introduction

Body posture is a set of psychomotor habits related to somatic development, body composition and its structure, which are influenced by somatic, morphological, neurophysiological, emotional-volitional and environmental factors [37].

The developed posture of the human body depends on genetic factors, age, the stage of ontogenesis, as well as general physical and mental health [40]. Irregularities in body posture are often attributed to incorrect lifestyle (lack of physical activity or sedentary lifestyle, inadequate nutrition or visual and hearing impairment). Disorders of the statics of the body most often result from the uneven distribution of loads in the fascia-muscular system through stretching and weakening of certain elements of the musculoskeletal system, as well as excessive load and shortening of the antagonistic structures. Incorrect alignment between the main elements of the motor system leads to posture defects, and, as a consequence, discomfort, disorders and pain. Among the factors influencing the emergence of postural disorders, e.g., abnormal development of the spine, shoulder girdle and lower limbs, there are also conditions related to school education, such as excessively heavy school backpacks [1].

* Corresponding author: Marta Stępień-Słodkowska, Faculty of Physical Culture and Health, University of Szczecin, al. Piastów 40B building 6, 71-065 Szczecin, Poland. Phone: +48 609 648 857, e-mail: marta.stepien-slodkowska@usz.edu.pl

Received: December February 24th, 2021
Accepted for publication: May 28th, 2021

The school bags of the pupils studied were heavier than recommended in 79% of the boys and in 64% of the girls. Overweight school bags after one school year have influenced changes in body posture abnormalities, especially in rotation parameters [8]. The research conducted by the Centre for Health Information Systems (CSIOZ) suggests that spinal deformities were diagnosed in 17.14% children and adolescents aged 0–18 years and in 9.7% at the age of 2–9. From the studies carried out by Górecki et al. [12], it appears that changes in the skeletal system of the spine, chest, pelvis, and upper and lower limbs account for 45–55% of all postural defects. Wawrzyniak et al. [36] believe that posture defects pose a significant health problem in the child population.

The review of available literature suggests that the frequency of body posture misalignments and defects depends, inter alia, on the assessment method and the adopted criteria for a correct body posture.

On the basis of 21,895 measurements of 112 posture traits, Mrozkowiak defined the normative ranges for the photogrammetric method [19]. In another study, the sizes of traits for the back KI (deep thoracic kyphosis and normal lumbar ice kyphosis), KIII (deep thoracic kyphosis and shallow lumbar lordosis), RI (thoracic kyphosis and low lumbar lordosis), RII (normal thoracic kyphosis and normal lumbar lordosis), RIII (normal lumbar kyphosis and lumbar lordosis) deep), LI (shallow thoracic kyphosis and deep lumbar lordosis), and LII (thoracic kyphosis and deep lumbar lordosis) were determined according to the Wolański typology [20].

Due to the observed tendency to limit physical activity in favour of sedentary activity, the health problem will increase significantly in later school age [7], [10]. Research shows the corrective effects of general fitness training 2–3 times a week for 45 minutes in 6-year-old children training in judo [37]. It is necessary to implement primary and secondary prevention to reduce possible adverse health effects, applying preventive procedures, postural screening tests and educating the public [9], [12], [21]. Taking care of the proper attitude of preschool children should be one of the main priorities of care during this period [16].

The influence of the pupil's environment on their attitude was investigated, among others, by Wandycz, Piętkiewicz [34], Wandycz [29]–[32], Wandycz, Jakiel, Chabza [33], Romanowska [25], Annetts et al. [6], Mrozkowiak [18]. In the literature, there are many valuable works on the effect of loads carried symmetrically and asymmetrically on the back [1], [11], [22], [35], [40]. Mrozkowiak [18] outlined this issue somewhat, describing the impact of the load imitating a school backpack on the changes in selected spatial features of body posture and the subsequent restitution of the sagittal and frontal parameters of the spine and pelvis after removing the load.

The authors' interest in the topic results from the persistently high percentage of static disorders in the body posture of pupils in the oldest preschool group and grades 1–3 of primary school, and the unclear impact of the mode of transporting school items on the statics of body posture [35]. The aim of the conducted research program was an attempt to define the influence of the weight of school supplies being carried by means of: the right- or left-hand carrying of a school backpack, the location of load on the back, chest or both, obliquely on the left shoulder and at the right hip or obliquely on the right shoulder and left hip. This paper is an attempt to prove the impact of the weight of a school backpack with school supplies carried on the right or left shoulder on body posture.

2. Materials and methods

The research was conducted in accordance with the principles of the Helsinki Declaration. For research purposes, the consent of a pupil, its legal guardian, its tutor, and the managing board of the school from which the children came, was obtained. A physician's consent was also received with regard to the participation of the children in functional physical tests with intense physical effort. The type of biomechanical body static disorders was not an exclusion criterion for participation in the research program.

The study of fitness and body posture was approved by the Research Ethics Committee of the Kazimierz Wielki University in Bydgoszcz (KEBN 2/2018).

The research material consisted of data obtained on a group of seven-year-old children (from 6 years 6 months and 1 day to 7 years 6 months) from randomly selected kindergartens in the Zachodnio-Pomorskie and Wielkopolskie Voivodships. The division of respondents into rural and urban environment was abandoned due to the fact that this feature never determines the homogeneity of the group, and on account of the blurred cultural and economic border of both environments. The age of the children was defined as the number of completed months of life on the day of each test. This enabled the authors to use the previously developed normative ranges appropriate for this age and sex category, diagnosing the quality of the body posture found on the day of the examination.

The total of 65 pupils (35 girls – 53.84% and 30 boys – 46.15%). The average body weight among girls was 24.46 kg and body height was 123.87 cm, whereas among boys the values were 24.56 kg and 123 cm, respectively. All children had a slender body type according to Rohrer's weight-height ratio (IR).

Before starting the measurements, the children were trained in order to avoid the stress associated with the procedure and the persons taking the measurements. The children were trained in their kindergarten group, with the participation of a babysitter. The children were shown what the test involved using vocabulary that the children understood. The preschool teacher's assistant of the study group was always present during the studies, which was to ensure the emotional stability of the children. The measurements were carried out according to the developed procedure, always with the same tools and by the same people. It was also encouraged to keep the anthropometric points on the subject's skin marked for the first time.

The Wrocław Physical Fitness Test was used to diagnose the general fitness of 3–7 year-old pupils [26]. According to the authors, the test has a high degree of reliability and is adequate in terms of discriminatory power and the difficulty level. The examination consisted of four trials: strength test – 1 kg medicine ball overhead, power test – standing long jump, speed test – 20 m high start, agility test – 4 × 5 m pendulum run carrying a block, according to [20]. The test was performed during a Sports Day, which significantly increased the motivation to exercise in the presence of parents. The authors added a fifth test to the Wrocław Physical Fitness Test, namely: endurance. The starting position was a standing position and movement consisted a 300 metre run. The time of the run from start to finish was assessed. The run took place on a recreational path with a hardened surface in full safety.

Different body posture loading was provided by the constructed (protection law of the utility model No. W.125734) diagnostic frame. Its structure enables the diagnosis of biomechanical disorders of variously loaded body posture using mora projection. The presence of the teacher's assistant during tests was intended to minimize the time from removing the load to the next recording of the size of postural features. Every effort was made to ensure that the loaded frame was individually adjusted to the type of a child's body. The adopted 10-minute loading time was an average time to travel from the place of residence provided in the questionnaire filled out by parents. However, a four-kilogram load was an average weight of school supplies transported by first-grade children from a randomly selected primary school [17]. Selected features of body posture were measured in eight positions. The first position – a habitual position (Fig. 1). The second position – after a 10-minute asymmetric loading; during the final five seconds (Figs. 2, 3). The third position –one minute after taking the load off (Fig. 1). The fourth position – two minutes after removing the load (Fig. 1). On the first day, all children were measured in positions 1, 2, 3 and 4 with a load on the right shoulder, and on the following days – in positions 1, 2, 3 and 4 on the left shoulder. The authors assumed that the load was supposed to imitate the mode of carrying school items. The pupil could move freely. In this way, it was attempted to exclude the overlapping of postural muscle fatigue during the test from one position to another. It was in line with the author's previous research results, which have shown that after this time the features may have the starting values [19]. When diagnosing the habitual position on the first day of the research program, it could be assumed that this posture was appropriate and relatively stable for each pupil. However, to ensure reliability in study research, it was assumed that any inconsistency with the size of the features from the first edition of the measurements may affect the final test result. Therefore, before putting on the posture load provided for in the relevant procedure, habitual features were always defined as a reference for the subsequent dynamic changes of the diagnosed features. The height and weight of children as well as the weight of transported school supplies were measured with a medical scale before the first day of the test battery.

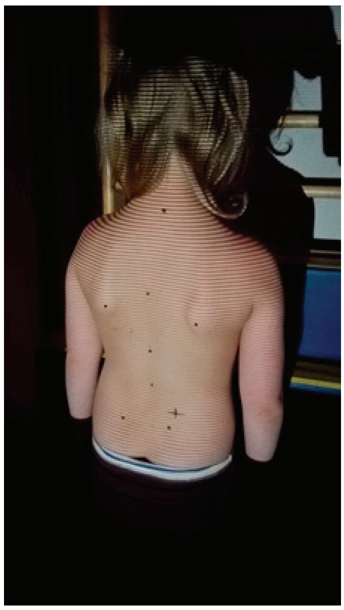

Fig. 1. Posture 1 – a habitual posture. Source: author's own research

Fig. 2. Position 2 – posture with asymmetrical load on the right shoulder

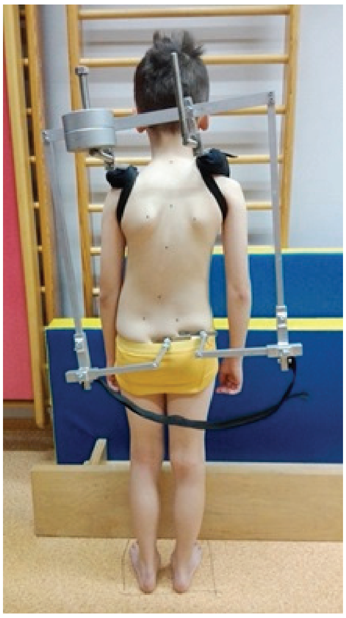

Fig. 3. Position 3 – posture with asymmetrical loading on the left shoulder

The measuring stand for the assessment of selected postural features consisted a computer, a dedicated graphics card, software, a display monitor, a printer and a projection-reception device with a camera to measure selected parameters of the pelvis-spine complex. The places where the child was standing and the camera was set were spatially oriented according to the camera's spirit levels and in relation to the child's toe line. Obtaining the spatial picture was possible thanks to displaying the lines of strictly defined parameters on a child's back. The lines, falling on the skin of the child got distorted depending on the configuration of the surface. The applied lens ensured that the imaging of the subject could be received by a special optical system with a camera, then transmitted to the computer monitor. The distortions of the line imaging recorded in the computer memory were processed through a numerical algorithm on the topographic map of the investigated surface. The obtained image of the back surface enabled multi-faceted interpretation of body posture. In addition to assessing the torso asymmetry in the frontal plane, it was possible to determine the values of angular and linear features describing the pelvis and physiological curvatures in the sagittal and transverse plane. The most important thing in this method is the simultaneous measurement of all real values of the spatial location of individual body sections [28].

To minimize the risk of measurement errors as regards selected postural features, the following test procedure was developed [19]:

1. Maintaining the habitual posture of the subject against the background of a white, slightly illuminated sheet: free, unforced posture, with feet slightly spaced apart, extended knee and hip joints, arms dangling along the torso and eyes directed straight ahead, back to the camera in the appropriate distance from it, with toes at a line perpendicular to the camera axis.
2. Marking the following points on the skin of the child's back: the peak of the spinous process of the last cervical vertebra (C_7), the spinous process at the peak of thoracic kyphosis (KP), the spinous process at the peak of lumbar lordosis (LL), the place where thoracic kyphosis goes into lumbar lordosis (PL), lower shoulder blades (Łl and Łp), upper posterior iliac spines (Ml and Mp), and vertebra S_1. A white necklace was placed on the pupil's neck for the purpose of unambiguous marking of points B_1 and B_3. Long hair was tied to cover point C_7.
3. After entering the necessary data about the respondent (name and surname, year of birth, body weight and height, remarks on: the condition of knees and heels, chest, injuries, surgical procedures, musculoskeletal disorders, gait, etc.), a digital image of the back and feet was recorded in the computer memory in each of the four positions of the middle phase of exhalation.
4. The recorded images were processed without the participation of the examined individual. After saving the mathematical characteristics of photos into the computer memory, the size of the features describing the body posture spatially was printed.

Research subject

The Wrocław Physical Fitness Test makes it possible to determine the level of strength, power, speed and agility of preschool children. The authors enriched the well-described Sekita test with an endurance test. Definitions of the analysed conditioning and complex motor skills are generally available in reference literature.

The measuring device defines several dozen postural features. 19 angular and linear features of the spine, pelvis and torso in the sagittal and transverse planes as well as body mass and height were selected for statistical analysis. The authors appreciated the need for the most reliable and spatially full view of a child's body posture, which allowed full identification of the measured factors (Table 1).

Our study results and the analysis of available literature suggest the following hypotheses [18]–[20] that:

1) there are significant differences between the size of habitual posture features and the size of the features of body posture affected by asymmetrical loading. The differences are greater in girls than boys;

Table 1. List of recorded trunk and morphological parameters

No.	Symbol	Parameters		
		Unit	Name	Description
Sagittal plane				
1	Alpha	degree	Inclination of lumbo-sacral region	
2	Beta	degree	Inclination of thoraco-lumbar region	
3	Gamma	degree	Inclination of upper thoracic region	
4	Delta	degree	The sum of angles	Delta = Alpha + Beta + Gamma
5	KPT	degree	Angle of extension	Defined as a deviation of the C7-S1 line from vertical position (backwards)
6	KPT –	degree	Angle of body bent	Defined as a deviation of the C7-S1 line from vertical position (forwards)
7	DKP	mm	Thoracic kyphosis length	Distance between LL and C_7
8	KKP	degree	Thoracic kyphosis angle	KKP = 180 – (Beta+Gamma)
9	RKP	mm	Thoracic kyphosis height	Distance between points C7 and PL
10	GKP	mm	Thoracic kyphosis depth	Distance measured horizontally between the vertical lines passing through points PL and KP
11	DLL	mm	Lumbar lordosis length	Distance measured between points S1 and KP
12	KLL	degree	Angle of lumbar lordosis	KLL = 180 – (Alpha + Beta)
13	RLL	mm	Lumbar lordosis height	Distance between points S1 and PL
14	GLL –	mm	Lumbar lordosis depth	Distance measured horizontally between the vertical lines passing through points PL and LL
Frontal plane				
15	UB –	degree	Angle of projection line of lower scapula angles, the left one more convex	Difference in the angles $UB_1 – UB_2$. Angle UB_2 between: the line passing through point $Ł_l$ and at the same time perpendicular to the camera axis and the straight line passing through points $Ł_l$ and $Ł_p$. Angle UB_1 between the line passing through point $Ł_p$ and perpendicular to the camera axis and the straight line passing through points $Ł_p$ and $Ł_l$. PLLB = LLB – PLB
16	UB	degree	Angle of projection line of lower scapula angles, the right one more convex	
17	KSM	degree	Pelvis rotated to the right	Angle between the line passing through point M_l and perpendicular to the camera axis and the straight line passing through points M_l and MP
18	KSM –	degree	Pelvis rotated to the left	Angle between the line passing through point Mp and perpendicular to the camera axis and the straight line passing through points Ml and MP
19	DCK	mm	Total length of the spine	Distance between C_7 and S_1, measured in vertical axis
Morphological features				
20	Mc	kg	Body mass	Measurement of body height and weight conducted by means of a digital medical scale
21	Wc	cm	Body height	

Source: author's own research.

2) when carrying school supplies on the left or right shoulder, postural disturbances are most influenced by overall physical fitness, including endurance and strength. The differences are smaller among children with higher fitness.

Statistical methods

The statistical analysis of the study results was conducted using the IBM SPSS Statistics 26 program. At the initial stage, Shapiro–Wilk and Kolmogorov–Smirnov tests were used to check whether the distributions of the analysed variables were consistent with the normal distribution. For most variables, statistically significant deviations from the normal distribution were found at $p < 0.05$. Therefore, it was decided to apply non-parametric tests and coefficients in statistical analysis.

The Wilcoxon rank test was used to determine whether there was a statistically significant disparity (change) between two measurements of quotient variable (within the same group) the distribution of which significantly deviated from the normal. The following symbols were used in the tables: M – arithmetic mean, Me – median, SD – standard deviation, Z – Wilcoxon test statistics, and "*p*" – significance of the Wilcoxon test. The significance level was set at $p < 0.05$ which was marked as * and, additionally, the significance level of $p < 0.01$ marked as **. Therefore, if $p < 0.05$ or $p < 0.01$, the difference between measurements is statistically significant.

Spearman's ρ correlation coefficient was applied to establish if there were any statistically significant correlations between variables measured at the quotient level whose distribution significantly deviated from normal. The significance level was set at $p < 0.05$, which was marked as * and, the significance level at $p < 0.01$ marked as **. Therefore, if $p < 0.05$ or $p < 0.01$, the correlation between variables was statistically significant. If correlation was statistically significant at $p < 0.05$, the correlation coefficient ρ was to be interpreted. The coefficient may range from –1 to +1. The more distant the coefficient is from 0 and the closer it is to –1 or +1, the stronger the correlation. Negative values mean that as the value of one variable increases, the value of the other variable decreases. Positive values, in turn, show that as the value of one variable increases, the value of the other variable increases.

The individual tables include only those variables (in rows) for which at least one statistically significant result was recorded.

An analysis of the correlation between the results of five physical fitness tests and the average difference between measurement 2 and 1of the values of features in the posture assumed during the loading of the right or left shoulder was also made, broken down by gender. The difference between the measurements was given in absolute values, so that negative differences would also indicate the size of the change. The authors took into account only those children who had been subjected to both physical fitness tests and body posture measurements, which considerably reduced the size of the group involved in the study. For this reason, it was impossible to calculate correlations for some variables. In these cases, there are empty cells in the tables. Statistically significant correlations are marked with a grey background.

Individual values of postural traits are expressed in different values and ranges so it is impossible to calculate the average difference for all these variables between two measurements. Analysis conducted in such manner would distort the results and increase the significance of the variables whose values are higher by definition, and reduce the significance of those variables with values lower by definition. That is why the assessment of correlations between the average difference in the values of postural features between measurement 2 and 1 concerning postures adopted during the right or left shoulder carriage and physical fitness was made separately for girls and boys, using absolute quantities, i.e., the ratio of the difference to the initial value, was used in the calculations instead of exact quantities concerning the differences. Owing to such an approach, no variables are over- or under-represented in the average result.

3. Results

The total of 65 subjects of both genders were involved in the study, which allowed to record 5,785 values of features describing body posture in habitual and dynamic positions, body weight and height as well as physical fitness.

The analysis of the results obtained in the Wrocław Physical Fitness Test and endurance tests revealed that the studied group of 7-year-old children from the West Pomeranian and Greater Poland regions represented a sufficient level of physical fitness, applying the following grading scale: unsatisfactory, satisfactory, good, very good.

The analysis of the differences in the results of posture features between measurements 1 and 2 in the carriage of school supplies on the right or left shoulder by boys and girls was aimed at showing significant changes in the size of posture features. Taking into account only boys, according to the Wilcoxon rank test, transport on the left and right shoulder showed a statistically significant difference in all studied variables. The exception was the inclination angle of the lumbosacral spine (Alpha) during transport on the right shoulder (Table 2). In the case of girls, significant differences were observed in all analysed features (Table 3).

Table 2. Significance of differences in the size of posture traits in the sagittal and transverse planes between measurement 1 and 2 in the case of load on the left and right shoulder among boys

Variable	Measurement 1			Measurement 2			Wilcoxon test	
	M	Me	SD	M	Me	SD	*Z*	*p*
Left sholuder								
DCK	308.98	314.05	22.87	297.53	301.75	23.10	–4.784	<0.001**
Alpha	8.28	8.45	1.52	12.19	11.70	2.10	–4.783	<0.001**
Beta	9.90	9.75	1.13	17.43	17.40	1.30	–4.784	<0.001**
Gamma	11.10	11.20	1.19	16.30	16.50	1.20	–4.786	<0.001**
Delta	29.28	29.65	2.45	45.96	45.65	2.45	–4.784	<0.001**
KPT–	3.73	4.15	1.34	9.26	9.50	1.21	–3.920	<0.001**
KPT+	4.40	4.75	0.69	1.61	1.50	0.92	–2.803	0.005**
DKP	278.15	279.00	8.96	264.56	264.75	10.24	–4.783	<0.001**
KKP	159.04	159.00	1.55	146.27	146.10	1.48	–4.789	<0.001**
RKP	185.63	185.30	13.49	173.23	174.05	13.21	–4.783	<0.001**
GKP	20.26	19.95	1.40	33.76	34.95	3.15	–4.783	<0.001**
DLL	246.61	247.00	11.98	239.76	240.95	12.30	–4.783	<0.001**
KLL	161.82	161.95	2.22	150.58	151.20	2.83	–4.783	<0.001**
RLL	134.86	135.60	11.07	128.59	129.95	10.84	–4.786	<0.001**
GLL	23.44	24.45	3.19	28.64	29.25	3.02	–4.785	<0.001**
UB–	2.70	3.30	1.96	0.88	0.80	0.75	–2.521	0.012*
UB+	3.79	4.00	2.64	9.04	9.35	0.83	–4.107	<0.001**
KSM–	3.19	2.45	2.78	0.48	0.40	0.43	–2.524	0.012*
KSM+	5.68	5.50	2.87	14.30	14.30	1.80	–4.107	<0.001**
Right shoulder								
DCK	308.98	314.05	22.87	291.73	290.55	22.43	–4.782	<0.001**
Beta	9.90	9.75	1.13	18.92	18.75	1.73	–4.786	<0.001**
Gamma	11.10	11.20	1.19	14.70	14.80	1.29	–4.784	<0.001**
Delta	29.28	29.65	2.45	42.39	43.30	3.45	–4.783	<0.001**
KPT–	3.84	4.25	1.43	9.23	9.40	1.00	–3.921	<0.001**
KPT+	4.40	4.75	0.69	2.41	2.20	1.01	–2.809	0.005**
DKP	278.15	279.00	8.96	264.34	264.20	8.59	–4.783	<0.001**
KKP	159.04	159.00	1.55	146.38	145.95	1.46	–4.786	<0.001**
RKP	185.63	185.30	13.49	171.91	172.95	13.20	–4.783	<0.001**
GKP	20.26	19.95	1.40	33.41	33.95	2.50	–4.783	<0.001**
DLL	246.61	247.00	11.98	238.83	238.90	12.52	–4.783	<0.001**
KLL	161.82	161.95	2.22	152.31	152.35	3.14	–4.783	<0.001**
RLL	134.86	135.60	11.07	127.93	128.40	10.67	–4.783	<0.001**
GLL	23.44	24.45	3.19	25.78	27.00	2.75	–4.640	<0.001**
UB–	2.70	3.30	1.96	7.60	7.75	2.04	–2.524	0.012*
UB+	3.72	3.65	2.66	1.12	1.10	0.85	–4.108	<0.001**
KSM–	3.19	2.45	2.78	12.15	12.00	2.45	–2.524	0.012*
KSM+	5.68	5.50	2.87	0.97	1.10	0.39	–4.107	<0.001**

Table 3. Significance of differences in the size of posture traits in the sagittal and transverse planes between measurement 1 and 2 in the case of load on the left and right shoulder among girls

Variable	Measurement 1			Measurement 2			Wilcoxon test	
	M	Me	SD	M	Me	SD	Z	*p*
Left shoulder								
DCK	295.09	294.10	21.66	283.69	284.40	21.76	–5.088	<0.001**
Alpha	8.96	8.90	1.40	12.32	12.10	1.91	–5.087	<0.001**
Beta	11.26	11.20	2.04	18.79	18.75	2.09	–5.102	<0.001**
Gamma	11.24	11.25	1.72	16.74	16.75	1.55	–5.092	<0.001**
Delta	31.46	31.00	2.83	47.85	47.20	3.30	–5.087	<0.001**
KPT–	3.84	4.10	1.30	9.54	9.50	0.94	–3.622	<0.001**
KPT+	3.94	4.20	1.07	1.31	1.50	0.75	–3.624	<0.001**
DKP	274.81	276.25	8.65	262.40	263.35	8.77	–5.088	<0.001**
KKP	157.50	157.70	2.72	144.46	144.75	2.72	–5.089	<0.001**
RKP	181.34	176.90	12.15	169.36	165.55	11.51	–5.087	<0.001**
GKP	20.40	20.45	1.06	34.69	35.40	2.84	–5.088	<0.001**
DLL	247.46	248.15	12.18	241.08	242.10	11.78	–5.088	<0.001**
KLL	159.79	159.90	1.98	148.91	148.95	2.81	–5.087	<0.001**
RLL	131.06	129.15	9.76	124.77	122.40	9.96	–5.089	<0.001**
GLL	23.02	23.40	3.18	28.74	29.00	3.15	–5.088	<0.001**
UB–	3.21	2.70	2.64	0.48	0.40	0.32	–3.825	<0.001**
UB+	3.92	2.80	2.19	9.28	9.40	1.20	–3.408	0.001**
KSM–	3.52	2.90	1.81	0.54	0.40	0.32	–3.823	<0.001**
KSM+	4.47	4.10	2.54	13.85	13.60	1.49	–3.408	0.001**
Right shoulder								
DCK	295.09	294.10	21.66	277.58	276.95	21.25	–5.087	<0.001**
Alpha	8.96	8.90	1.40	10.28	10.40	2.35	–2.497	0.013*
Beta	11.26	11.20	2.04	19.65	19.60	2.58	–5.088	<0.001**
Gamma	11.24	11.25	1.72	15.07	14.85	1.46	–5.087	<0.001**
Delta	31.46	31.00	2.83	45.01	44.40	3.29	–5.087	<0.001**
KPT–	3.84	4.10	1.30	9.48	9.60	0.90	–3.622	<0.001**
KPT+	3.94	4.20	1.07	2.11	2.30	0.85	–3.627	<0.001**
DKP	274.75	276.25	8.66	260.71	261.45	8.48	–5.087	<0.001**
KKP	157.50	157.70	2.72	145.01	144.90	2.45	–5.088	<0.001**
RKP	181.34	176.90	12.15	167.90	164.15	11.49	–5.087	<0.001**
GKP	20.40	20.45	1.06	33.84	34.55	2.15	–5.087	<0.001**
DLL	247.46	248.15	12.18	240.42	242.05	11.54	–5.070	<0.001**
KLL	159.79	159.90	1.98	150.20	150.20	2.67	–5.087	<0.001**
RLL	131.06	129.15	9.76	123.94	121.55	9.58	–5.088	<0.001**
GLL	23.02	23.40	3.18	25.35	25.15	2.68	–5.014	<0.001**
UB–	3.21	2.70	2.64	8.20	7.50	2.30	–3.825	<0.001**
UB+	3.92	2.80	2.19	1.04	0.80	0.58	–3.411	0.001**
KSM–	3.52	2.90	1.81	12.07	11.60	1.75	–3.833	<0.001**
KSM+	4.47	4.10	2.54	0.89	0.90	0.42	–3.408	0.001**

Source: Authors' own study.

The study of correlations between the sizes of fitness tests and the differences in the size of posture traits between measurements 1 and 2 in left shoulder transport showed that in boys, the higher the power the smaller the differences in the Gamma and KPT variables, and the higher the overall physical fitness, the smaller the difference in the DKP variable (Table 4).

However, in the analysis of the correlation between the sizes of fitness tests and the differences in the size of body posture traits between the 1st and 2nd measurements in transport on the left shoulder shows that in boys, the higher the power, the smaller the differences in the Gamma and KPT variables, and the higher the total fitness, the smaller the difference in the DKP variable (Table 4). However, in the transport on the right shoulder, the greater the force, the greater the difference in the KKP variable, and the smaller the difference in the DLL variable. The higher the power, the smaller the differences in the KPT– and GLL variables. The greater the agility, the smaller the difference in the DKP variable, and the higher the total efficiency, the smaller the difference in the DKP variable, and the greater in the KKP variable (Table 4). In the case of girls, the analysis showed that in transport to the left shoulder, the greater the endurance, the greater the differences in the GLL variable (Table 5). However, in the right shoulder transport, the greater the power, the greater the difference in the variable KKP (Table 5).

Table 4. Correlations between physical fitness and difference in the size of postural traits in the sagittal and transverse planes between measurement 1 and 2 in the case of load on the left and right shoulder among boys

Variable	Endurance		Speed		Strength		Power		Agility		Total	
	ρ	*p*	*ρ*	*p*	*ρ*	*p*	*ρ*	*p*	*ρ*	*p*	*ρ*	*p*
Left shoulder												
Gamma	0.387	0.154	0.147	0.600	0.044	0.876	–0.536	0.039	0.248	0.373	0.077	0.784
KPT–	–0.418	0.262	–0.220	0.569	–0.341	0.370	–0.792	0.011	–0.510	0.160	–0.517	0.154
DKP	–0.431	0.108	–0.322	0.241	–0.585	0.022	–0.15	0.594	–0.510	0.052	–0.645	0.009
RKP	0.242	0.385	0.268	0.334	0.544	0.036	0.146	0.603	0.112	0.691	0.501	0.057
Right shoulder												
KPT–	–0.429	0.250	–0.318	0.405	–0.509	0.162	–0.765	0.016	–0.647	0.06	–0.644	0.061
DKP	–0.250	0.369	–0.126	0.655	–0.462	0.083	–0.185	0.510	–0.562	0.029	–0.545	0.036
KKP	0.286	0.301	0.351	0.200	0.650	0.009	0.338	0.218	0.425	0.114	0.576	0.025
DLL	–0.209	0.455	–0.153	0.587	–0.645	0.009	–0.029	0.917	–0.397	0.142	–0.463	0.082
GLL	0.150	0.593	0.281	0.310	–0.153	0.587	–0.525	0.044	–0.163	0.561	–0.224	0.423

Source: Author's own study.

Table 5. Correlations between physical fitness and the difference in the size of posture features between 1 and 2 measurements of transport on the left and right shoulder among girls

Variable	Endurance		Speed		Strength		Power		Agility		Total	
	ρ	*p*	*ρ*	*p*	*ρ*	*p*	*ρ*	*p*	*ρ*	*p*	*ρ*	*p*
Left shoulder												
GLL	0.579	0.049	0.283	0.373	0.294	0.354	0.286	0.367	0.314	0.321	0.495	0.102
KNT–	0.908	0.005	0.477	0.279	0.372	0.412	0.187	0.688	0.176	0.706	0.546	0.205
KLB+	0.541	0.210	0.703	0.078	0.879	0.009	–0.569	0.182	0.837	0.019	0.821	0.023
UL.–	0.500	0.391	–0.300	0.624	0.632	0.252	0.894	0.041	0.700	0.188	0.700	0.188
OL+	0.500	0.391	0.300	0.624	0.949	0.014	0.783	0.118	0.800	0.104	0.800	0.104
TT+	0.655	0.111	0.782	0.038	0.406	0.366	0.259	0.574	0.284	0.536	0.613	0.144
TS–	–0.400	0.505	0.300	0.624	–0.791	0.111	–0.894	0.041	–0.700	0.188	–0.700	0.188
Right shoulder												
KKP	0.396	0.203	–0.120	0.710	0.092	0.777	0.618	0.032	–0.088	0.784	0.165	0.609
KNT+	0.000	1.000	0.900	0.037	–0.053	0.933	–0.447	0.450	–0.100	0.873	–0.100	0.873
KLB+	–0.450	0.310	–0.559	0.192	–0.954	0.001	0.312	0.496	–0.982	0.000	–0.893	0.007
UL.–	–0.700	0.188	–0.500	0.391	–0.949	0.014	–0.783	0.118	–0.900	0.037	–0.900	0.037
UB–	0.900	0.037	0.700	0.188	0.527	0.361	0.335	0.581	0.700	0.188	0.700	0.188
TT–	–0.700	0.188	–0.100	0.873	–0.949	0.014	–0.894	0.041	–0.900	0.037	–0.900	0.037
TT+	0.418	0.350	0.427	0.339	0.840	0.018	–0.296	0.519	0.927	0.003	0.757	0.049
TS+	–0.306	0.504	0.198	0.670	0.468	0.290	–0.771	0.042	0.418	0.350	0.214	0.645

Source: Author's own study.

4. Discussion

The research carried out in a group of 7-year-old children of both sexes allowed for the registration of 5785 values of body posture features in habitual posture and dynamic positions, as well as body weight and height, and physical fitness. The obtained results showed a sufficient level of physical fitness of the examined children. This level was significantly lower than the values obtained in the measurements by other authors from 2006, 1996, 1972 and 1967. The phenomenon of sexual dimorphism at the age of 7 was not confirmed. Carrying on the left or right shoulder showed statistically significant differences in all the analyzed variables, apart from the angle of inclination of the lumbosacral segment in the right shoulder among boys.

In the boys examined in this study, during carrying using the left shoulder, the greater the child's strength, the smaller the inclination of upper thoracic region and the angle of extension, and the higher the total efficiency, the lower thoracic kyphosis length. On the other hand, in the case of carrying using the right shoulder, the greater the child's strength, the greater the thoracic kyphosis angle, and the less the lumbar lordosis length. The greater the strength, the smaller the angle of body bend and lumbar lordosis depth. The greater the agility, the smaller the thoracic kyphosis length, and the greater the overall fitness, the smaller the thoracic kyphosis length and the greater the thoracic kyphosis angle. In the girls, the analysis showed that, in the case of carrying using the left shoulder, the greater the strength, the greater the lumbar lordosis depth. In contrast, in the case of carrying using the right shoulder, the greater the power, the greater the thoracic kyphosis angle.

Studies by different authors available in literature confirm results of the authors' of this work. They indicate a relationship between the load of the school supplies carried asymmetrically and the posture of children and teens.

Research conducted by Żuk [40] aimed at assessing the habits of shaping the body shape of students from selected primary schools showed that the weight of a backpack or school bag is considered a risk factor for posture disorders. On the day of the examination, the girls' backpacks weighed 4.76 kg on average, and the boys' 4.87 kg. In the study group, 59.4% showed a bad and very bad attitude. In 32.8% of children, the attitude was good, and in 7.8%, the attitude was very good. Opinions on the impact of the weight of a backpack or the way it is worn on the shaping of body posture are divergent [35].

Too heavy backpack was indicated by Adeyemi et al. [1] and Grimmer et al. [8] as the cause of posture defects in children and adolescents. The results presented by Deng et al. [11] and Zhang et al. [39] indicate the existence of a relationship between pain in the neck, back and posture defects, and overloading a school backpack.

A study by Rashid et al. [24] searched for the optimal backpack weight in children aged 9–14 years. They found that as the backpack load increased above 15% of the subject's body weight, significant kinematic changes were observed in the ankle, knee and hip joints.

A study conducted by Brzęk et al. [8] on 155 students aged 7–9 years at the beginning and end of the school year, estimated the weight of the school backpack, the length and symmetry of the backpack straps, the measurement of posture using the Adams test, the assessment of deviation from the gluteal cleft, the examination of the values of kyphosis and lordosis angles using the Dobosiewicz method, and the position of the pelvis and shoulder blades. The weight of backpacks in 3.2% of cases exceeded the recommended norms. Trunk rotation disorders were present in 35.3% of the girls and 60.9% of the boys. Increased kyphosis angle was noted in 48.5% of the girls and 36.8% of the boys.

A study of children aged 7–10 years free of neurological and orthopedic health problems by Hell et al. [14], aimed to determine the effect of a 4 kg school backpack on gait style and posture. They found that loading at an average of 15% of the child's body weight resulted in increased anterior pelvic and trunk tilt and increased hip flexion, which can consequently lead to postural defects.

Ahmad and Barbosa [2] also found that the weight of backpacks affects gait biomechanics, which may contribute to postural defects in children aged 7–9 years. Alfageme-Garcia et al. [3] came to those same conclusions by studying 627 subjects with an average age of 8.32 years.

Negrini [22], examining children aged 11–13 with no postural defects, showed that symmetrical carrying of 12 kg backpacks leads to a statistically significant reduction in the value of lumbar lordosis by an average of 16 degrees and a reduction of thoracic kyphosis by an average of 6 degrees. On the other hand, asymmetrical carrying of backpacks resulted in a spine rotation of 3–4 degrees. This was accompanied by slight changes in the shape of the spine in the sagittal plane.

Other studies have revealed that asymmetric load transfer increases the activity of paraspinal muscles and hip abductors [13], [38]. Studies carried out by Wu have shown that asymmetrically transferred load causes changes in body posture. Therefore, in order to reduce negative multi-system changes, the centre of gravity of the load should be as close to the body centre as possible [38]. Research by Hardie et al. [13] suggests that the change of the carriage method from symmetrical to asymmetrical has the greatest impact on the trapezius muscles, and the least on the latissimus dorsi. Obrębska et al. [23] came to similar conclusions. During the asymmetric transport of the bag on the shoulder, Grimmer found very high activity of trapezius muscles, which may result from the necessity of raising the upper limb. It may, therefore, suggest that these muscles tend to lift the upper limb to counteract its excessive load imposed by hand luggage. This, in turn, could have resulted in spinal asymmetry, leading to an attempt to shift the centre of gravity over the support point during the gait cycle. This was confirmed by the studies conducted by Obrębska et al. [23] who also showed that the average activity of these muscles obtained during asymmetrical carriage of a backpack (centre of gravity located closer to the axis of the body) is almost twice lower than in the case of walking while carrying a bag on one shoulder. Additionally, this muscle is more active on the same side as the load. The research conducted by Hardie et al. [13] and Obrębska et al. [23] has shown that in the case of paraspinal muscles, the lowest activity was observed for latissimus dorsi. This may result from the function of this muscle, as it is responsible for lowering the raised arm and abducting the limb, but only when the spine is in a fixed position (i.e., it is necessary to limit the spinal mobility).

Wearing a backpack in a proper way contributes to reducing musculoskeletal complications in children. The acceptable standard for the load carried on the back is a maximum of 15% of the child's body weight. However, studies of the consequences are quite limited due to the small group sizes in most articles and the lack of association with all postural parameters [15].

In response to the conditions related to school education, the WHO indicated that the weight of a child's backpack should not exceed 10% of the child's weight. According to the recommendations of the Chief Sanitary Inspector, the weight of the schoolbag/backpack should not exceed 10–15% of the child's body weight. The American Academy of Pediatrics (AAP) recommends school bags weighing 10–20% of body weight [4], and the American Occupational Therapy Association (AOTA) recommends a backpack weight not exceeding 10% of the child's body weight [5]. As the above-mentioned studies show, the statistics remain disturbing. The solution used by the Minister of Education and Sport in Poland was to introduce lockers in schools where children could leave their teaching aids and books [27].

The conducted research allowed to determine the influence of the load carried on the right and left arm on the body posture of the examined children.

The value of the study was the use of the photogrammetric method as one of the most objective methods of diagnosing body posture. For the purpose of the study, an original diagnostic tool was used to assess body posture – a patented frame. The uniqueness of the study also concerned the measurements of the size of features describing body posture after removing the external load.

Too short research period was a limitation of the research. Further research before the beginning of the year and after the end of the annual training cycle would be beneficial.

5. Conclusions

1. The method of transporting school supplies on the left or right shoulder may induce significant adaptive changes in the skeletal, muscular and nervous system according to Arndt–Schultz's law. It can be assumed that these changes are to be the greater the longer the carriage time, the greater the mass of the school backpack and the intensity of physical effort. Such changes are not gender specific.
2. The level of overall physical fitness has a diversified influence on the degree of changes in body posture features affected by the adopted method of transporting school supplies. Among boys, this influence is significant whereas among girls, it is less important. Among girls, changes in the size of posture traits in the loading of the left shoulder are affected by endurance, and of the right shoulder by power. Among boys, power and overall fitness are important in the loading of the left shoulder, whereas strength, power, agility and overall fitness are important for the right shoulder. The impact is gender dependent.
3. The mode of transporting the weight of school items with asymmetric loading of the body trunk adopted for the analysis should not be practised by 7-year-old children of both sexes. The load should be lower and symmetrically influence the body posture.

References

[1] ADEYEMI A.J., ROHANI J.M., RANI M.R., *Interaction of body mass index and age in muscular activities among male backpack carrying schoolchildren*, Work, 2015, 52 (3), 677–686.

[2] AHMAD H.N., BARBOSA T.M., *The effects of backpack carriage on gait kinematics and kinetics of schoolchildren*, Sci. Rep., 2019, 9 (1), 3364.

[3] ALFAGEME-GARCÍA P., CALDERÓN-GARCÍA J.F., MARTÍNEZ-NOVA A., HIDALGO-RUIZ S., MARTÍNEZ-ÁLVAREZ M., RICO-MARTÍN S., *Backpacks effect on foot posture in schoolchildren with a neutral foot posture: A three-year prospective study*, Int. J. Environ. Res. Public Health, 2020, 17 (19), 7313.

[4] American Acadamy of Pediatrics – AAP, *Back to school tips getting the year off to a good start from the AAP*, The Academy, 2020, https://www.aap.org/en-us/about-the-a-ap/app-press-room/news-features-and-safety-tips/PagesBack-to-School-Tips-Getting-the-Year-Off-to-a-Good-Start-from-the-AAP.aspx. (accessed: 10 January 2020).

[5] American Occupational Therapy Association (AOTA), *How heavy is your Child's backpack?* The Association, 2020, https://www.aota.org/Publications-News/ForTheMedia/Pressreleases/2018/091318-How-Heavy_backpack.aspx. (accessed: 10 January 2020.

[6] ANNETTS S., COALES P., COLVILLE R., MISTRY D., MOLES K., THOMAS B., VAN DEURSEN R., *A pilot investigation into the effects of different office chairs on spinal angles*, European Spine Journal, 2012, 21 (2), 165–170.

[7] BINKLEY T.L., SPECKER B.L., *The negative effect of sitting time on bone is mediated by lean mass in pubertal children*, J. Musculoskelet. Neuronal Interact., 2016, 16 (1), 18–23.

[8] BRZĘK A. et al., *The weight of pupils' schoolbags in early school age and its influence on body posture*, BMC Musculoskeletal Disorders, 2017, 18, 117.

[9] CALLONI S.F., HUISMAN T.A., PORETTI A. et al., *Back pain and scoliosis in children: When to image, what to consider*, Neuroradiol. J., 2017, 30 (5), 393–404.

[10] CAMARGO M.Z., DE OLIVEIRA M.R., FUJISAWA D.S., *Evolution of postural alignment in preschool and school phases: A longitudinal study Motriz*, J. Phys. Educ., 2017, 23 (2), e101779.

[11] DENG G. et al., *Effects of physical factors on neck or shoulder pain and low back pain of adolescents*, Zhonghua Yi Xue Za Zhi, 2014, 94 (43), 3411–4315.

[12] GÓRECKI A., KIWERSKI J., KOWALSKI I.M. et al., *Prevention of postural defects in children and adolescents in the teaching and educational environment – recommendations of experts*, Polish Annals of Medicine, 2009, 16, 168–177.

[13] HARDIE R., HASKEW R., HARRIS J., HUGHENS G., *The effects of bag style on muscle activity of the trapezius, erector spinae and latissimus dorsi during walking in female University Students*, Journal of Human Kinetics, 2015, 45, 39–47.

[14] HELL A.K., BRAUNSCHWEIG L., GRAGES B., BRUNNER R., ROMKES J., *The influence of backpack weight in school children: gait, muscle activity, posture and stability*, Orthopade, 2020, Dec. 9, DOI: 10.1007/s00132-020-04047-8.

[15] JANAKIRAMAN B., RAVICHANDRAN H., DEMEKE S., FASIKA S., *Reported influences of backpack loads on postural deviation among school children: A systematic review*, J. Educ. Health Promot., 2017, 5 (6), 41.

[16] LUDWIG O., HAMMES A., KELM J. et al., *Assessment of the posture of adolescents in everyday clinical practice: Intra-rater and inter-rater reliability and validity of a posture index*, J. Bodyw. Mov. Ther., 2016, 20 (4), 761–766.

[17] MROZKOWIAK M., *An attempt to determine the difference in the impact of loading with the mass of school supplies carried using the left- and right-hand thrust on body posture of 7-year-old pupils of both genders*, Pedagogy and Psychology of Sport, 2020, 6 (3), 44–71.

[18] MROZKOWIAK M., *Biomechanical analysis of changes in selected parameters of the pelvis-spine complex in the frontal and transverse planes during and after loading*. [In:] M. Gwoździcka-Piotrowska, A. Zduniak (eds.), *Education in a "risk" society. Security as a value*. v. 2. Scientific University Press of Higher School of Security, 2007, 339–342.

[19] MROZKOWIAK M., *Modulation, impact and relationships of selected parameters of body posture in children and adolescents aged 4 to 18 in the light of the mora projection*, University Press of Kazimierz Wielki University, Bydgoszcz, 2015.

[20] MROZKOWIAK M., STRZECHA M., *Mora projection – a contemporary diagnostic tool of body posture*, Anthropomotorics, 2012, 22 (60).

[21] NEIVA P.D., KIRKWOOD R.N., MENDES P.L. et al., *Postural disorders in mouth breathing children: a systematic review*, Braz. J. Phys. Ther., 2018, 22 (1), 7–19.

[22] NEGRINI S., NEGRINI A., *Postural effects of symmetrical and asymmetrical loads on the spines of schoolchildren*, Scoliosis, 2007, 2, 8.

[23] OBRĘBSKA P., OGRODNIK J., PISZCZATOWSKI S., *Wpływ sposobu przenoszenia bagażu podręcznego na aktywność wybranych mięśni szkieletowych*, Aktualne Problemy Biomechaniki, 2018, 15, 29–36 (in Polish).

[24] RASHID M., MATHEW J., RAJ V.S., RAJA K., *Optimization of backpack loads using gait parameters in school boys*, J. Bodyw. Mov. Ther., 2021, Jan. (25), 174–182.

[25] ROMANOWSKA A., *Change in the child's body posture under the influence of a schoolbag*, Physical and Health Education, 2009, 5, 13–19.

[26] SEKITA B., *Somatic development and physical fitness of children aged 3–7 years*, [In:] S. Pilicz (ed.), *Development of physical fitness and performance in children and adolescents – research reports*, Warsaw, 1988.

[27] ŚMIGIEŁ S., PAWLAK Ż., ANDRYSZCZYK M., TOPOLIŃSKI T., *Czynniki wpływające na zmianę postawy ciała u dzieci w wieku szkolnym*, Aktualne Problemy Biomechaniki, 2017, 12, 51–58 (in Polish).

[28] ŚWIERC A., *Computer posture diagnostics – instructions*, CQ Elektronik System, Czernica Wrocławska 2006, 3–4.

[29] WANDYCZ A., *Ailments of primary school students and the height of school furniture*, Annales, UMC-S, Sectio D. Medicina Lublin, 2007, LXII(XVIII)-8, 280–284.

[30] WANDYCZ A., *Mental and physical tiredness of the secondary school pupils in Zielona Góra based on the Japanese questionnaire*, Corrective and Compensating Procedure in Ontogenetic Development Disorders, 2011, 129–141.

[31] WANDYCZ A., *Musculoskeletal ailments of people at the age of 7–21*, University of Zielona Góra, 2013, 9–10.

[32] WANDYCZ A., *The height of school furniture against physical fatigue and ailments among junior high school students, Social and environmental health risks and welfare*, Publishing House NeuroCentrum, 2008, 157–169.

[33] WANDYCZ A., JAKIEL R., CHABZA M., *Working conditions and ailments related to computer work among primary school pupils*, Corrective and Compensating Procedure in Ontogenetic Development Disorders, 2011, 143–155.

[34] WANDYCZ A., PIĘTKIEWICZ K., *Height of school furniture and physical fatigue of students of selected primary schools in the Lubuskie Voivodship*, Applications of Ergonomics, 2006, 1–3, 117–125.

[35] WATSON K., PAPAGEORGIOU A., JONES G., TAYLOR S., SYMMONS D., SILMAN A, MACFARLENE G., *Low back pain in schoolchildren: the role of mechanical and psychological factories*, Arch. Dis. Child., 2003, 88 (1), 12–17.

[36] WAWRZYNIAK A., TOMASZEWSKI M., MEWS J., JUNG A., KALICKI B., *Postural defects in children and adolescents as one of the main problems in psychosomatic development*, Pediatria i Medycyna Rodzinna, 2017, 13 (1), 72–78.

[37] WILCZYŃSKI J., BIENIEK K., *Correlations of somatic traits and postural defects in girls and boys aged 10–12*, Acta Bioeng. Biomech., 2019, 21 (1), 79–86.

[38] WU G., MACLEOD M., *The control of body orientation and centre of mass location under asymmetrical loading*, Gait and Posture, 2001, 13, 95–101.

[39] ZHANG Y. et al., *Effects of non-psychical factors on neck and shoulder pain and low back pain of adolescents*, Zhonghua Yi Xue Za Zhi, 2014, 94 (37), 2923–2928.

[40] ŻUK B., *Nawyki nieprawidłowej postawy ciała uczniów VI klasy szkoły podstawowej, konieczność reedukacji*, Nowiny Lekarskie, 2008, 77 (2), 114–119 (in Polish).