The Effect of a School Backpack Mass Back Carried on the Features of Body Posture in the Frontal Plane of 7-year-old Students of Both Sexes

Mirosław Mrozkowiak
Physiotherapy Practice AKTON
Marta Stępień-Słodkowska (marta.stepien-slodkowska@usz.edu.pl)
University of Szczecin

Research Article

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Abstract

Background

The lifestyle of children has a significant impact on the future health of the whole society. Therefore, health education, prevention and monitoring of health determinants is important at every stage of ontogenesis. This requires a thorough knowledge of the schoolchild's environment, perceived as a wide set of stressors, including not only genetic but also epigenetic factors. One of them is the issue of the correct and abnormal body posture at school and on the way there.

Method

Body posture tests were carried out in a group of 65 students aged 7 years, using the projection moiré method in 4 positions: 1-habitual posture, 2-posture after 10-minute of asymmetric axial load, 3-a posture after one minute of the load removal, 4- a posture after two minutes of the load removal. Physical fitness was measured with the Sekita test.

Results

The significance of differences between the 1st and 2nd measurements was analyzed to determine the impact of the backpack load and the correlation with physical fitness, and to study its influence on the value of the differences in posture features.

Conclusions

Carrying school supplies on the back induces significant changes in the value of the features describing the body posture in the frontal plane. It should be assumed that the greater the weight of the container and, carrying time and intensity of physical effort is the greater the changes will be. Relatedly, it is not recommended to carry school supplies weighing more than 4 kg by first-grade students.

Physical fitness has a various and sex-dependent influence on the value of changes in body posture features because of carrying school supplies. Among boys it significantly affects the asymmetry of the torso bend, shoulder height, the waist triangles height and width, whereas among girls it affects the asymmetry of the shoulders and the distance of the angles of the lower shoulder blades from the line of the spinous processes of the spine. Among boys the changes in the value of posture features are mostly influenced by endurance and speed, but strength, power and agility are of lower influence, whereas among girls only agility matters.

Background

The student's environment plays a significant role in the development of biomechanical disorders of body posture. Both school and home should support the student in their pursuit of cultivating a healthy lifestyle according to Cendrowski’s set of ten principles [1]. One of the strategic goals of the project of the

National Health Program in Poland in 2007-2015 was to "reduce premature morbidity and reduce the negative effects of chronic diseases of the articular system". In order to achieve this goal, the work, study and leisure environments were modified to promote health. The determinants of health are well described by the French concept from 1991, which divides them into six groups: natural (geographic) environment, demographic, socio-economic, psycho-cultural, political and administrative, related to the organization and functioning of the health care system. In the case of a student, it will be a place to study in the classroom and at home inadequate to the physical conditions, often improper carrying of excessive school supplies, a resting position and a sedentary lifestyle. The Health Behavior in School aged Children report on children's health in Europe shows that the number of factors contributing to the development of bad posture increased significantly in the last decade. The authors of the report state that only every fourth of 11-year-olds and every sixth of 15-year-olds reaches the recommended volume, intensity and frequency of preventive physical activity. There was also a regress in the percentage of children who spend time passively in front of the TV in favor of dexterity computer games. As they further forecast, this time whereby will prolong due to the more frequently introduced e-textbooks [2]. Hong et al., after measurements carried out in a group of 410 boys aged 10 years, looked for relationships between the quality of body posture and the weight of the backpack carried without a load with 10%, 15%, 20% of body weight. There were no significant dysfunctions in body posture and gait when the weight of the backpack was 10% of the body weight. However, when the weight was 15% and 20% of the body weight, there was a statistically significant increase in the torso bend angle in the sagittal plane [3]. According to Polish Chief Sanitary Inspectorate’s recommendations regarding the proper choice and manner of carrying school items, a schoolbag cannot weigh more than 10-15% of the body weight and should be carried on both shoulders. There should be a stiffened support touching the back and with equal wide straps, and the heavier items should be placed on the bottom of the backpack whereas the lighter ones higher [4].

The author's interest in the issues stems from the persistently high percentage of static disorders in body posture of students in the oldest preschool group and grades 1st -3rd of primary school. The author also pays attention to a constantly proclaimed opinion about the negative impact of the way of carrying school items on the statics of body posture, and the lack of clear recommendations on the optimal contraindication. The goal of the implemented program was an attempt to determine the impact of the loading weight of carried school supplies in the following way: on the left or right shoulder with the left or right hand, on the chest, on the back and chest, obliquely on the left shoulder and at the right hip, and obliquely on the right shoulder and left hip. The partial goal is to show the influence of the weight of the back carried container with school supplies on body posture.

Methods

Research material

Children who participated in the study were from randomly selected kindergartens of the West Pomeranian and Greater Poland voivodships. Bad body postures and disorders were not a criterion excluding the participation in the research programme. The division of the respondents into rural and urban environments was abandoned because this feature will never determine the homogeneity of the group and the blurring of the cultural and economic boundary of both environments. The programme was qualified according to the scheme: if the subject was 6 years, 6 months and 1 day old and was under 7 years, he was included in the 7-year-old age group. This allowed to use the previously developed normative scopes appropriate for this age and sex category, diagnosing the quality of body posture found at the day of the examination [5]. In total, 65 students participated in the programme, of whom 53.84% (35 people) were girls and 46.15% (30 people) were boys. The average body weight among girls was 24.46 kg, the body height was 123.87 cm, and among boys: 24.56 kg and 123 cm, adequately. All children had a slender body type according to Rohrer's weight-growth index [6].

Research method

The research was carried out in accordance with the principles of the Declaration of Helsinki, and the consent for their implementation was obtained from the student and his legal guardian, the tutor and the kindergarten management and the bioethical committee (KEBN 2/2018, UKW Bydgoszcz). The research started on the 27th of May 2019, and always were conducted from 9.00 a.m. to 2.00 p.m. in the properly prepared same room. On the first day, all children were introduced with the purpose and course of the research. The children were also encouraged to keep the anthropometric points marked with a marker pen on the skin. A preschool teacher’s assistant of the study group was always present during the measurements, to ensure the children’s emotional stability. During the research, the adopted rules of the research procedure were followed.

General physical fitness

The Wroclaw Physical Fitness Test for 3-7-year-old children was used to diagnose the children’s physical fitness [7]. According to the author, the test has a high degree of reliability and is adequate in terms of discriminatory strength and difficulty level [8]. The proposed test consists of four trials carried out as part of the Sports Day, which significantly increased the motivation to exercise in the presence of parents: agility (pendulous run with carrying blocks at 4x5 m distance), strength (long jump), speed (running at 25 m distance), force (both hands overhead throw with a 1 kg ball). The author modified the test by adding a fifth attempt - endurance. Starting position - high starting stance. Movement - run at 300 m. The running race time from start to finish line was converted into points depending on the gained score and gender. If a child did not finish the race, the score was nil. The run took place on a fitness trail with a hardened surface in compliance with all safety standards [9].

Body posture

One of the most objective methods for diagnosing body posture is the photogrammetric method used in the research. It enables to determine the impact of various methods of carrying a container with school items on body posture, restitution of the values of the features after the load removal and the importance of physical fitness in disorders and restitution of the diagnosed values of the features.

Any loading of body posture was provided by the constructed diagnostic frame (utility design protection right no. W.125734). The presence of the assistant during the examination was dictated by the need to minimize the time from the load removal to second registration of the values of the posture features. Every effort has been made to ensure that the weighted frame is individually adapted to the type of a child's build. The adopted 10-minute load time was the average time to go from the place of living given in the questionnaire completed by the parents [10]. On the other hand, the load mass was determined by averaging the weight of school items carried by 1st grade children from a randomly selected primary school with the burden of 4 kg. Selected features of body posture were measured in 8 positions, 4 for each way of carrying. The first position - habitual position, pic. 1. Second position - posture after 10 minutes of asymmetric oblique loading (in the last 5 seconds), pic. 2. Third position - posture one minute after the load removal, pic. 1. Fourth position - posture two minutes after the load removal, pic. 1. The load was supposed to imitate the way of carrying school supplies. The subject could move freely. Thereby, there were attempts made to exclude the overlapping of postural muscle fatigue from one position to another during the examination. This is in line with the results of Mrozkowiak's research, which shows that after this time the features can take the initial values [11]. The children’s height and weight as well as the weight of the carried school supplies were measured with a medical balance before the first day of the tests.

The measuring station for the selected values of body posture features consists of a computer and a card, a programme, a monitor and a printer, a projection-receiving device with a camera for measuring selected parameters of the pelvis-spine syndrome. The place and the camera of a subject were oriented spatially in accordance with the camera's contours and in relation to the line of a child's toes. It is possible to obtain a spatial image with the lines projection on a child's back with strictly defined parameters. The lines falling on the body are distorted depending on the configuration of the surface. The lens usage enables the image of the examined person to be taken by a special optical system with a camera, and then transferred to the computer monitor. Line image distortions recorded in the computer memory are processed by a numerical algorithm into a contour map of the tested surface. The obtained image of the back surface enables a multistranded interpretation of the body posture. Apart from the assessment of the torso asymmetry in the frontal plane, it is possible to determine the values of the angular and linear features describing the pelvis and physiological curvatures in the sagittal and transversal planes. The most important aspect of this method is the simultaneous measurement of all real values of the spatial location of individual body sections [12, 13]. Due to the methodology of the research, the examination of a child standing on a strain gauge mat was abandoned [14].

To minimize the risk of making mistakes in the measurements of selected posture features, the following test procedure was developed [5, 13, 14]:

1. Habitual posture of the subject against the background of a white slightly lighted sheet: free unforced posture, with feet slightly apart, knee and hip joints in extension, arms sagging along the body and eyes directed straight ahead, backwards to the camera at 2.5 meters with toes at a perpendicular line to the camera axis.

2. Marking points on the back skin of the examined: the tip of the spinous process of the last cervical vertebra (C_7), the spinous process being the top of the thoracic kyphosis (KP), the spinous process being the top of the lumbar lordosis (LL), the transition from thoracic kyphosis to lumbar lordosis (PL), the lower angles of the shoulder (Łl and Łp), the posterior upper iliac spines (M1 and Mp), the S_1 vertebra. A white necklace was put around the subject's neck to clearly mark points B_1 and B_3. Long hair was bound to reveal the C_7 point.
3. After registration of the necessary data about the examined (name and surname, year of birth, weight and body height, comments: about the condition of the knees and heels, chest, past injuries, surgical procedures, diseases of the musculoskeletal system, walk, etc.), the digital image of the back was recorded in the computer memory in each of the four positions from the middle phase of free exhalation.
4. Processing of the recorded images takes place without the participation of the subject.
5. After saving the mathematical characteristics of the photos in the computer memory, the values of the body posture features that describe spatially the posture are printed, Fig. 1.
Subject of research

The Wrocław fitness test made it possible to measure the strength, power, speed and agility of preschool children. The author modified Sekita's test with a test of endurance. Definitions of the examined physical and complex motor skills are generally available in the literature on the subject.

The measuring device used in the test determines several dozen features describing the body posture. Sixteen angular and linear features of the spine were selected altogether with pelvis and torso in the frontal plane, as well as the body weight and height for statistical analysis. There was a need for the most reliable and spatially complete look at the child's body posture, which allowed for full identification of the measured discriminants, Tab. 1.

Table 1
List of registered torso and morphological features

No.	Symbol	Parameters		
		Label	**Name**	**Description**
Frontal plane				
1	KNT -	degrees	The angle of the torso bend to the side	It is determined by the deviation of the C_7-S_1 line from the vertical to the left.
2	KNT	degrees		It is determined by the deviation of the C_7-S_1 line from the vertical to the right.
3	KLB	degrees	The angle of shoulders line, where the right one is higher	The angle between the horizontal and the straight line going through the B2 and B4 points. PLBW=LBW-PBW
4	KLB –	degrees	The angle of shoulders line, where the left one is higher	
5	UL	degrees	The angle of shoulder blades, where the right one is higher	The angle between the horizontal and the straight line going through the Ł1 and Łp points.
6	UL -	degrees	The angle of shoulder blades, where the left one is higher	
7	OL	mm	The lower, more distant angle of the left shoulder blade	The difference in the distance of the lower angles of the shoulder blades from the line of the spinous processes of the spine, measured horizontally at the straight lines going through the Łl and Łp points.
8	OL -	mm	The lower, more distant angle of the right shoulder blade	
9	TT	mm	The left waist triangle is higher	The difference in the distance measured vertically between the T_1 and T_2 points and between T_3 and T_4 points. PLTT = LTT − PTT
10	TT –	mm	The right waist triangle is higher	
11	TS	mm	The left waist triangle is wider	The difference in the distance measured horizontally between the straight lines going through the T_1 and T_2 points and T_3 and T_4 points.
Source: own research				

No.	Symbol	Parameters		
		Label	Name	Description
12	TS -	mm	The right waist triangle is wider	
13	KNM	degrees	The pelvic tilt angle, the right ala of ilium is higher	The angle between the horizontal and straight line going through the M1 and Mp points.
14	KNM -	degrees	The pelvic tilt angle, the left ala of ilium is higher	
15	UK	mm	The maximum deviation of the spinous process of the vertebra to the right	The greatest deviation of the spinous process from the vertical coming from S_1. The distance is measured on the horizontal axis.
16	UK -	mm	The maximum deviation of the spinous process of the vertebra to the left	
Morphological features				
17	Mc	kg	The body weight	The body height and body weight were measured on an electronic medical balance
18	Wc	cm	The body height	
Source: own research				

Research questions and hypotheses

There are following research questions based upon the aim of the research:

Does the accepted way of carrying the school items significantly affect the value of the body posture features in the frontal plane and do these disorders depend on gender?

Does physical fitness show a significant relationship with the value of posture disorders and is this relationship dependent on gender?
Can the way of carrying school supplies be recommended to 7-year-old children?
Our own research results and the analysis of the available literature suggest that:

There are significant differences between the values of the features of habitual body posture and posture influenced by asymmetric load. The differences will be greater among girls than among boys.

In the adopted way of carryting the school supplies, deficiencies in body posture are mostly influenced by general fitness. The differences will be less visible among children with greater physical fitness.

The adopted way of carrying school supplies weighing 4 kg is not recommended for 7-year-old children because of significant disorders in body posture features.
Statistical methods

It was assumed that the standard deviation is a measure of differentiation. The higher it is in relation to the mean, the greater the variation of results in each group is. In analytical practice, it is a measure being incidental to the arithmetic mean, but in this study, it has no interpretative value. Therefore, for the sake of greater clarity, the reference to SD has been abandoned. They are only presented in the initial tables (where M was also given) as a formality. The value of SD in the analysis performed is not interpreted, especially as the analysis is based on non-parametric tests and the median (Me), but not on the mean (M). Therefore, D and M were finally removed to concentrate the tables and leave there only what is needed for the research.

The analysis of the research results was performed using the IBM SPSS Statistics 26 programme. At the initial stage, the Shapiro-Wilk and Kołmogorow-Smirnow tests were used to check, whether the distributions of the analyzed variables were consistent with the normal distribution. In the case of majority of the variables, there were statistically significant deviations from the normal distribution at the level of $p < 0.05$. Therefore, it was decided to use tests and nonparametric factors in the statistical analysis. The Wilcoxon's rank test was used to determine, whether there is a statistically significant difference (change) between two measurements (in the same group) of a ratiometric variable, which distribution is significantly different from the normal one. The following symbols are used in the tables: M - arithmetic mean, Me - median, SD - standard deviation, Z – Wilcoxon's test statistic, "p" – Wilcoxon's test significance. The level of significance was set at $p < 0.05$ marked as *, and additionally the significance level $p < 0.01$ marked as **. If there is $p < 0.05$ or $p < 0.01$, then the difference between the measurements is statistically significant. The Spearman's rho correlation factor was used to determine, whether there are statistically significant correlations between the variables measured at the ratiometric level, which distribution significantly differs from the normal one. If the correlation is statistically significant at the level of $p < 0.05$, then the correlation rho factor should be interpreted. It can take values from -1 to +1. The more distant it is from 0, and the closer it is to -1 or +1, the stronger the correlation is. Negative values mean that as the value of one variable increases, the value of the other variable decreases. On the other hand, positive values indicate that as the value of one variable increases, the value of the other variable increases, too. In the individual tables of correlation, only the variables (in the lines) were considered, for which at least one statistically significant result was recorded.

Individual values of posture features are expressed in different values and ranges, so it is not possible to calculate the average difference for all these variables between these two measurements. An analysis performed in such a way would distort the results and make the variables, in which the values are higher, of greater importance and the variables, in which the values were lower, of less importance. Therefore, the correlation between the averaged difference in the values of features between measurements and physical fitness was made separately for girls and boys, using absolute values. There were not used exact numerical values concerning the differences in the calculations, but the ratio of the difference to the initial value. This approach causes that none of the variables are overrepresented or underrepresented in the average result.

The analysis included a comparison of the volume of posture features between the 1st and 2nd measurement, separately for girls and boys. It was aimed at showing significant changes in the volume of posture features in the adopted way of carrying school supplies. To concentrate the results of the analysis as much as possible, the tables contain only the medians and the significance of the Wilcoxon's test results. An analysis of the correlation between the results of physical fitness tests and the difference between the 1st and 2nd measurement separately for boys and girls was also performed. Only those subjects who had both physical fitness tests and appropriate measurements of body posture were considered.

Results

In total, the research carried out in a group of 65 people of both sexes allowed for the registration of 5005 values of features describing body posture in a habitual posture and dynamic positions, body weight and height, and physical fitness.

Considering the differences in the volume of posture features among boys between the 1st and 2nd measurement, the Wilcoxon's rank test showed a statistically significant difference in the range of all analyzed variables, except for the torso bend angle to the right (KNT +). where no statistically significant change was noted, Tab. 2. A statistically significant difference in the volume of all analyzed variables was observed among the girls, Tab. 3.

Table 2
Significance of differences in the value of posture features in the frontal plane between 1st and 2nd measurement with the back loading among boys

No	Variables	Measurement 1			Measurement 2			Wilcoxon's Test	
		M	Me	SD	M	Me	SD	Z	p
1	DCK	308,98	314,05	22,87	290,72	292,65	21,15	-4,782	<0,001**
2	Alfa	8,28	8,45	1,52	4,82	4,85	2,10	-4,783	<0,001**
3	Beta	9,90	9,75	1,13	21,76	21,70	1,17	-4,785	<0,001**
4	Gamma	11,10	11,20	1,19	9,10	9,00	1,16	-4,788	<0,001**
5	Delta	29,28	29,65	2,45	35,69	35,40	2,70	-4,785	<0,001**
6	KPT-	3,74	4,15	1,34	5,72	6,40	1,59	-3,929	<0,001**
7	KPT+	4,40	4,75	0,69	15,43	16,50	2,32	-2,807	0,005**
8	DKP	278,15	279,00	8,96	269,48	273,10	20,01	-4,785	<0,001**
9	KKP	159,04	159,00	1,55	149,14	148,90	1,63	-4,785	<0,001**
10	RKP	185,63	185,30	13,49	181,28	180,50	13,68	-4,389	<0,001**
11	GKP	20,26	19,95	1,40	15,43	15,35	1,69	-4,786	<0,001**
12	DLL	246,61	247,00	11,98	242,15	242,90	12,20	-4,785	<0,001**
13	KLL	161,82	161,95	2,22	153,42	153,35	2,52	-4,784	<0,001**
14	RLL	134,86	135,60	11,07	130,68	131,55	10,78	-4,785	<0,001**
15	GLL	23,44	24,45	3,19	32,84	32,65	3,36	-4,788	<0,001**
16	KNT-	1,56	1,40	1,04	2,61	2,25	1,03	-4,116	<0,001**
17	KNT+	2,04	2,35	1,50	3,83	4,10	1,88	-2,524	0,012**
18	KLB-	2,60	1,90	1,64	4,31	4,00	1,31	-2,527	0,012**
19	KLB+	1,60	1,05	1,39	3,02	2,70	1,59	-4,112	<0,001**
20	UL-	3,01	4,15	2,30	4,35	5,30	2,29	-2,527	0,012**
21	UL+	2,43	1,95	1,59	3,74	3,55	1,39	-4,078	<0,001**
22	UB-	2,70	3,30	1,96	3,90	4,75	1,85	-2,536	0,011**
23	UB+	3,79	4,00	2,64	5,21	5,05	2,69	-4,079	<0,001**
24	OL-	8,89	8,10	5,71	10,52	10,15	5,64	-4,111	<0,001**

Source: own research

No	Variables	Measurement 1			Measurement 2			Wilcoxon's Test	
		M	Me	SD	M	Me	SD	Z	p
25	OL+	4,16	4,30	2,55	5,61	5,25	2,77	-2,527	0,012**
26	TT-	5,44	4,80	2,05	7,56	6,85	2,12	-2,521	0,012**
27	TT+	8,95	8,30	4,38	10,98	10,35	4,31	-4,110	<0,001**
28	TS-	5,74	5,10	1,63	8,11	7,70	1,32	-2,530	0,011**
29	TS+	8,44	8,35	4,99	10,44	10,20	4,83	-4,113	<0,001**
30	KNM-	6,29	7,50	3,48	8,38	8,80	3,56	-4,024	<0,001**
31	KNM+	3,62	3,40	2,36	5,78	5,60	2,47	-2,677	0,007****
32	KSM-	3,19	2,45	2,78	4,66	4,20	2,89	-2,524	0,012**
33	KSM+	5,68	5,50	2,87	7,95	7,75	2,67	-4,110	<0,001**
34	UK-	2,69	1,50	2,15	4,79	4,05	2,05	-2,527	0,012**
35	UK+	8,03	6,95	5,33	9,74	9,20	5,23	-4,110	<0,001**
Source: own research									

Table 3

Significance of differences in the value of posture features in the frontal plane between 1st and 2nd measurement with the back loading among girls

No	Variables	Measurement 1			Measurment 2			Wilcoxon's Test	
		M	Me	SD	M	Me	SD	Z	p
1	DCK	308,98	314,05	22,87	290,72	292,65	21,15	-4,782	<0,001**
2	Alfa	8,28	8,45	1,52	4,82	4,85	2,10	-4,783	<0,001**
3	Beta	9,90	9,75	1,13	21,76	21,70	1,17	-4,785	<0,001**
4	Gamma	11,10	11,20	1,19	9,10	9,00	1,16	-4,788	<0,001**
5	Delta	29,28	29,65	2,45	35,69	35,40	2,70	-4,785	<0,001**
6	KPT-	3,74	4,15	1,34	5,72	6,40	1,59	-3,929	<0,001**
7	KPT+	4,40	4,75	0,69	15,43	16,50	2,32	-2,807	0,005**
8	DKP	278,15	279,00	8,96	269,48	273,10	20,01	-4,785	<0,001**
9	KKP	159,04	159,00	1,55	149,14	148,90	1,63	-4,785	<0,001**
10	RKP	185,63	185,30	13,49	181,28	180,50	13,68	-4,389	<0,001**
11	GKP	20,26	19,95	1,40	15,43	15,35	1,69	-4,786	<0,001**
12	DLL	246,61	247,00	11,98	242,15	242,90	12,20	-4,785	<0,001**
13	KLL	161,82	161,95	2,22	153,42	153,35	2,52	-4,784	<0,001**
14	RLL	134,86	135,60	11,07	130,68	131,55	10,78	-4,785	<0,001**
15	GLL	23,44	24,45	3,19	32,84	32,65	3,36	-4,788	<0,001**
16	KNT-	1,56	1,40	1,04	2,61	2,25	1,03	-4,116	<0,001**
17	KNT+	2,04	2,35	1,50	3,83	4,10	1,88	-2,524	0,012**
18	KLB-	2,60	1,90	1,64	4,31	4,00	1,31	-2,527	0,012**
19	KLB+	1,60	1,05	1,39	3,02	2,70	1,59	-4,112	<0,001**
20	UL-	3,01	4,15	2,30	4,35	5,30	2,29	-2,527	0,012**
21	UL+	2,43	1,95	1,59	3,74	3,55	1,39	-4,078	<0,001**
22	UB-	2,70	3,30	1,96	3,90	4,75	1,85	-2,536	0,011**
23	UB+	3,79	4,00	2,64	5,21	5,05	2,69	-4,079	<0,001**

Source: own research

No	Variables	Measurement 1			Measurment 2			Wilcoxon's Test	
		M	Me	SD	M	Me	SD	Z	p
24	OL-	8,89	8,10	5,71	10,52	10,15	5,64	-4,111	<0,001**
25	OL+	4,16	4,30	2,55	5,61	5,25	2,77	-2,527	0,012**
26	TT-	5,44	4,80	2,05	7,56	6,85	2,12	-2,521	0,012**
27	TT+	8,95	8,30	4,38	10,98	10,35	4,31	-4,110	<0,001**
28	TS-	5,74	5,10	1,63	8,11	7,70	1,32	-2,530	0,011**
29	TS+	8,44	8,35	4,99	10,44	10,20	4,83	-4,113	<0,001**
30	KNM-	6,29	7,50	3,48	8,38	8,80	3,56	-4,024	<0,001**
31	KNM+	3,62	3,40	2,36	5,78	5,60	2,47	-2,677	0,007****
32	KSM-	3,19	2,45	2,78	4,66	4,20	2,89	-2,524	0,012**
33	KSM+	5,68	5,50	2,87	7,95	7,75	2,67	-4,110	<0,001**
34	UK-	2,69	1,50	2,15	4,79	4,05	2,05	-2,527	0,012**
35	UK+	8,03	6,95	5,33	9,74	9,20	5,23	-4,110	<0,001**
Source: own research									

Table 4
Correlations between physical fitness and the difference in the value of posture features in the frontal plane between the 1st and 2nd measurement with the back loading among boys n = 30

Variables	**The difference beeween 1st and 2nd measurment**					
	WY	**SZ**	**SI**	**MO**	**ZW**	**OG**
KNT-	0,25	0,27	0,18	0,30	0,13	0,24
KNT+	-1,00**	1,00**	-1,00**	-1,00**	-1,00**	-1,00**
KLB-	-1,00**	1,00**	-1,00**	-1,00**	-1,00**	-1,00**
UL-	0,23	0,14	0,51	0,22	-0,14	0,13
OL-	0,71**	0,58*	-0,05	-0,24	-0,07	0,09
OL+	0,24	0,17	0,10	-0,50	0,18	0,11
TT-	1,00**	-1,00**	1,00**	1,00**	1,00**	1,00**
TT+	0,43	0,47	0,13	-0,46	0,17	0,22
TS-	-1,00**	1,00**	-1,00**	-1,00**	-1,00**	-1,00**
TS+	-0,26	-0,01	0,44	0,50	-0,02	0,31
KNM-	-0,04	-0,15	-0,04	0,36	-0,15	-0,04
UK-	0,10	-0,18	0,21	0,22	0,17	-0,20
Source: own research						

Analyzing the correlation of differences between the 1st and 2nd measurement and the Sekita's test results among boys, it turned out that the greater the endurance is, the smaller the differences in the torso bend angle to the right are (KNT +) and the shoulders line angle is, where the left one is higher (KLB-) and the smaller the asymmetry of width of the waist triangles is, where the right one is wider (TS-), and the greater one at a distance from the angles of the lower shoulder blades to the line of the spinous processes of the spine, where the angle of the left shoulder blade is more spaced (OL-) and the height of the waist triangles, where the right one is higher (TT-). The higher the speed is, the smaller the height asymmetry of the waist triangles is, where the right one is higher (TT-), and the greater the differences in the torso bend angle to the right are (KNT +), the angle of the shoulders line, where the left one is higher (KLB-) and the greater the asymmetry in the distance of the lower angles of the shoulder blades from the line of the spinous processes of the spine, where the angle of the left shoulder blade is more spaced (OL-) and the width of the waist triangles where the right one is wider (TS-). The greater the strength is, the smaller the differences in the angle of the torso bend to the right are (KNT +), the angle of the shoulders line where the left one is higher (KLB-), -) and the smaller the asymmetry in the width of the waist triangles is, where the right one is wider (TS-) and the greater the height of waist triangles is where the right one is higher (TT-). The greater the power is, the smaller the differences in the torso bend angle to right are (KNT +), the shoulders line angle, where the left one is higher (KLB -), -), the smaller the asymmetry in the width of the waist triangles is, where the right one is wider (TS-), and the greater the height of waist triangles is, where the right one is higher (TT-). The greater the agility is, the smaller the differences in the angle of the torso bend to the right are (KNT +), the angle of the shoulders line, where the left one is higher (KLB-), the smaller the asymmetry of the width of the waist triangles is, where the right one is wider (TS-), and the greater the height of the waist triangles is, where the right one is higher (TT-). The greater the general fitness is, the smaller the differences in the torso bend angle to the right are (KNT +), the angle of the shoulders line, where the left one is higher (KLB-) and the smaller the asymmetry in the width of the waist triangles is, where the right one is wider (TS-) and the greater the height of the waist triangles where the right one is higher (TT-), Tab. 4. The correlation analysis among girls shows that the greater the agility is, the smaller the difference in the angle of the shoulders line is, where the right shoulder blade is higher (KLB +), and the greater the asymmetry of the distance of the lower shoulder blades angles from the line of the spinous processes of the spine is, where the angle of the left shoulder blade is more spaced (OL-), Tab. 5.

Table 5

Correlations between physical fitness and the difference in the value of posture features in frontal plane between the 1st and 2nd measurement with the back loading among girls n = 35

Variables	**The difference between 1st and 2nd measurment**					
	WY	**SZ**	**SI**	**MO**	**ZW**	**OG**
KLB+	-0,15	-0,08	-0,70	0,56	-0,79*	-0,53
UL+	-0,21	-0,45	-0,14	-0,46	-0,08	-0,33
OL-	0,16	0,00	0,67	-0,42	0,76*	0,54
TT+	0,47	0,61	0,22	0,00	0,31	0,29
TS-	-0,50	0,20	-0,16	-0,22	-0,30	-0,30
TS+	0,22	0,30	-0,26	0,18	-0,20	-0,11
KNM+	0,74	0,05	0,36	0,35	0,53	0,53
Source: own reasearch						

Discussion

Romanowska [15] and Mrozkowiak [11], based on the results of studies in a smaller group of adolescents, attempted to describe changes influenced by the student's posture loaded with an external load. The authors in their investigations came to very similar conclusions. The six-kilogram symmetrical load of the upper limb girdle in 12-year-old girls caused no significant changes in the value of selected posture features. Mrozkowiak [11] showed a complete restitution of the value of the diagnosed features two minutes after the load removal. The return to the initial value after the first minute was more intense. The author also concluded that symmetrically distributed load has little effect on the spine-pelvic syndrome in the frontal plane, including right-hand scoliosis at the Th3 level. Mrozkowiak [16] in his research on the effects of loading with school supplies in the left or right hand drag mode of the body posture in the frontal plane of a 7-year-old student showed that the increased load causes significant changes in the value of selected body posture features among girls and boys. He believes that the greater the weight of the container, the carrying time and the intensity of manual effort is the grater the changes will be. Therefore, this way of carrying school supplies by first-grade students should not be recommended. He also proved that there is a various relationship with the values of changes in body posture with the level of general physical fitness. This relationship is more common among boys than among girls and only with the right hand drag mode. Considering individual abilities, among boys there are relationships with significant differences in the value of posture features like speed, power, endurance and agility, and among girls there is strength additionally. Mrozkowiak [17] made a different analysis of the same results to answer the question, which of the ways of carrying disturbs the child's habitual posture less? It turned out that there was simultaneously significant and negative disturbance in the posture stability caused by the left and right hand drag mode. The author believes that it may cause disorders and, consequently, defects in body posture in the long term. Therefore, neither of them should be recommended. The author also claims that general physical fitness has a greater positive significance in disorders of biomechanical body posture statics among boys than girls. Its relationships with particular features are similar in both modes of carrying among boys, whereas among girls greater relationships occur in the case of right-hand drag mode. The most significant motor skills among boys are endurance and strength, and among girls, speed and power. The restitution value of any of the analyzed features of body posture was not complete after 1 and 2 minutes when right or left hand drag mode stopped. This proves insufficient physical fitness, its laterality and slower restitution. The author's survey among parents of 7-year-old preschoolers shows there is the guardians' awareness about their children's health. They believe that a first grader will carry a four-kilogram schoolbag on their back, learn traditionally (not via online learning) and spend about 2 hours improving their physical fitness. According to the author, the accepted lifestyle will not improve physical fitness and prevent statics posture disorders [10].

According to Grimmer et al. carrying various loads by school children and adolescents can result in fatigue, muscle pain, back and shoulder pain, hand numbness, and in extreme cases, spine injury [18]. Research by Skoffer [19] and Grimmer et al. [20] showed that 50% of teenagers feel pain in the spine, which is caused by carrying various containers with school supplies. Studies by Negrini [21], Pau [22] and Heler [23] have shown that children's postural stability disrupted with an additional load in the form of a backpack may lead to impaired postural control, thus increase the risk of falls and an advance occurrence of back pain. The results of Pau's work indicate significant changes on postural features influenced by additional load in terms of swaying, the maximum range of deflection, the length of the COP path (center of foot pressure) and the posturogram envelope [22].

Adams' research indicates a significant influence of the shifted tightening loads on changes occurring in a single kinesthetic segment of the spine [24]. Pain associated with carrying a backpack are known as the so-called backpack syndrome. The syndrome includes the following factors: abnormal body posture causing headaches, fatigue, pain in the cervical and lumbar spine, and increased muscle tension in the neck, shoulders and back [25, 26].

The statistical analysis of the obtained measurements of selected posture features clearly shows that the method of transporting a backpack with school accessories weighing more than 4 kg should not be practiced by 7-year-old children because it significantly disturbs its habitual stability in the frontal plane. It should be assumed that the longer and more intensive the analyzed mode of transport, and the greater the mass of utensils, the more significant the adaptive changes will be. The age of the surveyed students is also important. The student's environment will influence the ongoing posturogenesis in accordance with the Arndt-Schultz law. The physical fitness presented by children and the relationship between its individual elements and the differences in the size of the posture features has a different and gender-dependent meaning. Larger among boys, very small among girls. Among boys, significant and the most common occur with endurance, speed and general fitness, smaller with strength, power and agility, among girls with agility and small with total efficiency, Fig. 2. Among boys, the weight of the backpack significantly and most often disturbs the verticality of the torso (KNT +), the symmetry of the height of the shoulders (KLB-), the distance of the lower shoulder blades angles from the line of the spinous processes of the spine (OL-), the height (TT-) and width (TS-) of the waist triangles, and among girls symmetry of the shoulder height (KLB +) and the distance of the lower shoulder blades angles from the line of the spinous processes of the spine (OL-), Fig. 3.

Conclusions

1. Carrying school supplies on the back causes significant changes in the value of the features describing the body posture in the frontal plane. It should assumed that the greater the weight of the container, the transport time and the intensity of the effort physical is, the greater the changes will be. Therefore, carrying school supplies should not weigh more than 4 kg by first-graders.
2. Physical fitness has a diversified and sex-dependent influence on the value of the changes in body posture features under the influence of the adopted carrying of school supplies. Among boys it significantly affects the asymmetry of the torso bend, shoulder height, height and width of waist triangles, and among girls the asymmetry of the shoulders and the distance of the lower angles of the shoulder blades from the line of the spinous processes of the spine. Among boys, endurance and speed influence the changes in the value of the body posture features the most, but strength, power and agility less, whereas, among girls only agility matters.

Declarations

Ethics approval and consent to participate

The study was approved by the Bioethics Committee of the Kazimierz Wielki University in Bydgoszcz, Poland (no. KEBN 2/2018).

The consent for research implementation was obtained from the student and his legal guardian, the tutor and the kindergarten management.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

MM and MS designed research; MM conducted research; MM, MS analyzed data; MM and MS wrote the manuscript. MS had primary responsibility for final content. All authors read and approved the final manuscript.

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Authors information

Not applicable.

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Figures

Figure 1

An example of a record sheet of measurements of the posture features of the spine-pelvis syndrome

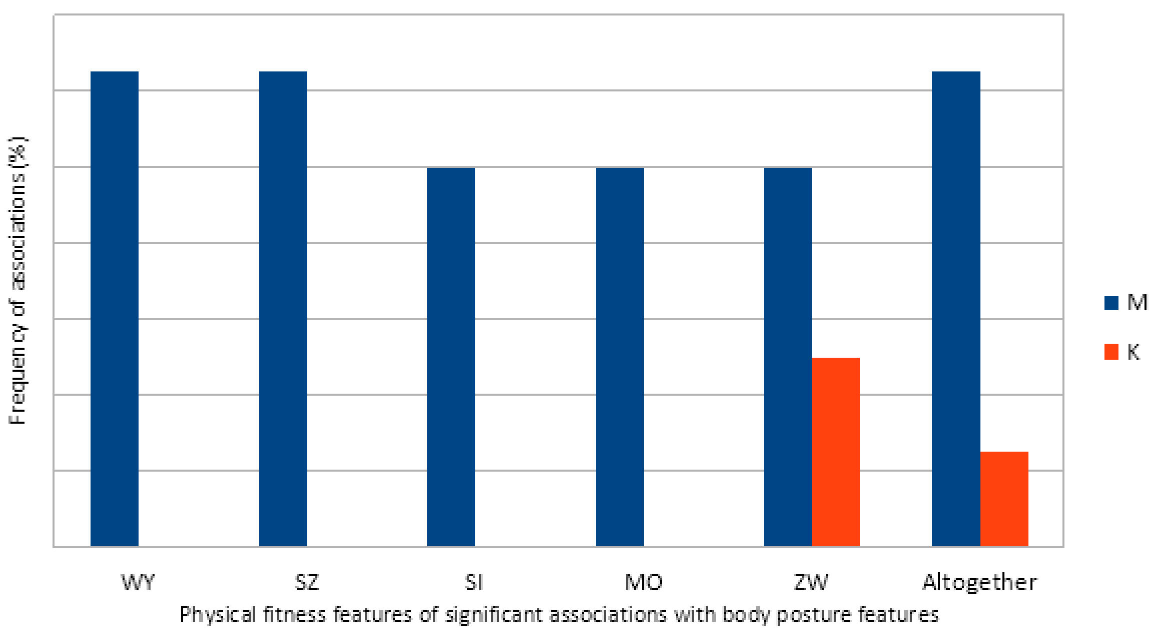

Figure 2

The frequency of significant associations of physical fitness features in the frontal plane with the body posture features among 7-year-old boys and girls n=65 The legend WY: endurance, SZ: speed, SI: strength, MO: power, ZW: agility Altogether – the percentage of physical fitness features of significant associations with body posture features M – boys K – girls

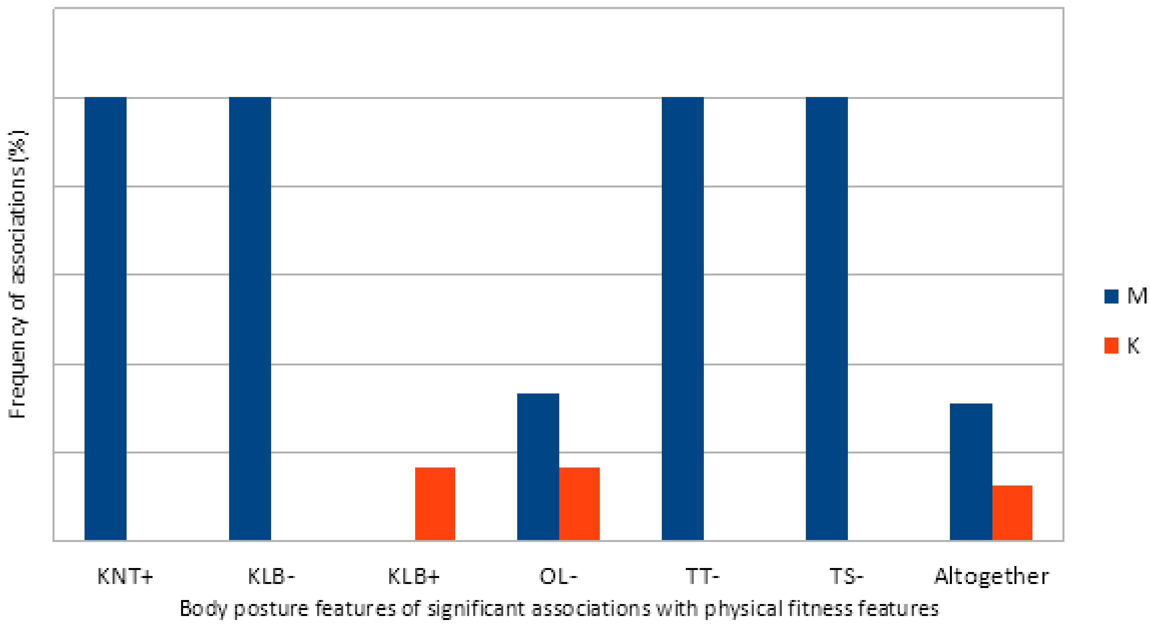

Figure 3

The frequency of significant associations of body posture features in the frontal plane with physical fitness features among 7-year-old boys and girls n=65 The legend WY: endurance, SZ: speed, SI: strength, MO: power, ZW: agility Altogether – the percentage of physical fitness features of significant associations with body posture features M – boys K – girls

Supplementary Files

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- floatimage1.png
- floatimage2.png