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Research Article

The Influence of the Schoolbag's Weight Carried on the Chest on the Body Posture Features in the Frontal Plane and its Correlations with Physical Fitness in 7-Year-Old Children of Both Sexes

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Summary

Introduction: The analysis of the student's environment is a set of stressors in the field of human ecology, which includes not only the genetic factor, but also the epigenetic factor.

Material and Method: The body posture tests were carried out in a group of 65 students aged 7years, using the moiré projection method in 4 positions: 1st-habitual posture, 2nd-posture after a-10-minute loading, 3rd-one minute after the load removal, 4th-two minutes after the load removal. Physical fitness was measured with the Sekita test, completed by an endurance test.

Results: The values of the habitual posture features were analyzed together with a load of a 4-kg backpack after 10minutes of loading to determine the significance of differences in their value and correlation with physical fitness.

Conclusions:

a) School supplies carried on the chest can induce significant adaptive changes in the skeletal and muscular systems. It should be assumed that the longer the carrying time, the greater the weight of the container and the intensity of physical effort the greater the changes. However, the changes are not gender specific. There may be also a disturbance in the range of motion and the respiratory rhythm of the chest.

b) The features of physical fitness show sex-dependent relationships with the values of changes in the of body posture features under the influence of the adapted load. There are also sex-dependent relationships between changes in the values of body posture features and the features of physical fitness. Relationships are much more frequent among boys.

c) It is not recommended to carry a 4-kg schoolbag on the chest by 7-year-old students of both sexes.

Keywords: Children's health, Moiré topography, Physical fitness, Postural asymmetry factor

Introduction

The student's environment, especially home and school one, plays a significant role in the development of biomechanical disorders in body posture. Thus, incorrect position of learning in the classroom and at home, incorrect carrying of the weight of school supplies, resting position, and sedentary lifestyle are the most frequently mentioned ones. Hence, assuring a child hygienic condition during school and home learning, rational time of work and rest with considered time for play and movement inside and outside, as well as full-value nutrition, can significantly reduce the formation and development of defects [1]. The report of the District Sanitary and Epidemiological Station in Zielona Góra shows that out of 34 qualified facilities, 9 of them conducted corrective and compensatory classes, which 1,317 students participated in. The post-inspection recommendations include, inter alia, teaching children by parents to carry backpacks on their backs, not on one shoulder or in their hand, paying attention to the appearance and type of material when buying a satchel, controlling the percentage of the weight of the backpack in relation to the weight of the child [2]. According to Siwek, a child's sedentary lifestyle, low level of physical activity and the weight of a schoolbag lead to back pain syndromes. That's why the right weight of a school bag should be in the range of 7.5-15% of the child's weight. In fact, the highest loads carried by children are in the range of 46-53% of the child's body weight. The consequence of being overloaded by the schoolbag is back pain in adulthood. The back pain affects 56% of primary school children and often affects the cervical and lumbar spine [3]. According to the report of *Wawrzyniak, et al.,* [4], postural defects are a significant health problem in the child population. Due to the observed tendency to limit physical activity in favor of the sedentary one, the problem will increase significantly. It is necessary to implement primary and secondary prophylaxis in order to reduce possible adverse health effects. The conclusions from the considerations of *Kratenova, et al.,* [5] are in line with the Polish recommendations that school age is the most optimal period for carrying out proactive steps to prevent the development of posture defects [5]. Primary prophylaxis completed by secondary one will be an effective and comprehensive action.

The influence of the student's environment on their body posture was investigated by, among others, *Wandycz* [6-10], *Romanowska* [11], *Annetts, et al.,* [12], *Mrozkowiak* [13,14], *Mrozkowiak and Żukowska* [15]. Researchers have usually focused on the role of a school chair and a table in a student's posturogenesis, ignoring the impact of school supplies carried. The author's early research lined this problem out a bit, exploring the impact of the load imitating a schoolbag on changes in selected spatial body posture features and the restitution of the value of the sagittal and frontal features of the spine and pelvis after the load removal [13]. The author's interest in the issues stems from the persistently high percentage of disorders of the body posture of students from the oldest preschool group and 1st-3rd grades of primary school, the constantly proclaimed opinion about the negative impact of the way of carrying school supplies on body postures, and the lack of clear recommendations about the optimal weight and contraindications against the negative way of carrying these utensils. The general objective of the implemented research programme is an attempt to determine the impact of weight of carried school supplies in the following way: obliquely on the right shoulder or left shoulder and at the heteronymous hip, on the left or right shoulder, on the back, on the chest, on the back and chest, dragged with the left or right hand.

The aim of the research is to show the influence of the weight of the container with school supplies carried on the chest on selected body posture features of the frontal plane and the relationship with the physical fitness features.

Research Material

The study involved children from randomly selected kindergartens in the West Pomeranian and Greater Poland voivodeships. Body posture defects and disturbances were not a criterion that excluded participation in the research programme. The division of the respondents into those from rural and urban environments was abandoned since this feature would never determine the homogeneity of the group and the cultural and economic blurring boundary of both environments. The respondent was qualified to the programme according to the following scheme: if the respondent was 6years, 6months and 1day old and under 7years, he was included in the 7-year-old age group. This allowed to use the previously developed normative ranges appropriate for this age and sex category, diagnosing the quality of the body posture from the test day [16-20]. In total, 65 students participated in the programme, of which 53.84% (35 people) there were girls and 46.15% boys (30 people).

Research Method

The research was conducted in accordance with the principles of the Helsinki Declaration. For their implementation, there was consent obtained from the student and his legal guardian, tutor and management of the kindergarten, and bioethics commission (KEBN 2/2018, UKW Bydgoszcz). The research was conducted from May 27th, 2019, always from 9a.m. to 2p.m. and in the same properly prepared place. Before the measurements started, the children were instructed with the research procedure. A preschool teacher's assistant of the study group was always present during the research, which was to ensure the emotional stability of the children. Measurements were carried out in accordance with the developed procedure. The children were also encouraged to keep the anthropometric points marked with a marker on the skin, which was to effectively eliminate deviations in their repeated indication. The research was carried out by a physiotherapist with a 20-year-old experience in the diagnosis of body posture using the moiré projection method.

Overall Physical Fitness

The Wroclaw Physical Fitness Test for 3-7-year-old children was used to diagnose physical fitness [16]. According to the author, the test is of a high degree of reliability and is adequate in terms of discriminatory ability and degree of difficulty [17]. The proposed test, which significantly increased the motivation to exercise in the presence of parents, consists of four tests implemented as a part of the Sports Day: agility (pendulous run over 4x5m with carrying blocks), power (standing long jump), speed (running at 25m), and force (a 1kg ball both-hands-throw from the head). The author modified the test by a fifth attempt-endurance. Starting position-high starting stance. Movement-run over 300m. The running time from the start to finish was assessed and converted into points depending on the result and gender. If the child did not finish the race, they got score “0”. The run took place on a recreational path with a hardened surface, remaining all safety rules [18] Visualization [19].

Body Posture

The applied method using the projection moiré phenomenon determines the value of several dozen features describing the body posture. It makes it possible to determine the influence of various methods of carrying a bag with school supplies on body posture, restitution of the value of features after removing the load, and the importance of physical fitness in disorders and restitution of the value of the diagnosed features [20,21].

A custom-designed diagnostic frame was provided to ballast the body posture (utility model no. W.125734) Picture 1. The presence of an assistant during the examination was dictated by the need of minimizing the time from the load removal to the second registration of the value of the posture features. Every effort has been made to ensure that the custom-designed loaded frame was individually adapted to the type of child’s body structure. The adopted 10-minute load time was the average time to walk from the place of residence given in the questionnaire completed by the parents [22]. However, the load was determined by averaging the weight of school supplies to 4kg carried by first-class children from a randomly selected primary school. Selected features of body posture were measured in 8 positions, 4 for each way of carrying. The first position-habitual position, Picture 2. Second position-posture after 10minutes of symmetric loading on the back (in the last 5seconds), Picture 1. Third position-posture one minute after the load removal, Picture 2. Fourth position-posture two minutes after the load removal, Picture 1. The load was supposed to imitate the way of carrying school supplies. The subject could move freely. This was in line with the previous results of Mrozkowiak’s research, which showed that after this time, the values of posture features could be at the starting point [13]. It could be assumed that it was an appropriate and relatively constant for each student when diagnosing the habitual posture on the first day of the research programme. However, in order to maintain the reliability of the research, it was assumed that any inconsistency with the value of the features from the first stage of the measurements may affect the final test result. Therefore, before pulling the load up destined by the procedure, the features of the habitual posture were always determined as a reference for the subsequent dynamic changes of the diagnosed features. The height and weight of the children as well as the weight of the carried school supplies were measured with a medical balance before the first day of the tests (Pictures 1,2).

Picture 1: Positon 2nd: posture with an asymmetrical axial load on the chest.

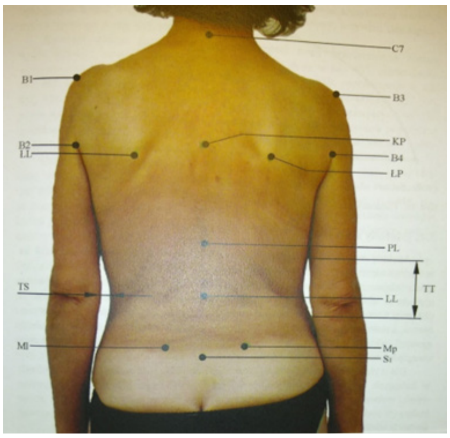
Picture 2: Position 1st, 3rd and 4th: presentation of habitual posture.

The measurement site for the value of selected features of the body posture 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 of the subject and the camera were oriented spatially in accordance with the levels on the camera and in relation to the line of the child's toes. It is possible to obtain a spatial image thanks to the projection of lines on the child's back with strictly defined parameters, which falling on the body are distorted depending on the configuration of its surface. Thanks to the use of the lens, the image of the examined person is 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 multi-layered interpretation of the body posture. It is possible to determine the size of the angular and linear features describing the pelvis and physiological curvatures in the sagittal and transversal planes apart from the assessment of the torso asymmetry in the frontal plane [23,24].

The following test procedure was developed in order to minimize the risk of making mistakes in the measurements of selected posture features [24]:

a) Habitual posture of the subject against the background of a white, lightly illuminated sheet: free, unforced posture, with feet slightly apart, knee and hip joints in extension, arms hanging along the body and eyes looking straight ahead, with the back to the camera at 2.5 meters, toes at a perpendicular line to the camera axis.

b) Marking points on the back skin of the examined: the top 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 place from thoracic kyphosis to lumbar lordosis (PL), the lower angles of the scapulae (Łl and Łp), the posterior upper iliac spines (Ml and Mp), and the S1 vertebra. A white necklace was put on the subject's neck to clearly mark the B1 and B3 points, Picture 3. Long hair up to reveal C_7 point.



Picture 3: Location and markings of the points in the frontal plane.

c) The digital image of the back was recorded in the computer memory in each of the tested positions from the middle phase of free exhalation after entering the necessary data about the examined person (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, gait, etc.).

d) Processing of the recorded images takes place without the participation of the subject.

e) The value of the features describing the body posture spatially are printed after saving the mathematical characteristics of the photos in the computer memory, Figure 1.

MAGMAR Olsztyn
Mirosław Mrozkowiak
Phone number: 602 529 652
COMPUTERIZED EXAMINATION OF THE BODY POSTURE

Name: Height: 119 cm, Year of birth: 1993
Data: 1SP1MK\0CIOLL00, Date of examination: 2000-12-02, Printout: 2001-01-23
Medical intelligence: Comments:

Global parametres

Length of the spine: DCK 346.6 [mm] meaning 29.1% of height
Tilt angles [deg.]: ALFA 10.1, BETA 15.2, GAMMA 13.9 In total: 39,2 [deg.]
Torso tilt angle: KPT 6.3 [deg.] Compensation rate: 3.8 [deg.]

Thoracic kyphosis

D.LL_C7 DKP 309.9 [mm] (89.4%) KKP angle 150.9 [deg.]
D.PL_C7 RKP 195.7 [mm] (56.5%) GKP depth 32.7 [mm] (WKP 0.167)

Lumbar lordosis

D.S1_KP DLL 271.2 [mm] (78.2%) KLL angle 154.7 [deg.]
D.S1_PL RLL 150.9 [mm] (43.5%) GLL depth -30.8 [mm] (WLL -0.204)

Frontal plane

Torso tilt angle KNT 1.4 [deg.]
Left shoulder higher about 8.2 [mm] Angle of shoulder blades line KLB -1.7 [deg.]
Left shoulder blade higher about 6.1 [mm] (-2.4 deg.) (UL), closer about 20.6 [mm] (-8.0 deg.) (UB)
The difference of the distance of shoulder blades from the spine OL: 2.4 [mm] (1.7%)
Left waist triangle higher about -46.2 [mm] (TT), wider about -14.7 [mm] (TS)
The pelvis: tilt angle KNM 1.5 [deg.], turn angle KSM -6.4 [deg.]
Shoulder's asymmetry rate regarding KK WBS = -10.5 (-3.8%), regarding C7 WBC = 6.3 (2.3%)
Shoulder- pelvis asymmetry rate vertical WBK = 10.2 (1.9%) horizontal WBX = -10.5 (-5.3%)
Maximum deviation of 1. spinous process from C7_S1 UK 11.1 [mm] at Th6 level

DESCRIPTION

The manufacturer of the measuring device of Computerized Examination Of the Body Posture, feet,…:
CQ Electronic System, M.E. Artur Świerc, Na Niskich Lakach street, 19/2, Wroclaw, phone numer: 0601 794162

MAGMAR Olsztyn
Mirosław Mrozkowiak
tel.602 529 652
KOMPUTEROWE BADANIE POSTAWY CIAŁA

Nazwisko: [redacted] Wzrost: 119 cm, Rok ur. 1993 ,
Dane: 1SP1MK\0CIOLL00, Data badania: 2000-12-02, Wydruk dnia,2001-01-23
Wywiad: Uwagi:
Parametry globalne
Długość kręgosłupa DCK 346.6 [mm] czyli 29.1 % wzrostu
Kąty pochylenia [st] : ALFA 10.1, BETA 15.2, GAMMA 13.9, Łącznie: 39.2 [st]
Kąt pochylenia tułowia: KPT 6.3 [st]. Wskaźnik kompensacji 3.8 [st]
Kifoza piersiowa
D.LL_C7 DKP 309.9 [mm] (89.4%) Kąt KKP 150.9 [st]
D.PL_C7 RKP 195.7 [mm] (56.5%) Głębokość GKP 32.7 [mm] (WKP 0.167)
Lordoza lędźwiowa
D.S1_KP DLL 271.2 [mm] (78.2%) Kąt KLL 154.7 [st]
D.S1_PL RLL 150.9 [mm] (43.5%) Głębokość GLL -30.8 [mm] (WLL -0.204)
Płaszczyzna czołowa
Kat nachylenia tułowia KNT 1.4 [st]
Lewy bark wyżej o 8.2 [mm] Kąt linii barków KLB -1.7 [st]
L.łopatka wyżej o 6.1[mm] (-2.4st)(UL), bliżej o 20.6[mm] (-8.0st)(UB)
R. oddal. łopatek od kręgosłupa OL: 2.4 [mm] (1.7%)
Lewy tr.talii wyższy o -46.2 [mm] (TT) szerszy o -14.7 [mm] (TS)
Miednica: kąt nachylenia KNM 1.5 [st], kąt skręcenia KSM -6.4 [st]
Wsp.asym.barków względem KK WBS=-10.5 (-3.8%), wzg.C7 WBC= 6.3 (2.3%)
Wsp.asym.bark-miednica pion WBK= 10.2 (1.9%) poziom WBX= -10.5 (-5.3%)
Maks. odch. l.wyrost. kol. od C7_S1 UK 11.1 [mm] na wys.Th6

OPIS

Producent aparatury do Komputerowego Badania Postawy Ciała, stóp,...:
CQ Elektronik System, mgr inż. Artur Swierc, ul.Na Niskich Łąkach 19/2, Wrocław, tel. 0601 794162

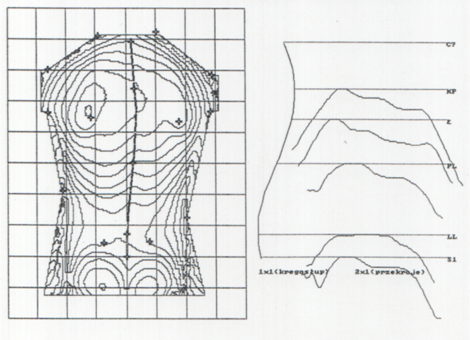


Figure 1: An example of a record sheet of measurements of the posture features of the spine-pelvis syndrome.

Subject of Research

The Wrocław fitness test allowed to measure the strength, power, speed and agility of preschool children. The author modified Sekita's test for a test of endurance. Definitions of the tested physical and complex motor skills are generally available in the literature [17].

The applied method, which uses the phenomenon of the projection moiré, defines several dozen features describing the body posture. For statistical analysis, 16 angular and linear features of the spine, pelvis, and torso in the frontal plane as well as body weight and height were selected. It was guided by the need of the most reliable and spatially complete look at the child's body posture, which allowed to fully identify the measured discriminants (Tables 1,2) (Picture 3).

Table 1: The boys chest.

Variables	The Difference Between 1st and 2nd Measurement						
	WY	SZ	SI	MO	ZW	OG	
DCK	-0,15	-0,07	0,37	0,53*	0,03	0,24	1
Alfa	-0,62*	-0,31	-0,25	0,08	-0,28	-0,39	1
Beta	-0,30	-0,42	-0,40	-0,33	-0,26	-0,43	
Delta	-0,40	-0,37	-0,54*	0,09	-0,46	-0,59*	2
KKP	0,09	-0,20	-0,24	0,14	-0,19	-0,19	
RKP	0,11	0,04	-0,23	-0,11	-0,15	-0,14	
GKP	-0,25	-0,05	0,23	-0,11	-0,02	-0,04	
DLL	0,00	-0,24	0,12	-0,14	0,23	0,09	
KLL	-0,62*	-0,67**	-0,70**	-0,10	-0,62*	-0,78**	5
UB-	1,00**	-1,00**	1,00**	1,00**	1,00**	1,00**	6
UB+	0,01	0,22	0,05	-0,39	0,44	0,08	
KSM-	-1,00**	1,00**	-1,00**	-1,00**	-1,00**	-1,00**	6
KSM+	-0,31	-0,29	-0,12	0,07	-0,21	-0,25	
	4	3	4	3	3	4	
Variables	**WY**	**SZ**	**SI**	**MO**	**ZW**	**OG**	
KNT+	-1,00**	1,00**	-1,00**	-1,00**	-1,00**	-1,00**	6
KLB-	-1,00**	1,00**	-1,00**	-1,00**	-1,00**	-1,00**	6
KLB+	0,24	0,47	0,41	-0,08	0,32	0,35	
UL-	1,00**	-1,00**	1,00**	1,00**	1,00**	1,00**	6
OL-	0,79**	0,54	0,05	-0,31	0,11	0,20	1
OL+	-1,00**	1,00**	-1,00**	-1,00**	-1,00**	-1,00**	6
TT-	1,00**	-1,00**	1,00**	1,00**	1,00**	1,00**	6
TS-	-1,00**	1,00**	-1,00**	-1,00**	-1,00**	-1,00**	6
TS+	-0,24	-0,05	0,59*	0,15	0,38	0,41	
KNM-	-0,24	-0,49	-0,01	0,28	0,05	-0,04	
KNM+	-0,50	0,87	0,50	-0,87	0,50	0,50	
	7	6	7	6	6	6	

Table 2: The girls chest.

Variables	The difference between 1st and 2nd measurement						
	WY	SZ	SI	MO	ZW	OG	
RKP	0,15	0,60*	0,31	-0,57	0,35	0,34	1
DLL	-0,57	-0,64*	-0,31	0,09	-0,24	-0,41	1
		2					
TT+	0,83*	0,14	0,14	0,50	-0,04	0,34	1
UK-	-0,70	-0,50	-0,95*	-0,78	-0,90*	-0,90*	3
	1		1		1	1	

Research Questions and Hypotheses

The following research questions arise from the aim of the research:

a) Will the load of an adopted way of carrying school supplies influence significantly and sex-dependently on the values of the body posture features?

b) Will physical fitness show significant and gender-specific relationships with the change in the value of the body posture features?

c) Can the way of carrying the school container be recommended for 7-year-old students?

d) Our own research results and the analysis of the available literature suggest that:

i. The adopted way of carrying the weight of school supplies will have a significant impact, irrespective of gender, on the value of the analyzed posture features.

ii. The physical fitness features will show significant and gender-dependent relationships with the change in the value of the posture features.

iii. The way of carrying a 4-kg weight of school supplies will not be recommended for 7-year-old students of both sexes due to significant changes in the value of 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 is in each group. There was no reference to it in the description of the results, but in analytical practice its application was treated as a concomitant measure of the arithmetic mean. In the used analysis, the reference to SD was abandoned. These were only given in the introductory tables (where M was also given) as a formality. SD was a concomitant measure of M. It was also assumed that the value of SD in the performed studies was not interpreted in any way, especially if the analysis was based on non-parametric tests and median (Me), but not the mean (M). Therefore, SD and M were finally removed in the initial analyzes to concentrate the tables and leave there only necessary issues for the research. Standard deviation is a concomitant measure of the arithmetic mean and therefore it is not valid to put it next to the median.

The analysis of the study results was performed using the IBM SPSS Statistics 26 programme. At the initial stage, the Shapiro-Wilk and Kołmogorow-Smirnow tests were used to ensure if the distributions of the analyzed variables were consistent with the normal distribution. For most 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 non-parametric coefficients in the statistical analysis. The Wilcoxon rank test was used to determine whether there was a statistically significant difference (change) between two measurements (in the same group) of the quotient variable whose distribution was significantly different from the normal one. The following symbols were used in the tables: M-arithmetic mean, Me-median, SD-standard deviation, Z-Wilcoxon test statistic, "p"-significance of the Wilcoxon test. The level of significance was set at $p<0.05$, marked as *, and additionally, the significance level $p<0.01$, marked as **. Thus, if $p<0.05$ or $p<0.01$, then the difference between the measurements was statistically significant. The Spearman's rho correlation coefficient was used to determine whether there were statistically significant correlations between the variables measured at the quotient level, which distribution significantly differed from the normal one. The level of statistical significance was set at $p<0.05$, marked as *, and additionally, the level of significance $p<0.01$, marked as **. Thus, if $p<0.05$ or $p<0.01$, then the correlation between the variables was statistically significant. If the correlation was statistically significant at the level of $p<0.05$, then the correlation coefficient rho should be interpreted. It could take values from -1 to +1. The more distant it was from 0, and the closer it was to -1 or +1, so the correlation was stronger. Negative values meant that as the value of one variable increased, the value of the other variable decreased. On the other hand, positive values indicated that as the value of one variable increased, the value of the other variable increased, too. In the individual tables of correlation, only the variables were considered (in the rows), which at least one statistically significant result was recorded for.

Individual values of posture features are expressed in different sizes and ranges, so it is not possible to calculate the average difference for all these variables between the two measurements. An analysis performed in such a way would distort the results and make the variables, in which the quantities are higher of greater importance, and the variables, in which the quantities were lower of less importance. Therefore, the correlation between the averaged difference in the value of features between the 1st and 2nd measurement and physical fitness was made separately for girls and boys, using absolute values, i.e., the calculations did not use exact numerical values concerning the differences, but the ratio of the difference to the initial value. This approach makes the variables not to be overrepresented or underrepresented in the average result.

The correlation analysis was conducted between physical fitness tests results and the difference between 1st and 2nd measurement separately for boys and girls. Only those individuals, who had both physical fitness tests and appropriate body posture measurements were considered. To concentrate the results of the analysis as much as possible, only the correlation coefficients (rho) were included in the tables. Correlations statistically significant at the level of $p<0.01$ are marked**, and correlations statistically significant at the level of $p<0.05$ are marked*. The individual tables include only those variables (in the rows), which at least one statistically significant result was recorded for.

Obtained Results

In total, the research carried out in a group of 65 people of both sexes aged 7years allowed to register 4,615 values of features describing body posture in habitual posture and dynamic positions, body weight and height, and physical fitness. Average body weight was as follows: among girls 24.46 kg, body height-123.87, and among boys: 24.56kg and 123cm, respectively. All children had a slender body type according to the Rohrer Weight and Growth Index [25]. Information was also obtained through a survey conducted among 65 parents of children reported to the research project [22].

The analysis of the results of the applied Wrocław fitness test and the endurance diagnostic trial showed that the tested group of children represented a sufficient level of physical fitness, assuming grading: insufficient, sufficient, good, very good. This level was significantly lower than the values obtained in the measurements of other authors from 2006, 1996, 1972 and 1967 [26-28]. The phenomenon of sexual dimorphism in the studied group of 7-year-olds of both sexes was not confirmed.

The analysis of the differences in the value of posture features between the 1st and 2nd measurement in carrying school supplies on the boys 'and girls' chests showed that the significance of the differences occurs between all the analyzed features of body posture (Table 3,4). Analyzing the correlation of differences between the 1st and 2nd measurement of the body posture features in carrying on the chest and the physical fitness features among boys, it turned out that the greater the endurance, the smaller asymmetries in the torso bend to the right (KNT +), shoulder height, where the left one was higher (KLB-), the distance of the angles of the lower shoulder blades from the line of the spinous processes, where the left angle was more distant (OL +) and the width of the waist triangles, where the right one was wider (TS-) and the smaller deviation of the spinous process to the left from the optimal course of the line of the spinous processes (UK-), but larger asymmetries in the height of the shoulder blades, where the left one was higher (UL-), the distance of the shoulder blades from the line of the spinous processes of the spine, where the right lower angle was more distant (OL-) and the height of the waist triangles, where the right one was higher (TT-). The greater the speed, the smaller the asymmetries in the height of the shoulder blades where the left one was higher (UL-) and the height of the waist triangles where the right one was higher (TT-) and the smaller the deviation of the spinous process to the left of the optimal course of the line of the spinous processes (UK-), but greater in the torso bend to the right (KNT +), shoulder height, where the left one was higher (KLB-), the distance of the angles of the lower shoulder blades from the line of the spinous processes, where the left angle was more distant (OL +) and the width of the triangles waist, where the right one was wider (TS-). The greater the strength, the smaller the asymmetries in the torso bend to the right (KNT +), the height of the shoulders, where the left one was higher (KLB-), the distance of the angles of the lower shoulder blades from the line of the spinous processes, where the left one was more distant (OL +) and the width of the waist triangles, where the right one was wider (TS-), but the greater in the height of the shoulder blades, where the left one was higher (UL-), the height of the waist triangles where the right one was higher (TT-) and the width where the left one was wider (TS +) and a greater deviation of the spinous process to the left of the optimal course of the spinous process line (UK-).

Table 3: The significance of differences of posture features in the frontal plane between 1st and 2nd measurement with a load on the chest among boys.

No.	Variables	Measurement 1			Measurement 2			Wilcoxon's Test	
		M	Me	SD	M	Me	SD	Z	p
1	KNT-	1,56	1,40	1,04	4,10	4,05	1,11	-4,113	<0,001**
2	KNT	2,04	2,35	1,50	4,85	4,85	1,24	-2,527	0,012*
3	KLB-	2,60	1,90	1,64	5,45	5,25	1,36	-2,521	0,012*
4	KLB	1,60	1,05	1,39	4,77	4,80	1,13	-4,108	<0,001**
5	UL-	3,01	4,15	2,30	6,24	6,30	0,99	-2,527	0,012*
6	UL	2,43	1,95	1,59	5,65	5,40	1,49	-4,108	<0,001**
7	OL-	8,89	8,10	5,71	12,16	10,90	5,50	-4,109	<0,001**
8	OL	4,16	4,30	2,55	8,65	7,75	3,95	-2,524	0,012*
9	TT-	5,44	4,80	2,05	12,75	13,55	2,61	-2,527	0,012*
10	TT	8,95	8,30	4,38	14,40	14,45	4,16	-4,107	<0,001**
11	TS-	5,74	5,10	1,63	13,28	13,55	1,84	-2,521	0,012*
12	TS	8,44	8,35	4,99	15,88	15,35	4,27	-4,109	<0,001**
13	KNM-	6,29	7,50	3,48	11,27	10,50	4,18	-4,015	<0,001**
14	KNM	3,62	3,40	2,36	9,87	9,80	2,03	-2,668	0,008**
15	UK-	2,69	1,50	2,15	6,70	5,50	2,45	-2,533	0,011*
16	UK	8,03	6,95	5,33	12,48	10,95	5,55	-4,108	<0,001**

***Source:** Own research.

Table 4: The significance of differences of posture features in the frontal plane between 1st and 2nd measurement with a load on the chest among girls.

No.	Variables	Measurement 1			Measurement 2			Wilcoxon's Test	
		M	Me	SD	M	Me	SD	Z	p
1	KNT-	1,39	0,40	1,66	4,58	4,60	0,71	-3,409	0,001**
2	KNT	1,22	0,80	0,93	4,46	4,70	0,89	-3,825	<0,001**
3	KLB-	1,64	1,40	0,97	5,02	5,10	0,75	-3,825	<0,001**
4	KLB	1,89	1,50	1,41	5,05	5,10	0,87	-3,408	0,001**
5	UL-	2,33	2,80	1,59	6,13	5,90	1,45	-3,824	<0,001**
6	UL	2,94	3,20	1,32	5,67	5,40	1,32	-3,409	0,001**
7	OL-	7,76	7,60	3,36	11,38	12,70	3,74	-3,409	0,001**
8	OL	5,03	4,30	3,72	8,83	8,20	3,11	-3,823	<0,001**
9	TT-	5,65	4,70	2,88	12,46	12,10	2,77	-3,824	<0,001**
10	TT	6,88	4,80	3,46	13,41	13,20	2,45	-3,408	0,001**
11	TS-	5,59	4,90	2,44	13,75	13,80	2,43	-3,823	<0,001**
12	TS	7,86	5,10	4,57	14,85	13,80	3,73	-3,409	0,001**
13	KNM-	4,32	2,70	3,57	11,09	11,30	3,08	-3,408	0,001**
14	KNM	3,04	2,90	2,20	9,82	9,80	1,32	-3,823	<0,001**
15	UK-	3,61	3,60	2,14	7,36	6,90	2,38	-3,825	<0,001**
16	UK	4,97	3,70	2,98	8,85	6,90	3,87	-3,408	0,001**

***Source:** Own research.

Table 5: Correlations between physical fitness and the difference of posture features in the frontal plane between 1st and 2nd measurement with a load on the chest among boys.

Variables	The Difference Between 1st and 2nd Measurement					
	WY	SZ	SI	MO	ZW	OG
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**
KLB	0,24	0,47	0,41	-0,08	0,32	0,35
UL-	1,00**	-1,00**	1,00**	1,00**	1,00**	1,00**
OL-	0,79**	0,54	0,05	-0,31	0,11	0,20
OL	-1,00**	1,00**	-1,00**	-1,00**	-1,00**	-1,00**
TT-	1,00**	-1,00**	1,00**	1,00**	1,00**	1,00**
TS-	-1,00**	1,00**	-1,00**	-1,00**	-1,00**	-1,00**
TS	-0,24	-0,05	0,59*	0,15	0,38	0,41
KNM-	-0,24	-0,49	-0,01	0,28	0,05	-0,04
KNM	-0,50	0,87	0,50	-0,87	0,50	0,50
UK-	-1,00**	-1,00**	1,00**	-1,00**	-1,00**	-1,00**

Note*: WY – Endurance, SZ – Speed, SI – Strength, MO – Force, ZW – Agility, OG – Overall Fitness
***Source:** Own research.

The greater the force, the smaller the asymmetries in the torso bend to the right (KNT +), the height of the shoulders, where the left one was higher (KLB-), the distance of the angles of the lower shoulder blades from the line of the spinous processes, where the left angle was more distant (OL +) and the width of the waist triangles, where the right one was wider (TS-) and a smaller deviation of the spinous process to the left of the optimal course of the spinous processes line (UK-), but greater in the height of the shoulder blades, where the left one was higher (UL-) and the height of the waist triangles where the right one was higher (TT-). The greater the agility, the smaller the asymmetries in the torso bend to the right (KNT +), shoulder height, where the left one was higher (KLB-), the distance of the angles of the lower shoulder blades from the spinous process line, where the left angle was more distant (OL +

) the width of the waist triangles, where the right one was wider (TS-) and a smaller deviation of the spinous process to the left of the optimal course of the spinous processes line (UK-), but greater in the height of the shoulder blades, where the left one was higher (UL-) and the height of the waist triangles, where the right one was higher (TT-). The greater the overall fitness, the smaller the asymmetries in the torso bend to the right (KNT +), the height of the shoulders, where the left one was higher (KLB-), the distance of the angles of the lower shoulder blades from the line of the spinous processes, where the left angle was more distant (OL +) and the width of the waist triangles, where the right one was wider (TS-) and a smaller deviation of the spinous process to the left of the optimal course of the spinous processes line (UK-), but greater in the height of the shoulder blades, where the left one was higher (UL-) and the height of the triangles waist, where the right one was higher (TT-) (Table 5).

Analyzing the correlation of differences between the 1st and 2nd measurement of body posture features in carrying on the chest and fitness among girls, it turned out that the higher the endurance, the greater the asymmetry in the height of the waist triangles, where the left one is higher (TT +). The greater the strength, agility, and overall efficiency, the smaller deviation of the apical spinous process to the left (UK-) (Table 6).

Table 6: Correlations between physical fitness and the difference of posture features in the frontal plane between 1st and 2nd measurement with a load on the chest among girls.

Variables	The Difference Between 1st and 2nd Measurement					
	WY	SZ	SI	MO	ZW	OG
KLB-	0,60	0,20	0,00	0,11	0,30	0,30
KLB	-0,07	0,23	-0,20	0,12	-0,48	-0,13
UL-	0,32	0,74	0,11	-0,29	0,11	0,11
TT	0,83*	0,14	0,14	0,50	-0,04	0,34
KSM-	-0,80	-0,50	-0,37	-0,34	-0,60	-0,60
UK-	-0,70	-0,50	-0,95*	-0,78	-0,90*	-0,90*

Note*: WY – Endurance, SZ – Speed, SI – Strength, MO – Force, ZW – Agility, OG – Overall Fitness
***Source:** Own research.

Discussion

Negrini, et al., [29], *Pau, et al.*, [30] and *Heler, et al.*, [31] pay attention to the assessment of children's postural stability after loading them with additional weight of the school backpack, because impaired postural control may lead to an increased risk of falling down and earlier occurrence of back pain syndromes (ZBK). The works of *Pau, et al.*, [30] and *Rugeli, et al.*, [32] indicate significant changes in postural features such as the range of deviations, the maximum range of sticking, the path length of the center foot pressure on the ground (COP) and envelope of the posturogramme. *Negrini, et al.*, [29], Grimmer, et a*l.*, [33] and *Chow, et al.*, [34] pay attention to changes in the sagittal curvature of the spine, the location of shoulder blades and shoulders, which, according to the authors, are a consequence of compensation patterns depending on the weight of the carried backpack. The study of *Peterson, et al.*,[35] shed light on this problem, who proved that children under 12 years of age are not able to fully use visual and vestibular stimuli in postural control. The studies of Steindl, et al., [36] seem to confirm this theory. The authors showed that there is a lack of integration of stimuli from the organ of vision and the vestibule in adolescents up to 15-16years of age, when maintaining a vertical posture. *Cupryś, et al.*, [37] believe that in children aged 6-7 the development processes are harmonious. Therefore, there are no clear biological factors that would increase the percentage of defective postures. The authors seek the causes of negative changes in the conditions of functioning at school, which are new for the child and referred to as "school shock". Researchers include difficulties in adjusting the dimensions of school desks, distance from the blackboard, loading the posture by incorrect sitting, carrying heavy backpacks, fatigue, difficult experiences causing the head hanging and functional deepening of thoracic kyphosis. *Dobosz, et al.,* [38] conducted research on the change of COP under loading conditions and after the backpack removal.

The no-loading test was the benchmark. When wearing the backpack in the traditional way, with a load value of 5% of body weight, the COP shifted backwards, which caused a strong compensatory reaction, which led to its displacement forward. Although it is not clear from statistical calculations, this trend occurs whenever the backpack is on the back at any load value, whereby the greater the load, the lower the compensation value. On the other hand, with the backpack on the front of the body, no postural reaction was observed to the COP shifted forward in relation to its position in the test without load, which in this case may indicate the lack or insufficient compensation at the child, whereby the greater the load value was, the further the COP shifted. This is only a trend that has not been confirmed statistically. It may result from the feeling of greater safety in the front bend and the awareness of the possibility of cushioning the fall with the upper limbs. The sticking values at the time of putting the backpack on in the traditional way with the load value of 10% of the body weight are statistically significantly lower than the sticking values during the tests with the same load but with the backpack on the front side of the body. Such a relationship occurs at all load values during the test with eyes open. Closing the eyes results in a significant increase in sticking for the trials with the backpack on the back with a load of 10% of the body weight and for the trials with the backpack on the front side with the load of 15% of the body weight. Similar changes as a trend occur in each backpack position and each load. *Romanowska* [11] and *Mrozkowiak* [13] in the conducted research in a group of 12-year-old girls attempted to describe the changes on the student's body posture under the influence of the external load. The authors came to very similar conclusions in their investigations. The influence of the six-kilogram symmetrical load of the upper limb girdle of 12-year-old girls showed insignificant changes in the values of selected posture features. It also showed a full restitution of the value of the diagnosed features two minutes after the load removal.

The return to the initial values after the first minute was more intense, whereby. Mrozkowiak also concluded that symmetrical load has little effect on the spine-pelvic syndrome in the frontal plane, including right-sided scoliosis at the Th_3 level. Research by *Mrozkowiak* [39] on the difference in the impact of the weight load of a school backpack carried in the left or right hand drag mode on the body posture of a 7-year-old student showed that a 4-kilogram schoolbag carried both ways significantly and negatively disturbs the biomechanical statics of the body of a 7-year-old child, which may cause mistakes and, consequently, defects in body posture in the long run. Therefore, this method of carrying school supplies for first-year students should not be recommended. The author also showed that overall physical fitness has a greater positive significance in biomechanical statics disorders of body posture in boys than in girls. Among boys, the relationships of its particular features are similar in both modes of carrying, whereas among girls greater relationships occur in the case of the right-hand drag. The most significant motor skills among boys are endurance and strength, and among girls it is speed and force. Other studies by *Mrozkowiak* [40] on the effect of the weight of a school backpack carried obliquely on the right or left shoulder and at the heteronymous hip on posture features in the sagittal and transversal plane in the same group of children have shown that this way of carrying may also cause significant changes in the skeletal and muscular system. The author believes that the longer the carrying time, the greater the weight of the schoolbag and the intensity of manual effort, the greater the changes. However, the changes are not gender specific. Therefore, the analyzed method of carrying should not be practiced among 7-year-old children of both sexes. He also showed that the level of overall fitness shows a diversified relationship with changes in the values of body posture features because of the carrying way of school supplies. The relationship is greater among boys. Among girls, there is the relationship mainly with endurance, usually with the size of the inclination angle of the thoracolumbar spine. Among boys, there is the relationship with all the features of fitness, usually with the asymmetry of convexity of the lower angles of the shoulder blades and the pelvis tilt in the transversal plane. This time the impact is gender dependent. In Dobosz's research on the effects of overloading the body posture with a backpack, a habitual body posture without a load was adopted as a reference point. At the time of putting the backpack on in the traditional way, with a load of 5% of body weight, the COP shifted back, which resulted in a strong compensatory reaction, which leading to its forward displacement. Although it does not come from statistical calculations, this trend occurs in every situation when the schoolbag is on the back at any load value, whereby the greater the load, the lower the compensation value. On the other hand, with the schoolbag on the front of the body, no postural reaction was observed to COP shifted forward in relation to its position in the test without load, which in this case may indicate the lack or insufficient compensation of the child, whereby the higher the load value, the COP shifted further. This is only a trend that has not been confirmed statistically. It may result from the feeling of greater safety in the front bend and the awareness of the possibility of cushioning the fall with the upper limbs [38]. The statements quoted by *Bittman and Badtke* [41] and provided by Schild should be considered that the changes in the movement system of 5-7-year-old children depend primarily on the genetic determinants of the maturation of the musculo-nervous system. During this period, external factors, including physical activity, do not play a major role. It seems that the influence of external factors on the development of the locomotor system begins to increase with age and maturation of the muscular and nervous systems around the age of 7-8.

Based on the conducted research, it can be concluded that all the features of the tested fitness are very often associated with significant differences in the values of posture features among boys. The relationships among girls were significantly smaller and they occur with endurance, strength, agility and overall fitness (Figure 2). Among boys, the discriminants of physical fitness most often showed a significant relationship with the asymmetry of the torso bend to the right (KNT +), shoulder height, where the left one is higher (KLB-), shoulder blades, where the left one is higher (UL-), the distance of the shoulder blades from the line of the spinous processes where the left one is more distant (OL +), the height where the right one is higher (TT-) and the width of the waist triangles (TS-) where the right one is wider. Among girls there were significant relationship with asymmetry in the height of the waist triangles, where the left one is higher (TT +) and with the size of the maximum deviation of the spinous process of the vertebra to the left (UK-) (Figure 3).

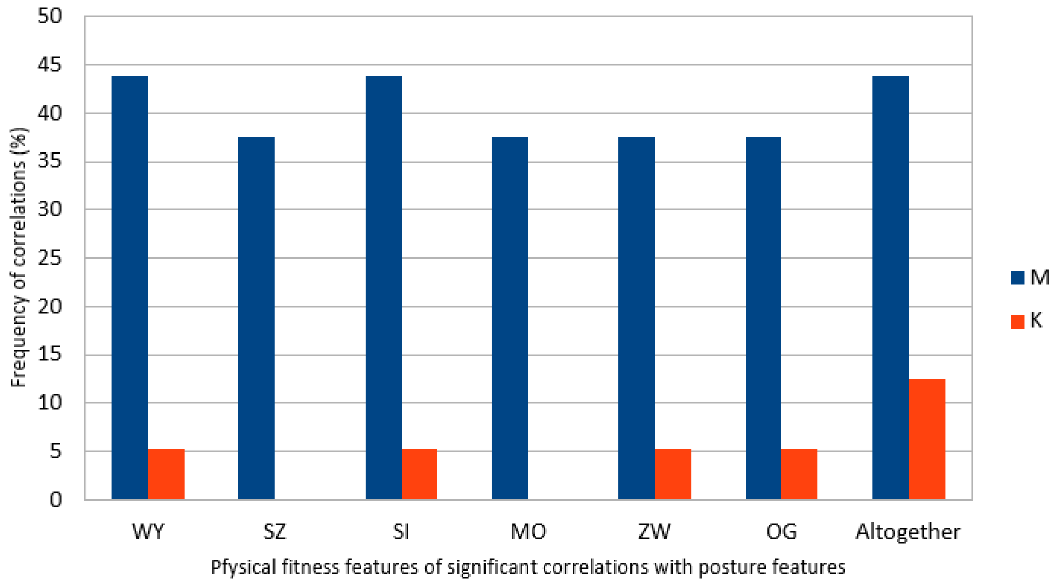


Figure 2: The frequency of significant correlations of physical fitness with posture features in the frontal plane among 7-year-old boys and girls n=65.
***Note:** WY-Endurance; SZ-Speed; SI-Strength; MO-Force; ZW-Agility; OG-Overall Fitness; M-Boys; K-Girls.

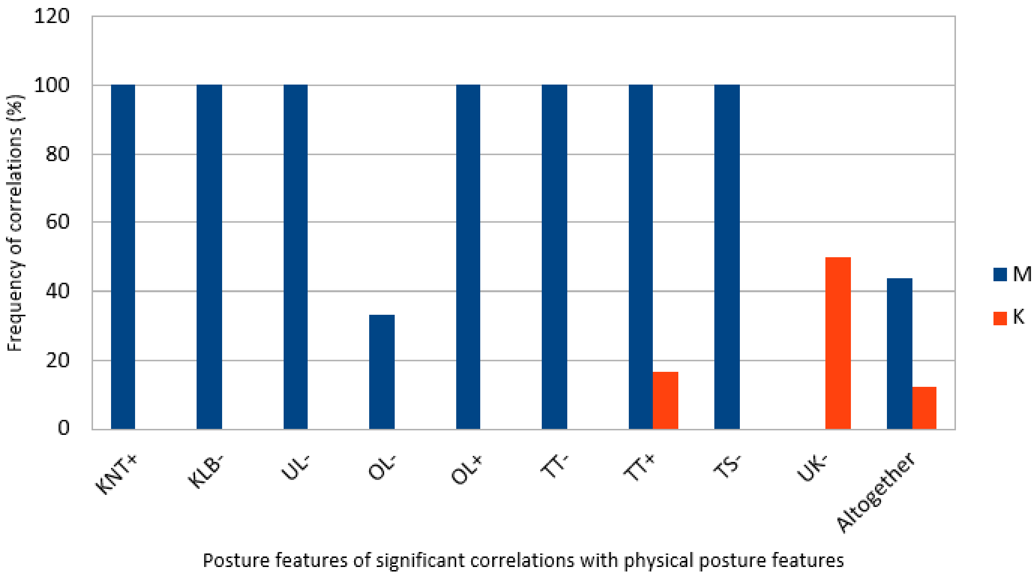


Figure 3: The frequency of signifficant correlations of posture features in the frontal plane with physical fitness features among 7-year-old boys and girls n=65.
***Note:** Symbols of posture features explained in Table 1; M-Boys; K-Girls.

Conclusions

a. Carrying school supplies on the chest may induce significant adaptive changes in the skeletal and muscular systems. It should be assumed that the longer the carrying time, the greater the weight of the schoolbag and the intensity of manual effort, the greater the changes. However, the changes are not gender specific. There may also be a disturbance in the range of motion and the respiratory rhythm of the chest.

b. The physical fitness features show sex-dependent relationships with the value of the changes in the body posture features under the influence of the assumed load. There are also sex-dependent relationships between changes in the values of body posture features and the features of physical fitness. Relationships are much frequent among boys.

c. Carrying a 4kg weight of school supplies on the chest should not be practiced among 7-year-old students of both sexes.

Acknowledgement

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Conflict of Interest

None.

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