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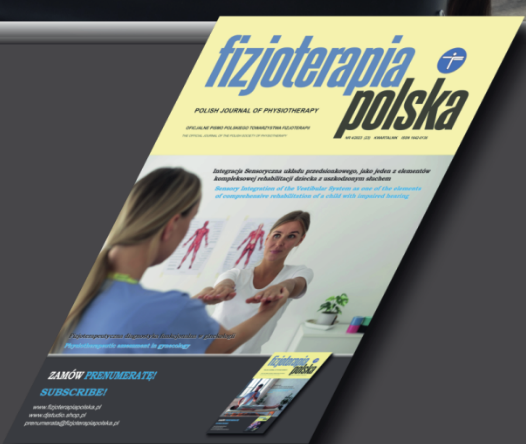

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Which way of carrying a four-kilogram schoolbag disturbs the body posture the least and which disturbs the most in 7-year-old students of both sexes?

Który sposób noszenia czterokilogramowego szkolnego plecaka zaburza najmniej, a który najbardziej postawy ciała 7-letnich uczniów obojga płci?

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Abstract

Introduction. The aim of the research was to determine, which of the analyzed ways of carrying shows the strongest and the weakest correlations with the values after a 10-minute loading with a four-kilogram schoolbag after two-minute restitution. Material, method. The body posture research was carried among a group of 65 children aged 7 with the projection moiré in 4 positions: 1- habitual position, 2- position after a 10-minute loading, 3 – after one minute of the load removal and 4- after two minutes of the load removal. Results. There were analyzed correlations of the differences values of the frontal, sagittal and transversal plane features in a habitual position with the values after a ten-minute loading with a four-kilogram schoolbag as well as with values after two-minute restitution. Conclusions. (1) Carrying a four-kilogram loading in two equal containers on the chest and back or one on the back disturbs body posture statics the least of a 7-year-old student. (2) The fullest restitution of the values of body posture features takes place after carrying two equal containers on the chest and back or one on the back. (3) The most unfavourable changes of the values of body posture features during carrying and restitution appear when the schoolbag is carried on the chest and dragged with right or left hand.

Key words:

children's health, moire topography, physical fitness, postural asymmetry factor

Streszczenie

Wprowadzenie. Celem badań było ustalenie, który z analizowanych sposobów transportu szkolnego plecaka wykazuje największe, a który najmniejsze związki z wielkościami po 10-minutowym obciążeniu 4-kilogramowym plecakiem oraz z wielkościami po 2-minutowej restytucji.

Materiał, metoda. Badania postawy ciała przeprowadzono w grupie 65 dzieci w wieku 7 lat, metodą mory projekcyjnej w 4 pozycjach: 1 – postawie habitualnej, 2 – postawie po 10-minutowym obciążeniu, 3 – po jednej minucie od zdjęcia obciążenia, 4 – po dwóch minutach od zdjęcia obciążenia. Wyniki. Analizowano korelacje różnic wielkości cech płaszczyzny czołowej, strzałkowej i poprzecznej w postawie habitualnej z wielkościami po 10-minutowym obciążeniu 4-kilogramowym plecakiem oraz z wielkościami po 2-minutowej restytucji. Wnioski. 1. Transport czterokilogramowej masy przyborów szkolnych w dwóch równych pojemnikach na klatce piersiowej i grzbiecie lub jednego na grzbiecie najmniej zaburzastatykę postawy ciała 7-letniego ucznia. 2. Najpełniejsza restytucja wielkości cech postawy ciała zachodzi po transporcie dwóch równych pojemników na klatce piersiowej i grzbiecie lub jednego na grzbiecie. 3. Największe niekorzystne zmiany wielkości cech postawy w czasie transportu i restytucji występują w niesieniu plecaka na klatce piersiowej i ciągu pojemnika lewą lub prawą ręką.

Słowa kluczowe:

zdrowie dzieci, mora projekcyjna, sprawność fizyczna, wskaźnik asymetrii postawy

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Introduction

The rucksack or schoolbag term applies only to a student, regardless of weight, shape, size or color of the container. This is the most popular form of carrying the necessary supplies in school education around the world [1-4]. Studies have shown that the frequency of schoolbag use by children in developed countries reaches 90% [5]. In recent years, non-specific pain in the back, neck, shoulders and body posture disorders of school-age children have often been the subject of research, focusing mainly on the side-effects of transporting an excessive weight of a school bag [13-16]. The large weight of a schoolbag carried for a long time affects the muscular and skeletal system. This can contribute to the development of pain in the cervical spine and shoulders. Some back pain subsides, but there are also those followed by irreversible deformations of the skeletal system [2, 5, 8, 9]. The frequency of back pain in children and adolescents is lower than in adults, but it is considered a strong predictor of back pain in adulthood [10, 11]. Other authors have shown that the school trolleys create very favorable conditions for the occurrence of musculoskeletal disorders [6, 12-14]. Al Qallaf [15] is of the opposite opinion. There are very interesting studies carried out by Brackely et al. [3] in a group of 15 10-year-old students, who got a specially designed and equipped backpack put on, enabling the mass of school supplies to be placed in the required place and continuous measurement of changes in the angle of torso bent in the sagittal plane, craniovertebral and lumbar lordosis. The values of selected features were recorded in the posture without a backpack (position "0"), in the posture with a backpack and after having finished a 1000-metre walk. The obtained results showed that significant changes occurred in the values of the torso bent angle in the sagittal plane when the backpack was loaded up to 15% of body weight. Less backpack load resulted in smaller changes in the craniovertebral angle compared to the "0" measurement than in the case of high and medium loads. The overall analysis showed less changes in the lumbar lordosis angle at low loads. In conclusion, the authors claim that future backpack designs should place the load lower on the spine to minimize adaptive student responses. It should be remembered that the first-grade students of primary school face a period of accelerated growth and development of the skeletal system, and the development of bone structures of the spine takes longer than other elements of the skeletal system. In addition, the spinal ligaments and torso musculature system are not fully developed until the age of 16 [16]. Consequently, the applied postural loads may threaten the integrity of the adult posture [5, 15].

Completed research program entitled “The backpack as an epigenetic factor initiating posture defects was one of the first attempts to empirically define the relationship between physical fitness features and body posture statics disorders resulting from various ways of carrying school supplies by a 7-year-old student”. A further goal of the implemented program was to define the features of fitness that the most immunize body posture to disorders resulting from carrying a schoolbag. The author investigated the significance of differences between the "0" measurement values (habitual posture) and the values from the last 5 seconds of a 10-minute load with 4-kilogram mass in carrying obliquely on the right or left shoulder and at the heteronymous hip, in the drag mode with the right or left hand, on the back, on

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the chest, on the back and chest, and on the left or right shoulder. The restitution of the value of features describing the posture after 1 and 2 minutes from the load removal was also examined. The analysis of the obtained measurement results showed significant changes in all thirty-six values of features describing the body postures of male and female students, as well as incomplete restitution in each plane and mode of carrying. The analysis also included the relationships between the tested physical fitness (endurance, speed, strength, power, agility and overall fitness) with changes in the value of posture features. There has been demonstrated a large differentiation of compounds in each mode of carrying and gender [17-23]. The research is aimed at examining the critical relationship, which is still evolving, between the method of carrying the schoolbag to the body, which is believed to affect health. The lack of reliable and authoritative posture measurement instruments that can be used confidently in any setting are a poor evidential base for the posture - pain relationship.

The aim of the research was to determine, which of the analyzed ways of carrying a school backpack shows the greatest and the weakest relationships with the values after a 10-minute load with a 4-kilogram backpack and with the values of posture characteristics after a 2-minute restitution.

Materiał i metody

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 6 years, 6 months and 1 day old and under 7 years, 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 [24].

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

Before the measurements started, the children were instructed in order to avoid the stress associated with the research procedure and the people responsible for it (Fig.1). 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.

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Fig. 1. Insructing the examined children

The applied method using the projection moiré phenomenon determines the value of several dozen features describing the body posture, tab. 1.

It makes 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. A custom-designed diagnostic frame was provided to ballast the body posture (utility model no. W.125734). 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 [24]. However, the load was determined by averaging the weight of school supplies to 4 kg carried by first-class children from a randomly selected primary school. Selected features of body posture were measured in 4 positions. The first position – habitual position, Fig. 2. Second position – posture after a 10-minute loading (in the last 5 seconds, Fig. 3–11). Third position – posture one minute after the load removal, Fig. 2. Fourth position – posture two minutes after the load removal, Fig. 2. The load was supposed to imitate the way of carrying school supplies. The subject could move freely.

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

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Tab. 1. The list of registered body and morphological features

No.	Symbol	Label	Name	Description
			Sagittal plane	
1	Alfa	degrees	Lumbosacral slope	
2	Beta	degrees	Thoracolumbar slope	
3	Gamma	degrees	Upper thoracic slope	
4	Delta	degrees	Sum of angular values	Delta = Alfa + Beta + Gamma
5	KPT	degrees	Torso extension angle	Determined by the declination of the C_7-S_1 line from the vertical (backwards)
6	KPT–	degrees	Torso flexion angle	Determined by the declination of the C_7-S_1 line from the vertical (forwards)
7	DKP	mm	Thoracic kyphosis length	Distance between points C_7 and LL
8	KKP	degrees	Thoracic kyphosis angle	KKP = 180 – (Beta + Gamma)
9	RKP	mm	Thoracic kyphosis height	Distance between points C_7 and PL
10	GKP	mm	Thoracic kyphosis depth	Distance measured horizontally between vertical lines passing through points PL and KP
11	DLL	mm	Lumbar lordosis length	Distance between points KP and S_1
12	KLL	degrees	Lumbar lordosis angle	KLL = 180 – (Alfa + Beta)
13	RLL	mm	Lumbar lordosis height	Distance between points PL and S_1
14	GLL–	mm	Lumbar lordosis depth	Distance measured horizontally between vertical lines passing through points PL and LL, at the level of point LL
			Frontal plane	
15	KNT–	degrees	Angle of body bent to the side	Defined as deviation of the C_7-S_1 line from the vertical axis to the left
16	KNT	degrees		Defined as deviation of the C_7-S_1 line from the vertical axis to the right
17	KLB	degrees	Angle of shoulder line, right shoulder up	Angle between the horizontal line and the straight line passing through points B_2 and B_4
18	KLB–	degrees	Angle of shoulder line, left shoulder up	

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Parameters				
No.	Symbol	Label	Name	Description
19	UL	degrees	Angle of scapula line, right scapula up	Angle between the horizontal line and the straight line passing through points $Ł_1$ and $Ł_p$
20	UL–	degrees	Angle of scapula line, left scapula up	
21	OL	mm	Lower angle of left scapula more distant	Difference in the distance of lower angles of scapulas from the line of spinous processes measured horizontally along the lines passing through points $Ł_l$ and $Ł_p$
22	OL–	mm	Lower angle of right scapula more distant	
23	TT	mm	Left waist triangle up	Difference in the distance measured vertically between points T_1 and T_2 and points T_3 and T_4
24	TT–	mm	Right waist triangle up	
25	TS	mm	Left waist triangle wider	Difference in the distance measured horizontally between straight lines passing through points T_1 and T_2 and points T_3 and T_4
26	TS–	mm	Right waist triangle wider	
27	KNM	degrees	Pelvis tilt, right ilium up	Angle between the horizontal line and the straight line passing through points M_l and M_p
28	KNM–	degrees	Pelvis tilt, left ilium up	
29	UK	mm	Maximum inclination of the spinous process to the right	Maximal deviation of the spinous process from the line from S_1. The distance is measured in horizontal line
30	UK–	mm	Maximum inclination of the spinous process to the left.	
31	Nr kręgu/ Vertebra's number	kg	Vertebra's number with maximum deviation to the left or right	Number of the vertebra most deviated to the left or right in the asymmetric line of the spinous processes, counting 1 as first cervical vertebra (C_1). If the arithmetic mean takes the value from 12.0 to 12.5, it is Th_5, if it takes from 12.6 to 12.9, it is Th_6

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Parameters				
No.	Symbol	Label	Name	Description
Transversal plane				
32	UB−	stopnie / degrees	The angle of convex line of lower shoulder blades, where the left is more convex	The angle difference of $UB_1 - UB_2$. The UB_2 angle between a line crossing the Łl point and being simultaneously perpendicular to the camera axis and the straight-line crossing $Ł_1$ and Łp points. The UB_1 angle is between the line crossing the $Ł_p$ point and being simultaneously perpendicular to the camera axis and the straight-line crossing $Ł_p$ and $Ł_1$ points.
33	UB	stopnie / degrees	The angle of convex line of lower shoulder blades, where the right is more convex	
34	KSM	stopnie / degrees	Pelvic tilt to the right	The angle between a line crossing M_1 point and being simultaneously perpendicular to the camera axis and a straight-line crossing M_1 and MP points
35	KSM−	stopnie / degrees	Pelvic tilt to the left	
36	DCK	mm	Total length of the spine	The distance between C_7 and S_1 points measured vertically.
Morphological features				
37 38	Mc Wc	kg cm	Body weight	The body height and weight was measured with electrical medical balance.

Wszystkie tabele – źródło: badania własne / All tables – source: own research

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 plane [25].

The following test procedure was developed in order to minimize the risk of making mistakes in the measurements of selected posture features [26, 27]:

1. 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, Fig. 12.
2. 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 spi-

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Fig. 2. Position 1st, 3rd, 4th: Habitual posture presentation

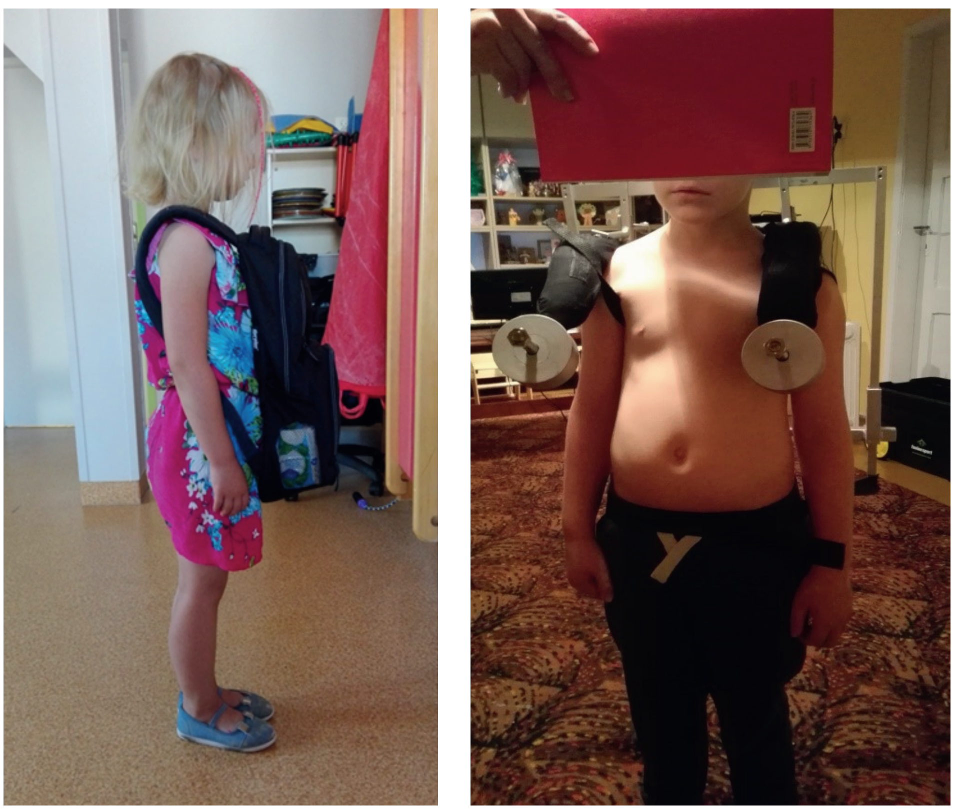

Fig. 3. Position 2nd: Presentation of chest loading

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Fig. 4. Position 2nd: Presentation of back loading

Fig. 5. Position 2nd: Presentation of the back-chest loading

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Fig. 6. Position 2nd: Presentation of the right shoulder loading

Fig. 7. Position 2nd: Presentation of the left shoulder loading

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Fig. 8. Position 2nd: Presentation of the diagonal loading on the right shoulder and left hip

Fig. 9. Position 2nd: Presentation of the diagonal loading on the left shoulder and right hip

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Fig. 10. Position 2[nd]: Presentation of the right hand drag mode loading

Fig. 11. Position 2nd: Presentation of the left hand drag mode loading

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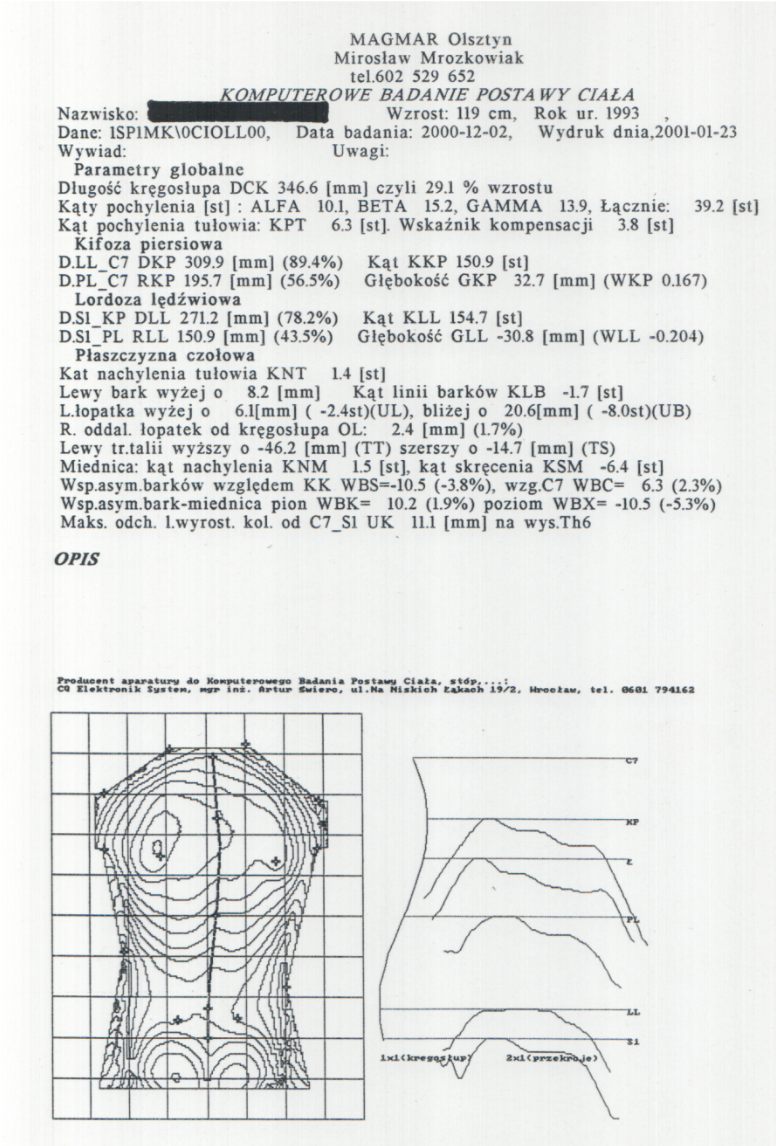
Fig. 12. Diagnostic workstation of body posture by projection moire

nes (Ml and Mp), and the S_1 vertebra. A white necklace was put on the subject's neck to clearly mark the B1 and B3 points. Long hair up to reveal C_7 point.

3. 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.).
4. Processing of the recorded images takes place without the participation of the subject.
5. The value of the features describing the body posture spatially are printed after saving the mathematical characteristics of the photos in the computer memory, Fig.1.

Subject of research

The applied method, which uses the phenomenon of the projection moiré, defines several dozen features describing the body posture. For statistical analysis, 36 angular and linear features of the spine, pelvis and torso in the frontal, transversal and sagittal 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, tab. 1, fig. 13.


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 Świerc, ul.Na Niskich Łąkach 19/2, Wrocław, tel. 0601 794162

Fig. 13. An example of a record sheet of measurements of the posture features of the spine-pelvis syndrome

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

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Research questions and hypotheses

The result of my own experience and analysis of the literature on the subject is a research question: which of the analyzed ways of carrying school supplies disturbs the least and which disturbs the most after a two-minute restitution and a 10-minute carrying the body posture in the frontal, transversal and sagittal planes? The results of own research allow us to believe that in each of the planes the body posture features are the least disturbed after a two-minute restitution and in a 10-minute carrying of two containers on the back-chest, but the most on the chest.

Statistical methods

Only test results obtained in accordance with the adopted procedure were qualified for statistical analysis. A meta-analysis was conducted, in which data on the correlation between the difference in the measurements of attitude characteristics and physical fitness characteristics were the unit of analysis. There were two categories analyzed:

• Correlations between the values of a change in each of posture traits between the 1st and 2nd measurement and the values of physical fitness traits in each aspect separately. Therefore, the following were analysed: the number and percentage of statistically significant positive correlations (they mean that greater physical fitness in a given aspect causes a greater change in a posture – an undesirable situation), the number and percentage of statistically significant negative correlations (they mean that greater physical fitness in a given feature causes less change of posture – desirable situation), the number and percentage of features, which change does not correlate statistically significantly with a given value of the physical fitness feature (neutral situation).

• Correlations between the values of a change, considering the restitution of each of the body posture features between the 1st and 4th measurement, and the values of physical fitness features in each aspect separately. Therefore, the following were analysed: the number and percentage of statistically significant positive correlations (they mean that greater physical fitness in a given trait causes a greater change in a posture – an undesirable situation), the number and percentage of statistically significant negative correlations (they mean that greater physical fitness in a given trait causes a less change of posture – desirable situation), the number and percentage of features, which change does not correlate statistically significantly with a given feature of physical fitness (neutral situation).

In order to separate individual features of physical fitness in terms of greater and less impact on changes in the values of body posture features, cross charts were prepared for individual ways of carrying presenting the numerosity (N) and percentages (%) of statistically significant positive and negative correlations and lack of correlations between changes in the values of posture features and the values of a given physical fitness feature. The analyzes were made separately for boys and girls and for individual ways of carrying.

Obtained results

In total, the research carried out in a group of 65 people of both sexes made it possible to register 10,010 values of features describing habitual posture and in dynamic positions, as well as

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body mass and height. The average body weight among girls was 24.46 kg, body height 123.87, and among boys, respectively: 24.56 kg, 123 cm. All children had a slender body type according to the Rohrer's weight-height index [28].

Statistical analysis showed that carrying two containers on the back-chest by boys causes the smallest changes (differences between the 1st and 2nd measurement) in the values of body postures in the frontal, sagittal and transversal planes, and the largest in the drag mode with the right hand. Carrying on the back-chest causes significantly less changes than carrying on the left or right shoulder, chest, or in a drag mode with left or right hand. In addition, carrying the utensils on the back causes significantly smaller changes than the drag mode with the right or left hand, tab. 2, Fig. 14. Among girls, the smallest changes in body posture are caused by carrying a school bag on the back-chest, and the largest on the chest. Carrying school supplies on the back-chest causes significantly smaller changes than carrying them on the left shoulder, in a drag mode with the right or left hand and on the chest, tab. 3, Fig. 14. Among girls, the smallest changes in body posture are caused by carrying the backpack on the back-chest, and the largest on the chest. Carrying school supplies on the back-chest causes significantly smaller changes than carrying them on the left shoulder, in a drag mode with the right or left hand and on the chest, tab. 3, Fig. 14. The smallest changes in the values of body postures of the frontal, sagittal and transversal planes among boys in the restitution phase (differences between the 1st and 4th measurement) are caused by the carrying two containers on the back-chest, and the largest in the left-hand drag mode. Carrying on the back-chest causes significantly less changes than a drag mode with the right or left hand. In addition, the method of carrying on the back causes significantly smaller changes than a drag mode with the left hand, tab. 4, Fig. 15. Among the girls, the smallest changes in body posture are caused by carrying on the back-chest, and the largest by the left hand drag mode. Carrying a school bag on the back-chest causes significantly smaller changes than a drag mode with the right or left hand, tab. 5, Fig. 15.

Statistical analysis showed that carrying two containers by boys and girls on the back-chest causes the smallest changes (differences between the 1st and 2nd measurement) in the values of body postures in the frontal, sagittal and transversal planes, and the largest on the chest. Statistically significant differences were observed between carrying on the back-chest and on the back, which causes smaller changes than carrying on the right or left shoulder, in a drag mode with the left or right hand and on the chest, tab. 6, Fig. 16. The smallest changes in the values of body postures of the frontal, sagittal and transversal planes among boys and girls in the restitution phase (differences between the 1st and 4th measurement) are caused by the carrying two containers on the back-chest, and the largest changes in the right or left hand. Carrying on the back-chest causes significantly less changes than on the chest, and in a drag mode with the right or left hand. In addition, carrying a school bag on the back, diagonally on the right shoulder and on the left hip and on the left shoulder causes significantly smaller changes than a drag mode with the right or left hand, and carrying the backpack diagonally on the left shoulder and on the right hip causes significantly smaller changes than a drag mode with the left hand. hand, tab. 7, Fig. 17.

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Tab. 2. Comparison of individual ways of carrying in terms of the differences values of body posture features in three planes between the 1st and 2nd measurement among 7-year-olds boys n = 30

Way of carrying – boys	Change value (1–2)		
	M	Me	SD
1 Back-chest	36.40	26.25	35.00
2 Back	50.22	32.37	54.06
3 Right shoulder – left hip	72.51	54.02	80.87
4 Left shoulder – right hip	90.15	61.46	135.00
5 Left shoulder	112.47	75.76	172.21
6 Right shoulder	178.09	78.57	422.35
7 Chest	103.74	79.95	91.64
8 CLeft hand drag mode	147.17	83.67	238.97
9 Right hand drag mode	132.25	85.45	158.09
Kruskal-Wallis's Test: H = 37.223, p < 0.001**, R.I.:1 < 5,6,7,8,9, R.I.: 2 < 8.9			

Tab. 3. Comparison of individual ways of carrying in terms of the differences values of body posture features in three planes between the 1st and 2nd measurement among 7-year-olds girls n = 35

Way of carrying – girls	Change value (1–2)		
	M	Me	SD
1 Back-chest	47.12	39.22	59.56
2 Back	62.15	46.94	72.74
3 Right shoulder – left hip	81.68	54.67	104.92
4 Left shoulder – right hip	142.07	63.83	344.69
5 Right shoulder	117.22	75.00	162.73
6 Left shoulder	178.09	78.57	422.35
7 Right hand drag mode	160.30	83.86	247.97
8 Left hand drag mode	230.75	85.19	560.52
9 Chest	148.18	97.56	190.03
Kruskal-Wallis's Test: H = 31.941, p < 0.001**, R.I.:1 < 6,7,8,9			

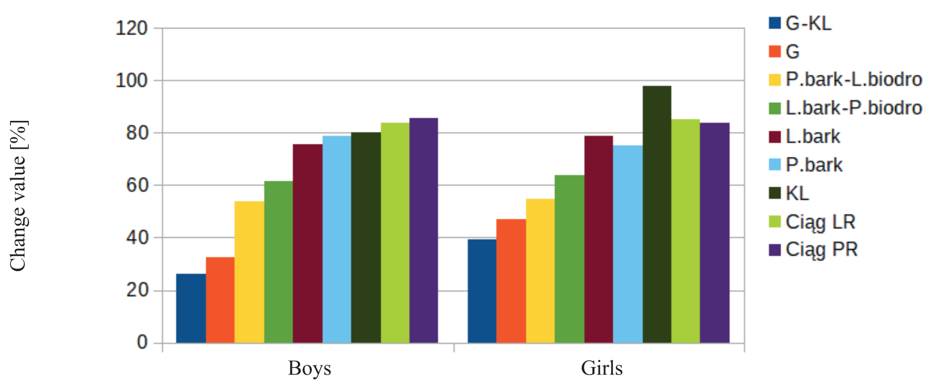

Fig. 14. Comparison of analyzed ways of carrying in terms of differences values of body posture features in F, S, T planes between 1st and 2nd measurement among 7-year-old students of both sexes n = 65

Legend
*G – back carrying; **G-KL** – back–chest carrying; **P.bark-L.biodro** – diagonal carrying on right shoulder-left hip; **L.bark-P.biodro** – diagonal carrying on left shoulder-right hip; **KL** – chest carrying; **P.bark** – right shoulder or in right hand carrying; **L.bark** – left shoulder or in left hand carrying; **Ciąg PR** – right hand drag mode carrying; **Ciąg LR** – left hand drag mode carrying*

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Tab. 4. Comparison of individual ways of carrying in terms of the differences values of body posture features in three planes between the 1st and 4th measurement among 7-year-olds boys n = 30

Way of carrying – boys	Change value after restitution (1–4)		
	M	Me	SD
1 Back-chest	9.69	6.02	13.57
2 Back	14.42	6.51	19.61
3 LLeft shoulder	15.08	10.84	18.30
4 Right shoulder – left hip	16.95	12.50	21.51
5 Right shoulder	22.96	12.77	53.65
6 Left shoulder – right hip	15.55	14.29	15.93
7 Chest	21.95	14.87	25.29
8 Right hand drag mode	29.92	22.67	31.90
9 Left hand drag mode	33.64	24.69	43.70
Kruskal-Wallis's Test: H = 37.223, p < 0.001**, R.I.:1 < 5,6,7,8,9, R.I.: 2 < 8.9			

Tab. 5. Comparison of individual ways of carrying in terms of the differences values of body posture features in three planes between the 1st and 4th measurement among 7-year-olds girls n = 35

Way of carrying – girls	Change value after restitution (1–4)		
	M	Me	SD
1 Back-chest	12.96	7.41	18.26
2 Right shoulder – left hip	16.35	10.16	22.49
3 Left shoulder – right hip	23.23	12.50	49.84
4 Left shoulder	22.96	12.77	53.65
5 Back	22.32	12.77	30.85
6 Right shoulder	22.01	16.22	23.61
7 Chest	46.56	24.32	103.80
7 Right hand drag mode	34.90	25.00	44.56
8 Left hand drag mode	48.17	25.32	116.35
Kruskal-Wallis's Test: H = 27.781, p < 0.001**, R.I.:1 < 8,9			

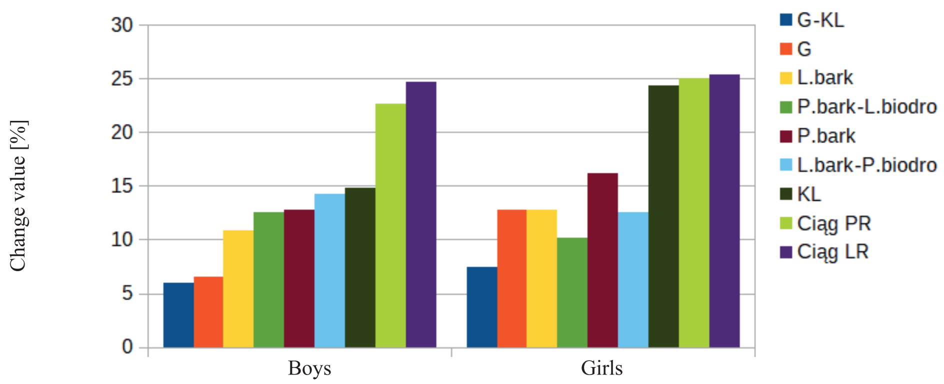

Fig. 15. Comparison of analyzed ways of carrying in terms of differences values of body posture features in F, S, T planes between 1st and 4th measurement among 7-year-old students of both sexes n = 65

Legend
G – back carrying; ***G-KL*** *– back–chest carrying;* ***P.bark-L.biodro*** *– diagonal carrying on right shoulder-left hip;* ***L.bark-P.biodro*** *– diagonal carrying on left shoulder-right hip;* ***KL*** *– chest carrying;* ***P.bark*** *– right shoulder or in right hand carrying;* ***L.bark*** *– left shoulder or in left hand carrying;* ***Ciąg PR*** *– right hand drag mode carrying;* ***Ciąg LR*** *– left hand drag mode carrying*

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Tab. 6. Comparison of individual ways of carrying in terms of the differences values of body posture features in three planes between the 1st and 2nd measurement among 7-year-olds students of both sexes n = 65

Way of carrying – total	Change value (1–2)		
	M	Me	SD
1 Back-chest	41.76	30.84	48.79
2 Back	56.18	42.58	63.90
3 Right shoulder – left hip	77.10	54.58	93.10
4 Left shoulder – right hip	116.11	62.82	261.17
5 Right shoulder	147.65	75.00	319.19
6 Left shoulder	145.28	76.84	321.87
7 Left hand drag mode	188.96	83.80	429.80
8 Right hand drag mode	146.28	85.26	206.92
9 Chest	125.96	91.19	149.78
Kruskal-Wallis's Test: H = 67.507, p < 0.001**, R.I.: 1,2 < 5,6,7,8,9			

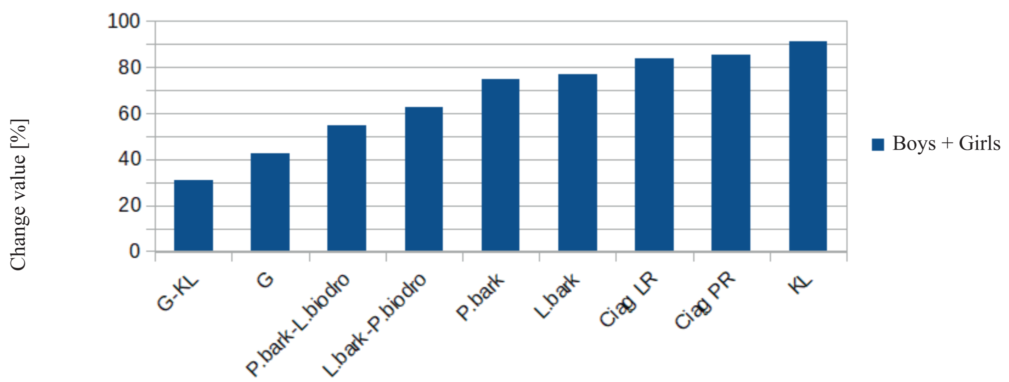

Fig. 16. Comparison of analyzed ways of carrying in terms of differences values of body posture features in F, S, T planes between 1st and 2nd measurement among 7-year-old students n = 65

Legend
G *– back carrying;* ***G-KL*** *– back–chest carrying;* ***P.bark-L.biodro*** *– diagonal carrying on right shoulder-left hip;* ***L.bark-P.biodro*** *– diagonal carrying on left shoulder-right hip;* ***KL*** *– chest carrying;* ***P.bark*** *– right shoulder or in right hand carrying;* ***L.bark*** *– left shoulder or in left hand carrying;* ***Ciąg PR*** *– right hand drag mode carrying;* ***Ciąg LR*** *– left hand drag mode carrying*

Tab. 4. Comparison of individual ways of carrying in terms of the differences values of body posture features in three planes between the 1st and 4th measurement among 7-year-olds boys n = 30

Way of carrying – total	Change value after restitution (1–4)		
	M	Me	SD
1 Back-chest	11.32	6.25	16.05
2 Back	18.37	10.68	25.97
3 Right shoulder – left hip	16.65	11.04	21.85
4 Left shoulder	19.02	11.83	39.99
5 Left shoulder – right hip	19.39	13.61	36.93
6 Right shoulder	22.48	13.87	41.15
7 Chest	34.26	19.03	76.02
8 Right hand drag mode	32.41	24.20	38.55
9 Left hand drag mode	40.90	24.85	87.55
Kruskal-Wallis's Test: H = 56.411, p < 0.001**, R.I.: 1 < 7,8,9, R.I.: 2,3,4 < 8,9, R.I.: 5 < 9			

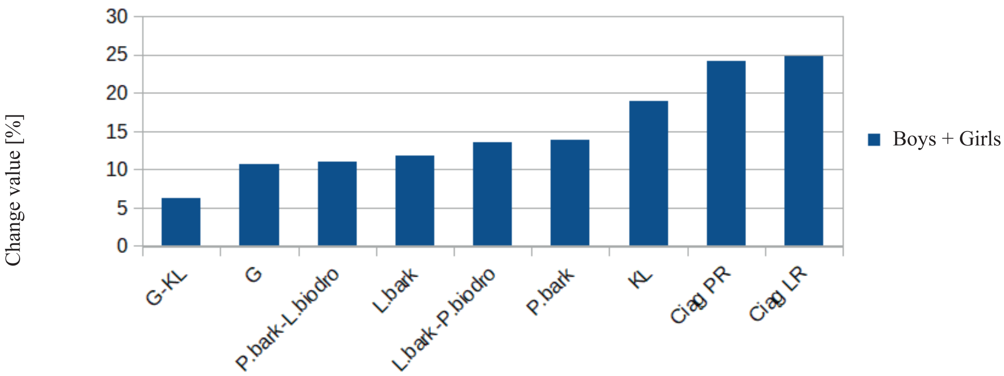

Fig. 17. Comparison of analyzed ways of carrying in terms of differences value of body posture features in F, S, T planes between 1st and 4th measurement among 7-year-old students n = 65

Legend
G *– back carrying;* ***G-KL*** *– back–chest carrying;* ***P.bark-L.biodro*** *– diagonal carrying on right shoulder-left hip;* ***L.bark-P.biodro*** *– diagonal carrying on left shoulder-right hip;* ***KL*** *– chest carrying;* ***P.bark*** *– right shoulder or in right hand carrying;* ***L.bark*** *– left shoulder or in left hand carrying;* ***Ciąg PR*** *– right hand drag mode carrying;* ***Ciąg LR*** *– left hand drag mode carrying*

Discussion

A review of the literature showed that studies focus mainly on the weight of the school bag, carrying time, age and gender of the student, less on the method of carrying, which may affect body posture [6]. The inconsistency of research results may be due to cultural differences, school curricula, the number of books and accessories, the quality of schoolbags and the physical abilities of students. Early research by Malhotra and Sengupt in 1965 on the consequences of different ways of carrying a school bag showed significant torso bend in the frontal plane and various disturbances in the symmetry of body posture [29, 30]. Repeatedly carrying, lifting and manipulating with a large mass of a backpack is associated with back muscles, straining the ligaments of the neck, shoulders and back. It can initiate abnormalities in body posture, leading to abnormal angular sizes of kyphosis, lordosis, shifting of the long axis of the body or scoliosis [15, 31]. Any load placed on the back between the shoulder blades will tend to extend the torso in the sagittal plane and shift the center of gravity backwards. The consequence will lead to a compensatory torso flexion forward to keep the body's center of gravity within the support area. In addition, the isometric tension of the postural muscles controlling these corrections is proportional to the weight of a carried school bag [5, 13, 9, 31, 32].

Forced correction of the trunk extension and head positioning may lead to forming force compression of the cervical spine vertebrae and the thoracolumbar junction. This will increase isometric muscle work and intensify fatigue [33] and pain in the back, neck, and head [34]. Grimmer et al. [31] found that carrying a backpack on the back at the level of the third lumbar vertebra caused the smallest postural shift. Kim et al. [35] suggested that carrying a backpack higher may normalize the foot arch. Rai et al. [36] believe that the most friendly schoolbags are those that have been specially designed and profiled in accordance with the shape of the lumbar spine, so that part of the load is carried just above the buttocks. Al Qallaf [15] and

Rai [36] believe that separate compartments in the backpack are also important, ensuring proper packing, organization and distribution of accessories. According to the authors, the largest and heaviest items should be at the bottom of the bag and put backward. This allows you to control the movement of the utensils in the backpack. According to other authors in the UK, the lobby of backpack manufacturers encouraged the use of schoolbags on wheels. However, it was not approved by students because of the difficulty of handling the container on the school stairs, corridors and buses, and storing them in school lockers.

The authors also claimed that the wheeled containers were significantly heavier than a regular backpack [14, 15, 4, 38]. Mackie et al. [6] showed that carrying a rucksack on the back can cause high tension of both straps, which will lead to high pressure on the shoulders. This can be rectified by adjusting length of the straps, backpack weight and the use of a hip belt [13, 36]. On the other hand, a tight fit of the backpack may limit chest movements, which in turn, may affect respiratory efficiency [6]. However, few students reported using a hip belt [15]. Hong et al. [37] concluded that carrying a school bag on the back with two shoulder straps is safer for climbing the stairs than a bag with one strap carried in hand. Other researchers point to the danger of deformation of the physiological curvatures of the spine and chest [33], lifestyle changes caused by postural disorders [34], an injury caused by bus or the school stairs fall [15]. In several publications, the authors drew attention to the varied duration of the school bag carrying. Students living in the city are usually taken by their parents' car together with the luggage, while others must often carry their bags for more than 20-30 minutes. The results of many studies have shown that the time of carrying a schoolbag affects the cervical and lumbar spine and the girdle of the upper limb, which may contribute to the pathogenesis of musculoskeletal ailments, both in the initiation and chronic phases [5, 8, 6, 13, 15, 39, 40-43]. It was found that children who reported tiredness while carrying a school bag for a long time experienced significantly more back pain [7, 15, 45]. Studies by Haselgrove et al. found that about half of the students carried a schoolbag for more than 30 minutes a day, with 85% carrying it on both shoulders, 54% complaining that it was too heavy, and 51% feeling very tired. The authors also showed that there were a higher risk of back pain and cervical spine pain among children carrying a school bag for more than 30 minutes a day and those taken by their parents by car [15, 46]. The results of other studies suggest that carrying a school bag with 10% of body weight is too heavy for students aged 6-7 to maintain the correct body posture for the relevant gender and age [40]. Subsequent studies have shown that the student's age has a significant negative relationship with the development of musculoskeletal disorders, especially among 11-14-year-old adolescents, in whom the spine is in a critical phase of growth and maturation [6, 7, 15, 47-50]. Several publications have shown that gender is an important factor in the development and recurrence of pain in school-aged children. Girls aged 6-10 years report pain more often than boys [36, 46, 49, 51-54]. This may be related to physiological differences or the greater weight of the girls' backpack. However, few studies have shown that girls carry heavier school bags than boys [41, 55, 56]. Other researchers found that the correlation between pain and the recommended percentage of the backpack weight in relation to

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the student showed that it was significantly positive among girls, and insignificant and negative among boys [3, 13, 15]. Dianat et al. [41] found no significant difference in this context. The authors also showed a relationship between gender and backpack carrying time. They also showed that long-term carrying of a school bag on one of the shoulders may strenghten an incorrect posture due to the asymmetry of the pelvis in the transversal plane. Hsu et al. indicate that children carrying backpacks on one shoulder must rebalance the weight of the bag by tilting their head to the opposite side [42]. Moreover, it creates high torque around the spine, which can cause scoliosis.

The conducted research shows that the safest way to carry school supplies are two smaller containers on the chest and back or a backpack on the back, whereas the most disruptive for the statics of body posture is carrying a backpack on the chest. Restitution of the values of the posture characteristics is the fastest after drag mode of the school bag with the left or right hand. It should be noted that the real weight of school supplies in the dragged container is not 4 kilograms, but about 2 kilograms. However, these are the two ways of carrying a container with school supplies, which, apart from carrying a backpack on the chest, disturb the body posture the most. It will be difficult to convince children and parents to change the way they carry a backpack. Contemporary criteria for choosing a school bag focus on colour, shape, quality of workmanship and material, which it is made from, rather than health benefits. Let's hope that the pro-ecological pre-orientation of lifestyle, which is being implemented more often, will cause a change in fashion and habits. Meanwhile, let's stay with carrying one backpack on the back. The current literature also provides evidence that the etiology of musculoskeletal pain is multifactorial and can be attributed to psychological, social and environmental factors, further complicating the identification of risk factors for musculoskeletal pain in adolescents [57].

It is puzzling that man, over many decades of experience, has intuitively chosen, by trial and error, the most optimal way of carrying for the body. Perhaps it was because of having free upper limbs. Women carrying babies with abducted lower limbs in a sling on their backs not only carried out prophylaxis of newborn hip joints and lowered the center of gravity to minimize the fall in life-threatening conditions, but also protected their spine against musculoskeletal ailments to the possibly greatest extent.

Conclusions

1. Carrying a four-kilogram weight of school supplies in two equal containers on the chest and back or one on the back disturbs body posture statics the least in a 7-year-old student.
2. The most complete restitution of the values of body posture features occurs after carrying two equal containers on the chest and back, or one on the back.
3. The greatest unfavorable changes in the values of postural features during carrying and restitution occur when a backpack is on the chest and dragged with a left or right hand.

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