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The role of body mass category in the development of faulty postures in school age children from rural areas

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Abstract

Objective. The aim of the study was to assess a relationship between Body Mass Index and incidence of abnormalities in selected parameters measured in the trunk area.

Design. Cross-sectional studies.

Setting. The research was conducted in a primary school in the rural area.

Participants. A group of 464 children, ranging in age from 6 to 16 years (234 boys and 230 girls), was recruited to participate in the study.

Interventions: Not applicable.

Outcome Measures. The examination of their body postures was conducted with the use of Zebris system. Body mass was determined using a body mass analyser Tanita MC – 780 MA. Body mass index (BMI) was calculated based on the acquired data.

Results. It has been noticed that people with overweight and obesity have incorrect position of the shoulders and pelvis in comparison to people with normal body weight. It was found that greater body mass (higher BMI index) coincided with a larger distance of the scapulae from the frontal plane (p=0.009).

Conclusions. Occurrence of bad postures in children is connected with their body mass category. Excessive weight appears to foster asymmetric position of the shoulders and scapulae. A failure to reduce excessive body mass may lead to more pronounced postural defects in the future.

Key words. Posture, Body Mass Index, Child, Rural Population

Strengths of this study

- The homogeneity and large size of the study group from rural areas.
- Objective and standardized measuring devices.
- Important and current issue confirming the connection between abnormal weight and incorrect body posture of the school-aged children

Limitations of this study

- One important but underexplored methodological limitation in the body mass composition research is that BMI is an imperfect measure. Although BMI has an elevated fat mass, BMI is not associated with fat.
- Can not entirely rule out the possibility of unmeasured or unknown confounding factors (parental genetic predisposition to higher BMI) that may account for the associations observed in this study. However, the homogeneity of the study population and comprehensive data on the risk factors minimized potential confounding.
- The participants included in this study were children in school age of European ancestry and it is unknown whether this findings could be generalized to other demographic or ethnic groups.

Introduction.

Child's correct body posture favourably affects the growth of the whole organism. It contributes for instance to the normal development and functioning of body organs, and improves effectiveness of motor activity and general well-being. If they are developed early in life, correct motor habits contribute to normal development of the muscles, joints and ligaments and provide beneficial stimulation to the child's growing skeleton. Even the smallest defects in the body posture of a school-age child can lead to the development of a habitual bad posture and, consequently, to health problems[1-2].

Body postures are subject to large changeability, which depends on such factors as age, sex, somatic type, ethnicity, environment and psychophysical condition. The major risk factors which may induce development of incorrect body posture include excessive body mass in relation to height and age[3-4]. Overweight and obesity in children, often associated with insufficient physical activity, lead to decreased use of the motor system; at the same time the increasing fat deposition contributes to overloading of the skeletal system, and this is a precondition for development of postural defects[5]. Children with body mass above the 95th centile (BMI z-score> +2 SD) far more often present postural defects involving the spine, thoracic cage, as well as lower limbs, and suffer from musculoskeletal pain[6].

Maciałczyk- Paprocka K. et al. report that postural deficits may affect as many as 74.1% of boys and 85.5% of girls with excessive body mass, and the predominant problems include knock knees and fallen arches[7]. Also, in the last decades there has been an unprecedented increase in the number of obese children, and the problem is associated with a number of functional disorders, i.e. pain, joint stiffness, reduced muscle strength, which contribute to development of poor posture. General rates of obesity among children worldwide are estimated at the level of 10% and, like in the case of postural deficits, the problem is constantly growing. The top of the ranking is dominated by the North American countries including the USA, where the level of overweight and obesity reaches the unprecedented rates of almost 32%. In Western Europe the rates reach up to 20%, whereas in Central and Eastern Europe they reach the level of 16% [8-9]. Overweight and obesity occur much more often among children and teenagers from rural areas, compared to towns and cities, mainly from multi-child families of low economic status, where the education level of the parents is quite low. The problem mainly affects population of the developmental age, and so the scale of the phenomenon is a matter of concern[10].

According to numerous clinical data, a child's body posture is particularly at risk during the periods of the fastest pace of growth, which mainly include the time corresponding to the start of school education (6-7 years of life) and the puberty period (12-16 years of life). In view of the above, research focusing on body posture in school-age children, taking into account body mass, is of particular importance[11-12]. The aim of the study was to assess a relationship between Body Mass Index and incidence of abnormalities in selected parameters measured in the trunk area.

Material and methods

The study was accepted by the local Bioethical Commission on 28 June 2016 (Consent No. 2016/06/28). The study does not report on or involve the use of any animals. The participants were informed about the course of the study. The examinations were conducted after written consent was received from the directors of schools, parents of children participating in the project and the children themselves.

Participants

464 school-age children, from 6 to 16 years of age (234 boys and 230 girls) were qualified for the study (from June 2016 to March 2018), designed to be conducted in schools in rural region. Examinations were conducted in nurses' offices in the relevant educational

facilities. In order to ensure the reliability of the measurements, all the subjects were examined in the morning, on an empty stomach, by the same members of a qualified team.

The study applied the following inclusion criteria: age from 6-16 years and consent of the parents and children for the examination. Exclusion criteria: metal implants, electronic implants, periods in girls, epilepsy, failure to refrain from eating in the morning, lack of consent of the parents and children.

Body Posture

The study was conducted with the use of Zebris system. At the start, topographic points were marked on the body of each subject to correspond with: acromion right and left, posterior iliac spine right and left, anterior iliac spine right and left, iliac crest right and left, the point where the thoracic spine meets the lumbar spine, Th 12/L1, inferior angle of the scapula right and left, spinous process of the spine.

During the examination the subject, wearing no shoes, was asked to assume a relaxed standing position, with his/her back to the measurement unit, and did not have with him/her any devices interfering with the transfer of data (e.g. smartwatch, mobile phone).

Following calibration of the horizontal plane, the subject's body posture was examined. The measurement, performed with an ultrasound pointer, involved registration of the topographic points marked earlier on the subject's body. The measurements were performed three times in each subject and the spine line was scanned 9 times (three times in each examination). The final result was the mean value of the measurements[13].

The following were taken into account in the assessment of the posture:

- in the sagittal projection: the distance of the right scapula (SDR in mm), the distance of the left scapula (SDL in mm), the difference in the distance of the scapula (SDD in mm),
- in the frontal projection: the difference in the height of the pelvis on the right side (PHDR in mm), the difference in the height of the pelvis on the left side (PHDL in mm), the difference in the height of the right shoulder (SHDR in mm), the difference in the height of the left shoulder (SHDL in mm), pelvic/shoulder obliquity.

Anthropometric Measurements and Bioelectrical Impedance

Body height was measured with an accuracy up to 0.1 cm, with the use of a portable stadiometer PORTSTAND 210. Body mass was measured with the analyzer Tanita MC – 780 MA with an accuracy up to 0.1 kg. The examinations were conducted in standard conditions.

During the measurement, each subject was barefoot and dressed in underwear, and was asked to assume upright extended position.

The data acquired during the measurement of body height and mass were used to calculate the body mass index (BMI). The BMI value was examined by reference to the growth chart, taking into account sex and age. Based on the achieved percentile ranking, the BMI status was classified in the following four categories of obesity (BMI ≥ 95. percentile), overweight (BMI ≥ 85. percentile and <95. percentile), normal body mass (BMI <85. percentile and ≥ 5. percentile), and underweight (BMI <5. percentile)[14].

Data analysis

Spearman's rank correlation test was applied to assess the correlation between the BMI and the body posture. Differences in the selected parameters between the groups were analysed using Kruskal-Wallis and Mann-Whitney tests. The accepted level of significance was $\alpha < 0.05$. All calculations and statistical analyses were performed with the use of STATISTICA ver. 10.0 (StatSoft, Poland).

Results

The characteristics of the study group are shown in Table 1 and 2. On average the subjects were 11.52 years old (SD=2.99). The mean body height was 152.48cm (SD=17.77) and the mean body mass was 45.39kg (SD=16.81). On average the subjects' body mass index was 18.8kg/m2 (SD=3.75) (Tab. 1).

Table 1. Characteristics of the study group

	n	Mean	Me	SD	Q_1	Q_3
All						
Age [years]	464	11.52	12.00	2.99	9.00	14.00
Height [cm]	464	152.48	155.50	17.77	137.00	167.00
Weight [kg]	464	45.39	44.75	16.81	30.40	56.45
BMI [kg/m²]	464	18.80	18.24	3.75	16.10	20.97
Girls						
Age [years]	230	11.55	12	2.96	9.00	14.00
Height [cm]	230	150.46	155	15.69	136.00	163.00
Weight [kg]	230	43.63	44.35	15.38	29.70	54.60
BMI [kg/m²]	230	18.64	18.00	3.87	15.90	20.90
Boys						

Age [years]	234	11.49	12	3.02	9.00	14.00
Height [cm]	234	154.46	156.50	19.43	138.00	172.00
Weight [kg]	234	47.13	45	17.97	31.80	60.00
BMI [kg/m²]	234	18.94	18.56	3.63	16.40	21.05

Me: median; n: number of subjects; Q_1: first quartile; Q_3: third quartile SD: standard deviation;

Taking into consideration the age of the study group, statistical significance was identified in the following parameters: pelvis rotation (p=0.049), pelvis obliquity (p=0.002), pelvis height on the right side (p=0.044), pelvis height on the left side (p=0.022), shoulder height on the right side (p=0.004). A correlation between the age of the subjects and their BMI was found (Tab.2).

Table 2. The assessment of the correlation between the body posture parameters and the age.

Variables	R	*p*
Pelvic torsion [degree] & Age	-0,09	0,049
Pelvic obliquity [degree] & Age	-0,14	**0,002**
Pelvic/shoulder obliquity [degree] & Age	0,00	0,929
Scapula distance difference [mm] & Age	-0,04	0,389
Pelvic height difference right [mm] & Age	0,09	**0,044**
Pelvic height difference left [mm] & Age	-0,11	**0,022**
Shoulder height difference right [mm] & Age	0,24	**0,004**
Shoulder height difference left [mm] & Age	0,01	0,877
BMI & Age	0,58	**<0,001**

p: test probability value; R- rang correlation of Sperman.

Based on the BMI percentiles the categorization of the body mass of the study group was performed. Underweight was found in 6.8% of the boys and in 7.4% of the girls. Normal body mass was identified in 72.7 % of the boys and 74.8 % of the girls. Overweight was found in 11.5% of the boys and in 12.2 % of the girls, and obesity was identified in 9 % of the boys

Shoulder distance from the frontal plane							
BMI category	**N**	**Mean (SD) (95%CI)**	**Me**	**Min.**	**Max.**	**Q1**	**Q3**
Underweight	33	4,58 (6,07) (3,13-6,02)	3,00	0,00	18,00	2,00	6,00
Normal Body Mass	342	6,90 (6,13) (6,27-7,53)	5,50	0,00	32,00	2,00	9,00
Overweight	55	8,04 (6,16)	6,00	0,00	28,00	4,00	10,00

and in 5.7% of the girls (Tab. 3).

Table 3. The body mass category based on BMI depending on the sex

BMI Category	**Sex**					
	Boys		**Girls**		**Total**	
	n	**%**	**N**	**%**	**n**	**%**
Underweight	16	6,8%	17	7,4%	33	7,1%
Normal body mass	170	72,7%	172	74,8%	342	73,7%
Overweight	27	11,5%	28	12,2%	55	11,9%
Obesity	21	9,0%	13	5,6%	34	7,3%
Total	234	100,0%	230	100,0%	464	100,0%
Significance(p)	$\chi^2(3)=1{,}90$ p=0,591					

%: percent of subjects; n: number of subjects; *p*: test probability value; χ^2- chi-square Pearson test.

Analyses of the correlations between BMI and the body posture parameters measured in the trunk area showed statistically significant differences in the case of the distance of the scapulae from the corresponding plane. Statistical significance was not observed in the position of the pelvis (H=5.33 p=0.150), and the BMI index. It was found that greater body mass (higher BMI index) coincided with a larger distance of the scapulae from the frontal plane (H=11.47 p=0.009). It has been noticed that people with overweight and obesity have incorrect position of the shoulders and pelvis in comparison to people with normal body weight. (Tab. 4).

		(6,34-9,73)					
Obesity	34	9,50 (6,10) (6,44-12,56)	7,00	0,00	41,00	4,00	10,00
		H=11,47 p=0,009					
Shoulder position							
BMI category	**N**	**Mean (SD) (95%CI)**	**Me**	**Min.**	**Max.**	**Q1**	**Q3**
Underweight	33	6,96 (6,90) (4,98-8,93)	5,50	0,10	19,60	2,10	10,80
Normal Body Mass	341	10,00 (6,72) (9,16-10,84)	8,00	0,10	59,80	4,10	14,60
Overweight	55	10,66 (8,45) (8,33-12,99)	7,40	0,50	32,80	3,70	16,50
Obesity	34	11,04 (7,74) (7,99-14,09)	9,35	0,50	39,90	5,20	15,10
		H=5,43 p=0,143					
Pelvis position							
BMI category	**N**	**Mean (SD) (95%CI)**	**Me**	**Min.**	**Max.**	**Q1**	**Q3**
Underweight	33	9,27 (5,57) (6,83-11,72)	7,70	0,10	23,20	3,60	12,50
Normal Body Mass	342	7,97 (7,90) (7,25-8,68)	6,30	0,00	35,60	2,60	11,10
Overweight	55	9,96 (8,62) (7,67-12,24)	7,40	0,10	37,40	4,50	14,70
Obesity	34	10,07 (8,74) (7,37-12,77)	7,50	0,20	28,80	4,70	15,90
		H=5,33 p=0,150					

Table 4. The correction between the body mass category, based on BMI and the body posture

H: Kruskall-Wallis test; SD: standard deviation; CI: confidence interval; Max: maximum value; Me: median; Min: minimum value; n: number of subjects; *p*: test probability value; Q1: quartile 25.; Q3: quartile 75.

Discussion

Start of school education marks the period when a child's posture is very sensitive to changes due to the new co-occurring environmental factors. The adverse risk factors include mainly the long periods when the child remains seated in class and during other school-related activities, wearing a heavy schoolbag, asymmetry of schoolbag straps, or asymmetric position of schoolbag worn by the child, as well as more frequently occurring fatigue and stressful experiences at school; all these may promote different postural habits involving more pronounced thoracic kyphosis and downward head positioning[15-16]. As a result, natural physical activity is restricted to a degree, and children tend to spend their free time in a passive way, in front of a computer or TV. This situation produces adverse effects because sedentary lifestyle not only increases the risk of excessive body mass in the children but also contributes to the development of postural deficits.

The time when a child attends school may produce beneficial effects as it is likely to foster development of habits related to physical activity and sport, of extreme importance for ensuring child's normal physical development[17-18]. This is equally important to enable early diagnosis, since body posture in adults to a large degree is a result of early stages of development[19-20]. It should be emphasised that early and non-invasive body posture studies among school age children, with the use of the external diagnostic systems, are crucially important.

The current study enabled assessment of body posture parameters in relation to the body mass index category identified in children going to primary and middle schools. In the study group underweight was identified in 6.8% of the boys and in 7.4% of the girls. Normal body mass was found in 72.7% of the boys and 74.8% of the girls. Overweight was identified in 11.5% of the boys and in 12.2% of the girls. Obesity was found in 9% of the boys and in 5.7% of the girls. These values are similar to the data published by the WHO, according to which in 2016 overweight and obesity were found in 18% of children and adolescents between 5 and 19 years of age[21].

The current study shows a strong correlation between the BMI and the body posture parameters. Also a correlation was found between the height of the left shoulder and excessive weight. Children with higher BMI were far more often found with decreased distance between the scapula and the frontal plane.

A study by Batistão et al., involving 288 school age children, reported asymmetry in the position of shoulders in 74.3% of the subjects; the problem was particularly pronounced among older children, aged 13-15, which supports the claim that this type of deficit may be associated with the rapid growth of specific segments of the body occurring during puberty. In fact the problem appears to be more closely related to age than to body mass. These asymmetries in the position of shoulders may also be explained by varied overloads of the body linked with environmental factors, i.e. asymmetrical body posture in sitting position and carrying of schoolbags on one side, a habit frequently observed in teenagers[22]. As it is shown by the present study, incorrect body mass may also be a contributing factor, producing similar effects.

Many authors have discussed the relation of body posture and BMI. An important problem was pointed out by Pausić and others as well as Barszczyk and others who claim, that both excessively low and excessively high body mass lead to negative changes in the position of the spine, lower extremities, as well as feet[23-24]. Partly similar results were reported by Walicka- Cupryś et al. These authors examined children with genu valgum and found that the defect was most common in overweight children (28.6%), followed by children with normal weight (14.7%), and it was least frequent in underweight subjects (10.7 %)[25].

Bogucka and others in their study examined body posture of 227 school age children. The authors observed that in the subgroup of underweight girls, the protruding scapulae were present significantly more often than in the peers with the normal weight and height. However, underweight boys more frequently than their peers with normal BMI were characterized by the asymmetry of the scapulae towards the spine. It was suggested that faulty body postures in the scapulae area occurred more frequently in underweight subjects ($r = 0.359$; $p<0.001$)[26].

Likewise, Grivas et al. reported that excessively low BMI is more frequently associated with body asymmetry in teenagers[27]. Similar conclusions can be drawn from the study by Grabara et. Al[28]. The present study identified an opposite tendency. Children with greater body mass (overweight and obesity) were found with larger distance between the scapulae and the frontal plane ($H=11.47$ $p=0.009$). However, all the above findings suggest that height and weight related abnormalities are closely linked with postural defects during developmental age.

People with overweight and obesity show higher abnormalities in the position of the shoulders and pelvis than people with normal weight. Age-related analysis of the study group showed a negative correlation between the subjects' age and oblique position of the pelvis ($r=0.09$, $p=0.049$). Similarly, Rosa et al. reported low rates of incorrect pelvis position in grade I-III children. No related abnormalities were identified in 68% of the girls and 72% of the boys[29]. Different findings were reported by Słoń, who performed similar measurements in a group of 162 primary school students (grades IV-VI) in Warsaw. The author observed incorrect position of the pelvis in 77% of the subjects[30].

The current study enabled assessment of BMI in relation to the incidence of abnormalities in selected parameters measured in the trunk area. In the literature we can find data related to the growing number of children and teenagers with excessive body weight, as well as more and more evidence proving adverse health related effects of overweight and obesity. Excessive body weight to a large extend contributes to postural defects, and adversely affects health condition, as well as body water and electrolyte balance. That is why it was justifiable to specify the body mass category based on BMI and to investigate its influence on the body posture in school-age children. In view of the fact that obesity is more and more common among children, schools should provide instruction on healthy diet and encourage students to take up physical activity.

Conclusions

Bad postures in children are linked with their body mass category. With the occurrence of overweight and obesity, the body posture of the children is incorrect within the trunk. Therefore, overweight and obesity among children and adolescents should be prevented by introducing educational programs for whole families and showing them the negative impact of obesity on body posture.

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Authors' contributions

WR- conception and design, revising critically for intellectual content, final approval of the manuscript, JL- acquisition of data, drafting the article, final approval of the manuscript; JB- acquisition of data, revising critically for intellectual content, final approval of the manuscript; MA- analysis and interpretation of data, drafting the article, final approval of the manuscript; Weres Aneta,- analysis and interpretation of data, drafting the article, final approval of the manuscript; RB- acquisition of data, drafting the article, final approval of the manuscript, GI- acquisition of data, revising critically for intellectual content, final approval of the manuscript; ECL- acquisition of data, revising critically for intellectual content, final approval of the manuscript, SP- acquisition of data, drafting the article, final approval of the manuscript; TP conception and design, revising critically for intellectual content, final approval of the manuscript.

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Conflicts of interest

The authors declare no conflict of interest.

Data sharing statement

The datasets generated and/or analysed during the current study are not publicly available due to protect the students' privacy, but are available from the corresponding author on reasonable request.

Reporting checklist for qualitative study.

Based on the SRQR guidelines.

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		Reporting Item	Page Number
	#1	Concise description of the nature and topic of the study identifying the study as qualitative or indicating the approach (e.g. ethnography, grounded theory) or data collection methods (e.g. interview, focus group) is recommended	1
	#2	Summary of the key elements of the study using the abstract format of the intended publication; typically includes background, purpose, methods, results and conclusions	2
Problem formulation	#3	Description and signifcance of the problem / phenomenon studied: review of relevant theory and empirical work; problem statement	3-4
Purpose or research question	#4	Purpose of the study and specific objectives or questions	4
Qualitative approach and research paradigm	#5	Qualitative approach (e.g. ethnography, grounded theory, case study, phenomenolgy, narrative research) and guiding theory if appropriate; identifying the research paradigm (e.g. postpositivist, constructivist / interpretivist) is also recommended; rationale. The rationale should briefly discuss the justification for choosing that theory, approach, method or technique rather than other options available; the assumptions and limitations implicit in those choices and how those choices influence study conclusions and transferability. As appropriate the rationale for several items might be discussed together.	4-6
Researcher characteristics and reflexivity	#6	Researchers' characteristics that may influence the research, including personal attributes, qualifications / experience, relationship with participants, assumptions and / or presuppositions; potential or actual interaction between researchers' characteristics and the research questions, approach, methods, results and / or transferability	4-6

Context	*#7*	*Setting / site and salient contextual factors; rationale*	*4-6*
Sampling strategy	*#8*	*How and why research participants, documents, or events were selected; criteria for deciding when no further sampling was necessary (e.g. sampling saturation); rationale*	*4-5*
Ethical issues pertaining to human subjects	*#9*	*Documentation of approval by an appropriate ethics review board and participant consent, or explanation for lack thereof; other confidentiality and data security issues*	*4*
Data collection methods	*#10*	*Types of data collected; details of data collection procedures including (as appropriate) start and stop dates of data collection and analysis, iterative process, triangulation of sources / methods, and modification of procedures in response to evolving study findings; rationale*	*n/a*
Data collection instruments and technologies	*#11*	*Description of instruments (e.g. interview guides, questionnaires) and devices (e.g. audio recorders) used for data collection; if / how the instruments(s) changed over the course of the study*	*4*
Units of study	*#12*	*Number and relevant characteristics of participants, documents, or events included in the study; level of participation (could be reported in results)*	*4-5*
Data processing	*#13*	*Methods for processing data prior to and during analysis, including transcription, data entry, data management and security, verification of data integrity, data coding, and anonymisation / deidentification of excerpts*	*6*
Data analysis	*#14*	*Process by which inferences, themes, etc. were identified and developed, including the researchers involved in data analysis; usually references a specific paradigm or approach; rationale*	*6*
Techniques to enhance trustworthiness	*#15*	*Techniques to enhance trustworthiness and credibility of data analysis (e.g. member checking, audit trail, triangulation); rationale*	*n/a*
Syntheses and interpretation	*#16*	*Main findings (e.g. interpretations, inferences, and themes); might include development of a theory or model, or integration with prior research or theory*	*6-10*
Links to empirical data	*#17*	*Evidence (e.g. quotes, field notes, text excerpts, photographs) to substantiate analytic findings*	*n/a*
Intergration with prior work, implications, transferability and contribution(s) to the field	*#18*	*Short summary of main findings; explanation of how findings and conclusions connect to, support, elaborate on, or challenge conclusions of earlier scholarship; discussion of scope of application / generalizability; identification of unique contributions(s) to scholarship in a discipline or field*	*10-12*
Limitations	*#19*	*Trustworthiness and limitations of findings*	*3*
Conflicts of interest	*#20*	*Potential sources of influence of perceived influence on study conduct and conclusions; how these were managed*	*16*
Funding	*#21*	*Sources of funding and other support; role of funders in data collection, interpretation and reporting*	*16*

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The role of body mass category in the development of faulty postures in school age children from rural areas- cross-sectional study

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The role of body mass category in the development of faulty postures in school age children from rural area- cross-sectional study

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Abstract

Objective. The aim of the study was to assess a relationship between Body Mass Index and incidence of abnormalities in selected parameters measured in the trunk area.

Design. Cross-sectional studies.

Setting. The research was conducted in a primary school in the rural area.

Participants. A group of 464 children, ranging in age from 6 to 16 years (234 boys and 230 girls), was recruited to participate in the study.

Outcome Measures. The examination of their body postures was conducted with the use of Zebris system. Body mass was determined using a body mass analyser Tanita MC – 780 MA. Body mass index (BMI) was calculated based on the acquired data.

Results. It has been noticed that children with overweight and obesity have incorrect position of the shoulders and pelvis in comparison to children with normal body weight. It was found that greater body mass (higher BMI index) coincided with a larger distance of the scapulae from the frontal plane (p=0.009).

Conclusions. Increase in children's BMI produces adverse effects in the position of shoulder blades, reflected by their greater distance from the frontal plane. Increase in BMI is not significantly related to the position of shoulder joints or pelvis, however the subjects with overweight or obesity presented a greater difference in the position of shoulder joints and pelvis.

Key words. Posture, Body Mass Index, Child, Rural Population

Strengths of this study

- The homogeneity and large size of the study group from rural areas.
- Objective and standardized measuring devices.
- Important and current issue confirming the connection between abnormal weight and incorrect body posture of the school-aged children

Limitations of this study

- Can not entirely rule out the possibility of unmeasured or unknown confounding factors (parental genetic predisposition to higher BMI) that may account for the associations observed in this study. However, the homogeneity of the study population and comprehensive data on the risk factors minimized potential confounding.
- Other elements which can affect trunk muscle tension include muscular problems, e.g. neonatal hypertonia or hypotonia and their consequences in childhood, as well as past injuries and chronic neurological diseases and these should be taken into account in the future studies.

Introduction

Child's correct body posture favourably affects the growth of the whole organism [1]. It contributes for instance to the normal development and functioning of body organs, and improves effectiveness of motor activity and general well-being [2]. If they are developed early in life, correct motor habits contribute to normal development of the muscles, joints and ligaments and provide beneficial stimulation to the child's growing skeleton. Even the smallest defects in the body posture of a school-age child can lead to the development of a habitual bad posture and, consequently, to health problems [3-4].

Body postures are subject to large changeability, which depends on such factors as age, sex, somatic type, ethnicity, environment and psychophysical condition. The major risk factors which may induce development of incorrect body posture include excessive body mass in relation to height and age [5-6]. A vast majority of overweight or obese children live in developing countries with growth rates over 30% higher compared to the developed countries. If the current trends continue, the number of overweight or obese infants worldwide will increase to 70 million in 2025 [7]. Overweight and obesity in children, often associated with insufficient physical activity, lead to decreased use of the motor system; at the same time the increasing fat deposition contributes to overloading of the skeletal system, and this is a precondition for development of postural defects [8]. Children with body mass above the 95th centile (BMI z-score> +2 SD) far more often present postural defects involving the spine, thoracic cage, as well as lower limbs, and suffer from musculoskeletal pain [9].

Maciałczyk- Paprocka K. et al. report that postural deficits may affect as many as 74.1% of boys and 85.5% of girls with excessive body mass, and the predominant problems include knock knees and fallen arches [10]. Also, in the last decades there has been an unprecedented increase in the number of obese children, and the problem is associated with a number of functional disorders, i.e. pain, joint stiffness, reduced muscle strength, which contribute to development of poor posture. General rates of obesity among children worldwide are estimated at the level of 10% and, like in the case of postural deficits, the problem is constantly growing. The top of the ranking is dominated by the North American countries including the USA, where the level of overweight and obesity reaches the unprecedented rates of almost 32%. In Western Europe the rates reach up to 20%, whereas in Central and Eastern Europe they reach the level of 16% [11-12].

According to numerous clinical data, a child's body posture is particularly at risk during the periods of the fastest pace of growth, which mainly include the time corresponding to the start of school education (6-7 years of life) and the puberty period (12-16 years of life). In view of the above, research focusing on body posture in school-age children, taking into account body mass, is of particular importance [12-14].

According to the data reported in the literature, the rate of overweight and obesity in children is consistently increasing [15]. A similar situation is observed in the case of postural defects [16]. In previously conducted studies numerous authors have investigated factors affecting obesity or postural defects, usually however, focusing on these problems separately [15,17-18]. There are no studies which would link these two aspects to each other. Additionally, majority of the reports are related to children from urban areas, more affected by globalisation, and those from highly developed countries where children more commonly present musculoskeletal disorders related to incorrect body posture [19-21]. On the other hand, it would be worthwhile to carry out related research focusing on rural areas where children grow up in more natural environments, have more opportunities for outdoors activity, and better access to healthy food, yet they are also frequently affected by the two problems [22-23]. Overweight and obesity occur much more often among children and teenagers from rural areas, compared to towns and cities, mainly from multi-child families of low economic status, where the education level of the parents is quite low. The problem mainly affects population of the developmental age, and so the scale of the phenomenon is a matter of concern [24]. There is also a scarcity of studies examining body posture with objective measurement methods, such as Zebris APGMS Pointer, which performs detailed assessment of static body posture, range of motion and the shape of spinal curves [10].

The aim of the study was to assess a relationship between Body Mass Index and abnormalities in the trunk area, i.e. scapula distance difference, pelvic height difference and shoulder height difference in children living in rural communities.

Material and methods

The study was accepted by the local Bioethical Commission on 28 June 2016 (Consent No. 2016/06/28). The participants were informed about the course of the study. The examinations were conducted after written consent was received from the directors of schools, parents of children participating in the project and the children themselves.

Participants

Firstly, the sample size was calculated with reference to the total number of children (n= 3790) living in the rural area in the relevant region, with a 95% confidence level and a confidence interval of 0.05. It was calculated that the minimum sample size should be 349. The study took into account 464 school-age children, from 6 to 16 years of age (234 boys and 230 girls). They were qualified for the study (from June 2016 to March 2018), designed to be conducted in schools in rural region. Examinations were conducted in nurses' offices in the relevant educational facilities. In order to ensure the reliability of the measurements, all the subjects were examined in the morning, on an empty stomach, by the same members of a qualified team.

The study applied the following inclusion criteria: age from 6-16 years and consent of the parents and children for the examination. Exclusion criteria: metal implants, electronic implants, periods in girls, epilepsy and failure to refrain from eating in the morning at the day of the study. Children with a diagnosis of neonatal hypertonia or hypotonia, chronic neurological diseases or past injuries and surgical interventions during the last 6 months before examination were excluded from the study group.

Body Posture

The study of body posture was conducted with the use of Zebris APGMS Pointer system. An examination is carried out with an ultrasound pointer used to mark characteristic anatomical locations corresponding to specific bone structures on the patient's body. These locations are treated by the software as passive points. Their position and movement are tracked and recorded in real time by the software. The study was carried out in static conditions, in motionless standing position.

The reference markers were three miniature transmitters attached to the patient with flexible straps. These define points, with reference to which the device specifies the positions of pointer markers. By applying the pointer to the characteristic anatomical locations on the body and by activating the device it is possible to visualise the relevant points on the screen and to create three-dimensional image of the body posture [25-26].

At the start, topographic points were marked on the body of each subject to correspond with: acromion right and left, posterior iliac spine right and left, anterior iliac spine right and left, iliac crest right and left, the point where the thoracic spine meets the lumbar spine, Th 12/L1, inferior angle of the scapula right and left, spinous process of the spine. A sample result of the examination as well as the defined topographic points are shown in Figure 1 (Fig.1).

Based on the defined topographic points, the software computes the values of selected body posture parameters. The following were taken into account in the assessment of the posture:

- in the sagittal projection: scapula distance difference (SDD in mm) (Fig.2),
- in the frontal projection: pelvic height difference (PHD in mm) and shoulder height difference (SHD in mm) (Fig.3).

During the examination the subject, wearing no shoes, was asked to assume a relaxed standing position, with his/her back to the measurement unit, and did not have with him/her any devices interfering with the transfer of data (e.g. smartwatch, mobile phone).

Following calibration of the horizontal plane, the subject's body posture was examined. The measurement, performed with an ultrasound pointer, involved registration of the topographic points marked earlier on the subject's body. The measurements were performed three times in each subject and the spine line was scanned 9 times (three times in each examination). The final result was the mean value of the measurements [27].

Anthropometric Measurements and Bioelectrical Impedance

Body height was measured with an accuracy up to 0.1 cm, with the use of a portable stadiometer PORTSTAND 210. Body mass was measured with the analyzer Tanita MC – 780 MA with an accuracy up to 0.1 kg. The examinations were conducted in standard conditions. During the measurement, each subject was barefoot and dressed in underwear, and was asked to assume upright extended position.

The data acquired during the measurement of body height and mass were used to calculate the body mass index (BMI). The BMI value was examined by reference to the growth chart, taking into account sex and age. Based on the achieved percentile ranking, the BMI status was classified in the following four categories of obesity (BMI ≥ 95. percentile), overweight (BMI ≥ 85. percentile and <95. percentile), normal body mass (BMI <85. percentile and ≥ 5. percentile), and underweight (BMI <5. percentile) [28].

Data analysis

Spearman's rank correlation test was applied to assess the correlation between the BMI and the body posture. Differences in the selected parameters between the groups were analysed using Kruskal-Wallis test. The accepted level of significance was $\alpha < 0.05$. All calculations and statistical analyses were performed with the use of STATISTICA ver. 10.0 (StatSoft, Poland).

Patient and public involvement

Patients and public were not involved in the design of the study. The parents of the children participated in the study have received the results of the measurement and recommendations about treatment opportunities.

Results

The characteristics of the study group are shown in Table 1 and 2. On average the subjects were 11.52 years old (SD=2.99). The mean body height was 152.48cm (SD=17.77) and the mean body mass was 45.39kg (SD=16.81). On average the subjects' body mass index was 18.8kg/m2 (SD=3.75) (Tab. 1).

Table 1. Characteristics of the study group

	N	Mean	Me	SD	Q_1	Q_3
			All			
Age [years]	464	11.52	12.00	2.99	9.00	14.00
Height [cm]	464	152.48	155.50	17.77	137.00	167.00
Weight [kg]	464	45.39	44.75	16.81	30.40	56.45
BMI [kg/m^2]	464	18.80	18.24	3.75	16.10	20.97
			Girls			
Age [years]	230	11.55	12	2.96	9.00	14.00
Height [cm]	230	150.46	155	15.69	136.00	163.00
Weight [kg]	230	43.63	44.35	15.38	29.70	54.60
BMI [kg/m^2]	230	18.64	18.00	3.87	15.90	20.90
			Boys			
Age [years]	234	11.49	12	3.02	9.00	14.00
Height [cm]	234	154.46	156.50	19.43	138.00	172.00
Weight [kg]	234	47.13	45	17.97	31.80	60.00
BMI [kg/m^2]	234	18.94	18.56	3.63	16.40	21.05

Me: median; n: number of subjects; Q_1: first quartile; Q_3: third quartile SD: standard deviation;

Based on the BMI percentiles the categorization of the body mass of the study group was performed. Underweight was found in 6.8% of the boys and in 7.4% of the girls. Normal body mass was identified in 72.7 % of the boys and 74.8 % of the girls. Overweight was found in 11.5% of the boys and in 12.2 % of the girls, and obesity was identified in 9 % of the boys and in 5.7% of the girls (Tab. 2).

Table 2. The body mass category based on BMI depending on the sex

BMI Category	**Sex**					
	Boys		**Girls**		**Total**	
	N	**%**	**n**	**%**	**N**	**%**
Underweight	16	6,8%	17	7,4%	33	7,1%
Normal body mass	170	72,7%	172	74,8%	342	73,7%
Overweight	27	11,5%	28	12,2%	55	11,9%
Obesity	21	9,0%	13	5,6%	34	7,3%
Total	234	100,0%	230	100,0%	464	100,0%
Significance(p)	$\chi^2(3)=1{,}90$ p=0,591					

%: percent of subjects; n: number of subjects; *p*: test probability value; χ^2- chi-square Pearson test.

Analyses of the correlations between BMI and the body posture parameters measured in the trunk area showed statistically significant differences in the case of the distance of the scapulae from the corresponding plane. Statistical significance was not observed in the position of the pelvis (H=5.33 p=0.150), and the BMI index. It was found that greater body mass (higher BMI index) coincided with a larger distance of the scapulae from the frontal plane (H=11.47 p=0.009). It has been noticed that people with overweight and obesity have incorrect position of the shoulders and pelvis in comparison to people with normal body weight. (Tab. 3).

Table 3. The correction between the body mass category, based on BMI and the body posture

Scapula distance difference (SDD in mm)								
BMI category	**N**	**Mean (95%CI)**	**SD**	**Me**	**Min.**	**Max.**	**Q1**	**Q3**
Underweight	33	4,58 (3,13-6,02)	6,07	3,00	0,00	18,00	2,00	6,00
Normal Body Mass	342	6,90 (6,27-7,53)	6,13	5,50	0,00	32,00	2,00	9,00
Overweight	55	8,04 (6,34-9,73)	6,16	6,00	0,00	28,00	4,00	10,00
Obesity	34	9,50 (6,44-12,56)	6,10	7,00	0,00	41,00	4,00	10,00
H=11,47 p=0,009								

Shoulder height difference (SHD in mm)								
BMI category	**N**	**Mean (95%CI)**	**SD**	**Me**	**Min.**	**Max.**	**Q1**	**Q3**
Underweight	33	6,96 (4,98-8,93)	6,90	5,50	0,10	19,60	2,10	10,80
Normal Body Mass	342	10,00 (9,16-10,84)	6,72	8,00	0,10	59,80	4,10	14,60
Overweight	55	10,66 (8,33-12,99)	8,45	7,40	0,50	32,80	3,70	16,50
Obesity	34	11,04 (7,99-14,09)	7,74	9,35	0,50	39,90	5,20	15,10
H=5,43 p=0,143								

Pelvis height difference (PHD in mm)								
BMI category	**N**	**Mean (95%CI)**	**SD**	**Me**	**Min.**	**Max.**	**Q1**	**Q3**
Underweight	33	9,27 (6,83-11,72)	5,57	7,70	0,10	23,20	3,60	12,50
Normal Body Mass	342	7,97 (7,25-8,68)	7,90	6,30	0,00	35,60	2,60	11,10
Overweight	55	9,96 (7,67-12,24)	8,62	7,40	0,10	37,40	4,50	14,70
Obesity	34	10,07 (7,37-12,77)	8,74	7,50	0,20	28,80	4,70	15,90
H=5,33 p=0,150								

H: Kruskall-Wallis test; SD: standard deviation; CI: confidence interval; Max: maximum value; Me: median; Min: minimum value; n: number of subjects; *p*: test probability value; Q1: quartile 25.; Q3: quartile 75.

Discussion

Start of school education marks the period when a child's posture is very sensitive to changes due to the new co-occurring environmental factors. The adverse risk factors include mainly the long periods when the child remains seated in class and during other school-related activities, wearing a heavy schoolbag, asymmetry of schoolbag straps, or asymmetric position of schoolbag worn by the child, as well as more frequently occurring fatigue and stressful experiences at school; all these may promote different postural habits involving more pronounced thoracic kyphosis and downward head positioning [29-30]. As a result, natural physical activity is restricted to a degree, and children tend to spend their free time in a passive way, in front of a computer or TV. This situation produces adverse effects because sedentary lifestyle not only increases the risk of excessive body mass in the children but also contributes to the development of postural deficits.

The time when a child attends school may produce beneficial effects as it is likely to foster development of habits related to physical activity and sport, of extreme importance for ensuring child's normal physical development [31-32]. This is equally important to enable early diagnosis, since body posture in adults to a large degree is a result of early stages of development [33-34]. It should be emphasised that early and non-invasive body posture studies among school age children, with the use of the external diagnostic systems, are crucially important.

The current study enabled assessment of body posture parameters in relation to the body mass index category identified in children going to primary and middle schools. In the study group underweight was identified in 6.8% of the boys and in 7.4% of the girls. Normal body mass was found in 72.7% of the boys and 74.8% of the girls. Overweight was identified in 11.5% of the boys and in 12.2% of the girls. Obesity was found in 9% of the boys and in 5.7% of the girls. These values are similar to the data published by the WHO, according to which in 2016 overweight and obesity were found in 18% of children and adolescents between 5 and 19 years of age [35].

The current study shows a strong correlation between the BMI and the body posture parameters. Also a correlation was found between the height of the left shoulder and excessive weight. Children with higher BMI were far more often found with decreased distance between the scapula and the frontal plane.

A study by Batistão et al., involving 288 school age children, reported asymmetry in the position of shoulders in 74.3% of the subjects; the problem was particularly pronounced among older children, aged 13-15, which supports the claim that this type of deficit may be associated with the rapid growth of specific segments of the body occurring during puberty. In fact the problem appears to be more closely related to age than to body mass. These asymmetries in the position of shoulders may also be explained by varied overloads of the body linked with environmental factors, i.e. asymmetrical body posture in sitting position and carrying of schoolbags on one side, a habit frequently observed in teenagers [36]. As it is shown by the present study, incorrect body mass may also be a contributing factor, producing similar effects.

Many authors have discussed the relation of body posture and BMI. An important problem was pointed out by Pausić and others as well as Barszczyk and others who claim, that both excessively low and excessively high body mass lead to negative changes in the position of the spine, lower extremities, as well as feet [37-38]. Partly similar results were reported by Walicka- Cupryś et al. These authors examined children with genu valgum and found that the defect was most common in overweight children (28.6%), followed by children with normal weight (14.7%), and it was least frequent in underweight subjects (10.7 %) [25].

Bogucka and others in their study examined body posture of 227 school age children. The authors observed that in the subgroup of underweight girls, the protruding scapulae were present significantly more often than in the peers with the normal weight and height. However, underweight boys more frequently than their peers with normal BMI were characterized by the asymmetry of the scapulae towards the spine. It was suggested that faulty body postures in the scapulae area occurred more frequently in underweight subjects ($r = 0.359$; $p<0.001$) [39].

Likewise, Grivas et al. reported that excessively low BMI is more frequently associated with body asymmetry in teenagers [40]. Similar conclusions can be drawn from the study by Grabara et. al [41]. The present study identified an opposite tendency. Children with greater body mass (overweight and obesity) were found with larger distance between the scapulae and the frontal plane ($H=11.47$ $p=0.009$). However, all the above findings suggest that height and weight related abnormalities are closely linked with postural defects during developmental age.

People with overweight and obesity show higher abnormalities in the position of the shoulders and pelvis than people with normal weight. Age-related analysis of the study group showed a negative correlation between the subjects' age and oblique position of the pelvis ($r=0.09$, $p=0.049$). Similarly, Rosa et al. reported low rates of incorrect pelvis position in grade I-III children. No related abnormalities were identified in 68% of the girls and 72% of the boys [42]. Different findings were reported by Słoń, who performed similar measurements in a group of 162 primary school students (grades IV-VI) in Warsaw. The author observed incorrect position of the pelvis in 77% of the subjects [43].

The current study enabled assessment of BMI in relation to the incidence of abnormalities in selected parameters measured in the trunk area. In the literature we can find data related to the growing number of children and teenagers with excessive body weight, as well as more and more evidence proving adverse health related effects of overweight and obesity. Excessive body weight to a large extend contributes to postural defects, and adversely affects health condition, as well as body water and electrolyte balance. That is why it was justifiable to specify the body mass category based on BMI and to investigate its influence on the body posture in school-age children. In view of the fact that obesity is more and more common among children, schools should provide instruction on healthy diet and encourage students to take up physical activity.

The results of the examinations made it possible to increase awareness among parents and primary school teachers related to the important role of body weight in a child's development, including the effects of this factor in body posture. Following the study, headmasters of the relevant schools initiated cooperation with a Rehabilitation Centre offering specialist consultations and optional corrective exercise programs for children with postural defects. Overweight and obesity among children and adolescents should be prevented by introducing educational programs for whole families and showing them the negative impact of obesity on body posture.

Conclusions

Increase in children's BMI produces adverse effects in the position of shoulder blades, reflected by their greater distance from the frontal plane. Increase in BMI is not significantly related to the position of shoulder joints or pelvis, however the subjects with overweight or obesity presented a greater difference in the position of shoulder joints and pelvis.

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Authors' contributions

WR- conception and design, revising critically for intellectual content, final approval of the manuscript, JL- acquisition of data, drafting the article, final approval of the manuscript; JB- acquisition of data, revising critically for intellectual content, final approval of the manuscript; MA- analysis and interpretation of data, drafting the article, final approval of the manuscript; Weres Aneta,- analysis and interpretation of data, drafting the article, final approval of the manuscript; RB- acquisition of data, drafting the article, final approval of the manuscript, GI- acquisition of data, revising critically for intellectual content, final approval of the manuscript; ECL- acquisition of data, revising critically for intellectual content, final approval of the manuscript, SP- acquisition of data, drafting the article, final approval of the manuscript; TP conception and design, revising critically for intellectual content, final approval of the manuscript.

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Conflicts of interest

The authors declare no conflict of interest.

Data sharing statement

The datasets generated and/or analysed during the current study are not publicly available due to protect the students' privacy, but are available from the corresponding author on reasonable request.

Figure legend

Fig. 1 Topographic points marked on the body of patients

Fig. 2 The difference in the distance of the scapula in the sagittal projection

Fig. 3 Pelvic height difference and shoulder height difference in the frontal projection

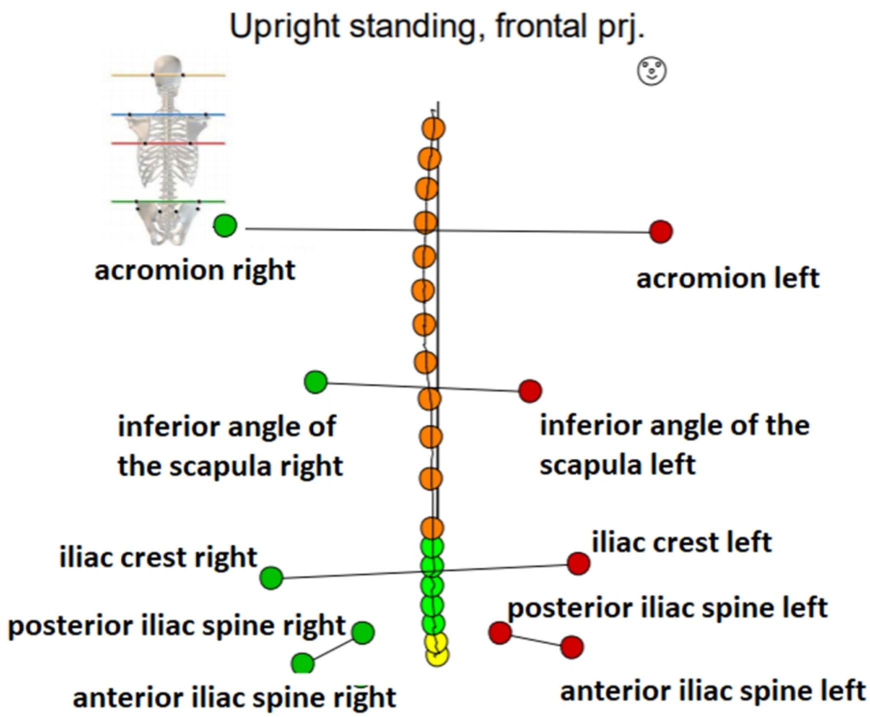

Fig. 1 Topographic points marked on the body of patients

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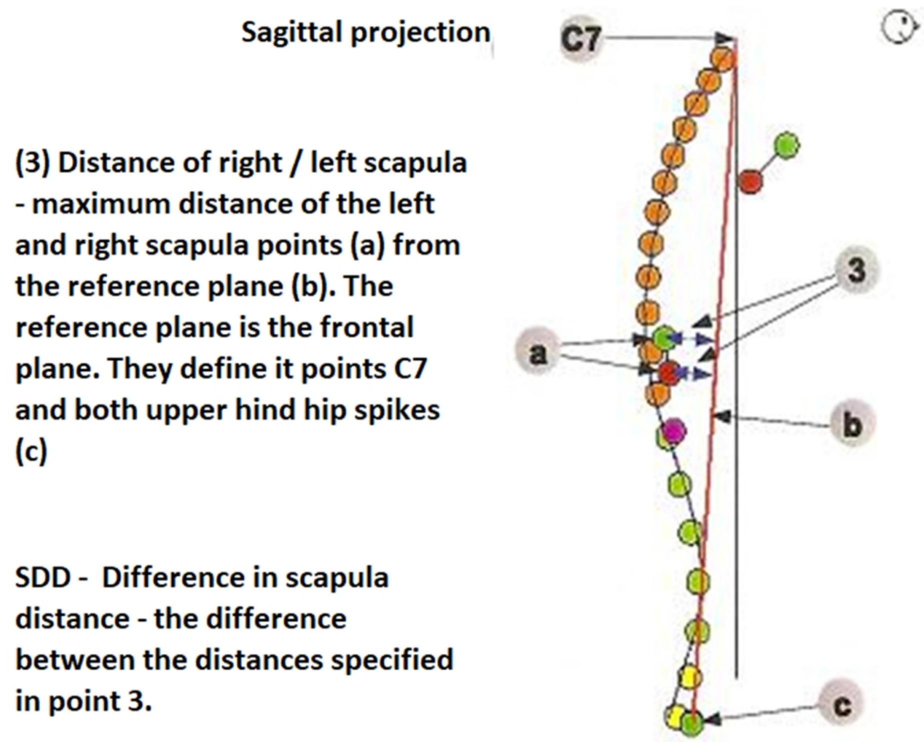

Fig. 2 The difference in the distance of the scapula in the sagittal projection.

128x95mm (300 x 300 DPI)

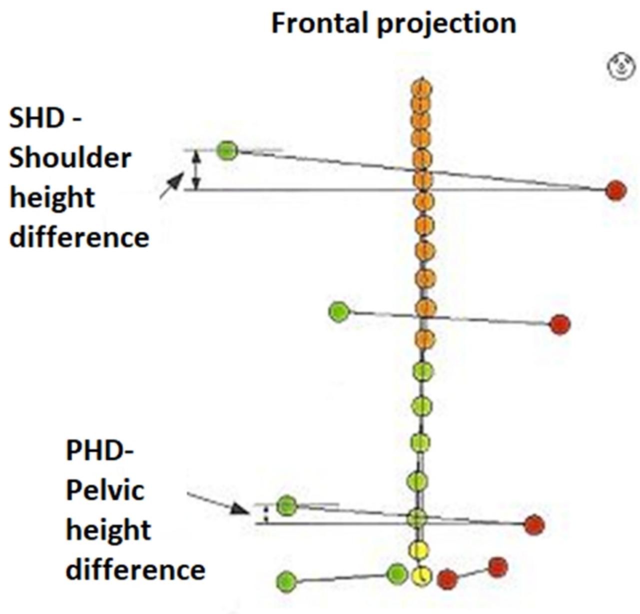

Fig. 3 Pelvic height difference and shoulder height difference in the frontal projection.

128x93mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	n/a
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	n/a
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	8
		(*e*) Describe any sensitivity analyses	8
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5
		(b) Give reasons for non-participation at each stage	5
		(c) Consider use of a flow diagram	n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	n/a
		(b) Indicate number of participants with missing data for each variable of interest	n/a
Outcome data	15*	Report numbers of outcome events or summary measures	n/a
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10-12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	10-12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

The role of body mass category in the development of faulty postures in school age children from a rural area in south-eastern Poland – a cross-sectional study

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Secondary Subject Heading:	Public health
Keywords:	posture, body mass index, child, rural population

The role of body mass category in the development of faulty postures in school age children from a rural area in south-eastern Poland – a cross-sectional study

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Abstract

Objective. The aim of the study was to assess the relationship between Body Mass Index and the incidence of abnormalities in selected parameters measured in the trunk area.

Design. Cross-sectional studies.

Setting. The research was conducted in a primary school in the Trzebownisko Municipality, a rural area in south-eastern Poland.

Participants. A group of 464 children, ranging in age from 6 to 16 years (234 boys and 230 girls), was recruited to participate in the study.

Outcome Measures. The examination of their body postures was conducted with the use of the Zebris system. Body mass was determined using a body mass analyser Tanita MC – 780 MA. Body mass index (BMI) was calculated based on the acquired data.

Results. It was noticed that the children with overweight and obesity tended to have an incorrect position of the shoulders and pelvis in comparison to children with normal body weight. It was found that greater body mass (higher BMI index) coincided with a larger distance of the scapulae from the frontal plane (p=0.009).

Conclusions. Increase in children's BMI produces adverse effects in the position of the shoulder blades, reflected by their greater distance from the frontal plane. Increase in BMI is not significantly related to the position of the shoulder joints or pelvis; however, the subjects with overweight or obesity presented a greater difference in the position of the shoulder joints and pelvis.

Key words. Posture, Body Mass Index, Child, Rural Population

Strengths of this study

- The homogeneity and large size of the study group from rural areas.
- Objective and standardized measuring devices.

Limitations of this study

- We cannot entirely rule out the possibility of unmeasured or unknown confounding factors (parental genetic predisposition to higher BMI) that may account for the associations observed in this study. However, the homogeneity of the study population and comprehensive data on the risk factors minimized potential confounding effects.
- Other elements that can affect trunk muscle tension include muscular problems, e.g. neonatal hypertonia or hypotonia and their consequences in childhood, as well as past injuries and chronic neurological diseases, and these should be taken into account in future studies.

Introduction

A child's correct body posture favourably affects the growth of their whole body [1]. It contributes for instance to the normal development and functioning of body organs, and improves the effectiveness of motor activity and general well-being [2]. If they are developed early in life, correct motor habits contribute to normal development of the muscles, joints and ligaments and provide beneficial stimulation to the child's growing skeleton. Even the smallest defects in the body posture of a school-age child can lead to the development of a habitual bad posture and, consequently, to health problems [3-4].

Body postures are subject to large changeability, which depends on such factors as age, sex, somatic type, ethnicity, environment and psychophysical condition. The major risk factors that may induce the development of incorrect body posture include excessive body mass in relation to height and age [5-6]. A vast majority of overweight or obese children live in developed countries with growth rates over 30% higher compared to the developing countries. If the current trends continue, the number of overweight or obese infants worldwide will increase to 70 million in 2025 [7]. Overweight and obesity in children, often associated with insufficient physical activity, lead to decreased use of the motor system; at the same time the increasing fat deposition contributes to overloading of the skeletal system, and this is a precondition for the development of postural defects [8]. Children with body mass above the 95th centile (BMI z-score> +2 SD) far more often present postural defects involving the spine, thoracic cage, as well as lower limbs, and suffer from musculoskeletal pain [9].

Maciałczyk- Paprocka K. et al. report that postural deficits may affect as many as 74.1% of boys and 85.5% of girls with excessive body mass, and the predominant problems include knock knees and fallen arches [10]. Also, in the last decades there has been an unprecedented increase in the number of obese children, and the problem is associated with a number of functional disorders, e.g. pain, joint stiffness and reduced muscle strength, which contribute to the development of poor posture. General rates of obesity among children worldwide are estimated at the level of 10% and, like in the case of postural deficits, the problem is constantly growing. The top of the ranking is dominated by the North American countries including the USA, where the level of overweight and obesity reaches the unprecedented rates of almost 32%. In Western Europe the rates reach up to 20%, whereas in Central and Eastern Europe they reach the level of 16% [11-12].

According to numerous clinical data, a child's body posture is particularly at risk during the periods of the fastest pace of growth, which mainly include the time corresponding to the start of school education (6-7 years of life) and the puberty period (12-16 years of life). In view of the above, research focusing on body posture in school-age children, taking into account body mass, is of particular importance [12-14].

According to the data reported in the literature, the rate of overweight and obesity in children is consistently increasing [15]. A similar situation is observed in the case of postural defects [16]. In previously conducted studies numerous authors have investigated factors affecting obesity or postural defects, though usually focusing on these problems separately [15,17-18]. There are no studies that link these two aspects to each other. Additionally, the majority of the reports are related to children from urban areas, more affected by globalisation, and those from highly developed countries where children more commonly present musculoskeletal disorders related to incorrect body posture [19-21]. On the other hand, it would be worthwhile to carry out related research focusing on rural areas where children grow up in more natural environments, have more opportunities for outdoor activity, and better access to healthy food, yet they are also frequently affected by the two problems [22-23]. Overweight and obesity occur much more often among children and teenagers from rural areas, compared to towns and cities, mostly from multi-child families of low economic status, where the education level of the parents is quite low. The problem mainly affects the population of developmental age, and so the scale of the phenomenon is a matter of concern [24]. There is also a scarcity of studies examining body posture with objective measurement methods, such as the Zebris APGMS Pointer, which performs detailed assessment of static body posture, range of motion and the shape of spinal curves [10].

The aim of the study was to assess the relationship between Body Mass Index and abnormalities in the trunk area, i.e. scapula distance difference, pelvic height difference and shoulder height difference in children living in rural communities.

Material and methods

The study was accepted by the local Bioethical Commission on 28 June 2016 (Consent No. 2016/06/28). The participants were informed about the course of the study. The examinations were conducted after written consent was received from the headmasters of the schools, parents of the children participating in the project and the children themselves.

Participants

Firstly, the sample size was calculated with reference to the total number of children (n= 3790) living in the Trzebownisko Municipality, a rural area in south-eastern Poland, with a 95% confidence level and a confidence interval of 0.05. It was calculated that the minimum sample size should be 349. The study took into account 464 school-age children, from 6 to 16 years of age (234 boys and 230 girls). They were qualified for the study (from June 2016 to March 2018), designed to be conducted in schools in a rural region. Five primary and secondary schools were randomly selected out of the nine schools located in the specific rural region in the south-eastern area of the country in which the study was conducted. Examinations were conducted in nurses' offices in the relevant educational facilities. In order to ensure the reliability of the measurements, all the subjects were examined in the morning, on an empty stomach, by the same members of a qualified team.

The study applied the following inclusion criteria: age from 6-16 years and consent of the parents and children for the examination. Exclusion criteria: metal implants, electronic implants, periods in girls, epilepsy and failure to refrain from eating in the morning on the day of the study. Children with a diagnosis of neonatal hypertonia or hypotonia, chronic neurological diseases or past injuries and surgical interventions during the last 6 months before examination were excluded from the study group.

Body Posture

The study of body posture was conducted with the use of the Zebris APGMS Pointer system. An examination is carried out with an ultrasound pointer used to mark characteristic anatomical locations corresponding to specific bone structures on the patient's body. These locations are treated by the software as passive points. Their position and movement are tracked and recorded in real time by the software. The study was carried out in static conditions, in a motionless standing position.

The reference markers were three miniature transmitters attached to the patient with flexible straps. These define points with reference to which the device specifies the positions of pointer markers. By applying the pointer to the characteristic anatomical locations on the body and by activating the device it is possible to visualise the relevant points on the screen and to create a three-dimensional image of the body posture [25-26].

At the start, topographic points were marked on the body of each subject to correspond with: acromion right and left, posterior iliac spine right and left, anterior iliac spine right and left, iliac crest right and left, the point where the thoracic spine meets the lumbar spine, Th 12/L1, inferior angle of the scapula right and left, spinous process of the spine. A sample result of the examination as well as the defined topographic points are shown in Figure 1 (Fig.1).

Based on the defined topographic points, the software computes the values of selected body posture parameters. The following were taken into account in the assessment of posture:
- in the sagittal projection: scapula distance difference (SDD in mm) (Fig.2),
- in the frontal projection: pelvic height difference (PHD in mm) and shoulder height difference (SHD in mm) (Fig.3).

During the examination the subject, wearing no shoes, was asked to assume a relaxed standing position, with his/her back to the measurement unit, and did not have with him/her any devices interfering with the transfer of data (e.g. smartwatch, mobile phone).

Following calibration of the horizontal plane, the subject's body posture was examined. The measurement, performed with an ultrasound pointer, involved registration of the topographic points marked earlier on the subject's body. The measurements were performed three times in each subject and the spine line was scanned 9 times (three times in each examination). The final result was the mean value of the measurements [27].

Anthropometric Measurements and Bioelectrical Impedance

Body height was measured with an accuracy up to 0.1 cm, with the use of a portable stadiometer PORTSTAND 210. Body mass was measured with the Tanita MC – 780 MA analyser with an accuracy up to 0.1 kg. The examinations were conducted in standard conditions. During the measurement, each subject was barefoot and dressed in underwear, and was asked to assume an upright extended position.

The data acquired during the measurement of body height and mass were used to calculate the body mass index (BMI). The BMI value was examined by reference to the growth chart, taking into account sex and age. Based on the achieved percentile ranking, the BMI status was classified in the following four categories: obesity (BMI ≥ 95^{th} percentile), overweight (BMI ≥ 85^{th} percentile and <95^{th} percentile), normal body mass (BMI <85^{th} percentile and ≥ 5^{th} percentile), and underweight (BMI <5^{th} percentile) [28].

Data analysis

Spearman's rank correlation test was applied to assess the correlation between BMI and body posture. Differences in the selected parameters between the groups were analysed using the Kruskal-Wallis test. The accepted level of significance was α <0.05. All calculations and statistical analyses were performed with the use of STATISTICA ver. 10.0 (StatSoft, Poland).

Patient and public involvement

Patients and the public were not involved in the design of the study. The parents of the children who participated in the study received the results of the measurements and recommendations about treatment opportunities.

Results

The characteristics of the study group are shown in Table 1 and 2. On average the subjects were 11.52 years old (SD=2.99). The mean body height was 152.48cm (SD=17.77) and the mean body mass was 45.39kg (SD=16.81). On average the subjects' body mass index was 18.8kg/m2 (SD=3.75) (Tab. 1).

Table 1. Characteristics of the study group

	N	Mean	Me	SD	Q_1	Q_3
All						
Age [years]	464	11.52	12.00	2.99	9.00	14.00
Height [cm]	464	152.48	155.50	17.77	137.00	167.00
Weight [kg]	464	45.39	44.75	16.81	30.40	56.45
BMI [kg/m²]	464	18.80	18.24	3.75	16.10	20.97
Girls						
Age [years]	230	11.55	12	2.96	9.00	14.00
Height [cm]	230	150.46	155	15.69	136.00	163.00
Weight [kg]	230	43.63	44.35	15.38	29.70	54.60
BMI [kg/m²]	230	18.64	18.00	3.87	15.90	20.90
Boys						
Age [years]	234	11.49	12	3.02	9.00	14.00
Height [cm]	234	154.46	156.50	19.43	138.00	172.00
Weight [kg]	234	47.13	45	17.97	31.80	60.00
BMI [kg/m²]	234	18.94	18.56	3.63	16.40	21.05

Me: median; n: number of subjects; Q_1: first quartile; Q_3: third quartile SD: standard deviation;

Based on the BMI percentiles a categorization of the body mass of the study group was performed. 6.8% of the boys and in 7.4% of the girls were found to be underweight. Normal body mass was identified in 72.7 % of the boys and 74.8 % of the girls. 11.5% of the boys and in 12.2 % of the girls were found to be overweight, and obesity was identified in 9 % of the boys and in 5.7% of the girls (Tab. 2).

Table 2. The body mass category based on BMI depending on the sex

BMI Category	Sex					
	Boys		Girls		Total	
	N	%	n	%	N	%
Underweight	16	6,8%	17	7,4%	33	7,1%
Normal body mass	170	72,7%	172	74,8%	342	73,7%
Overweight	27	11,5%	28	12,2%	55	11,9%
Obesity	21	9,0%	13	5,6%	34	7,3%
Total	234	100,0%	230	100,0%	464	100,0%
Significance(p)	$\chi^2(3)=1{,}90$ p=0,591					

%: percent of subjects; n: number of subjects; *p*: test probability value; χ^2- chi-square Pearson test.

Analyses of the correlations between BMI and the body posture parameters measured in the trunk area showed statistically significant differences in the case of the distance of the scapulae from the corresponding plane. Statistical significance was not observed in the relationship of the position of the pelvis (H=5.33 p=0.150) and the BMI index. It was found that greater body mass (higher BMI index) coincided with a larger distance of the scapulae from the frontal plane (H=11.47 p=0.009). It was noticed that people with overweight and obesity have incorrect position of the shoulders and pelvis in comparison to people with normal body weight. (Tab. 3).

Table 3. The correction between the body mass category, based on BMI and the body posture

Scapula distance difference (SDD in mm)								
BMI category	**N**	**Mean (95%CI)**	**SD**	**Me**	**Min.**	**Max.**	**Q1**	**Q3**
Underweight	33	4,58 (3,13-6,02)	6,07	3,00	0,00	18,00	2,00	6,00
Normal Body Mass	342	6,90 (6,27-7,53)	6,13	5,50	0,00	32,00	2,00	9,00
Overweight	55	8,04 (6,34-9,73)	6,16	6,00	0,00	28,00	4,00	10,00
Obesity	34	9,50 (6,44-12,56)	6,10	7,00	0,00	41,00	4,00	10,00
H=11,47 p=0,009								
Shoulder height difference (SHD in mm)								
BMI category	**N**	**Mean (95%CI)**	**SD**	**Me**	**Min.**	**Max.**	**Q1**	**Q3**
Underweight	33	6,96 (4,98-8,93)	6,90	5,50	0,10	19,60	2,10	10,80
Normal Body Mass	342	10,00 (9,16-10,84)	6,72	8,00	0,10	59,80	4,10	14,60
Overweight	55	10,66 (8,33-12,99)	8,45	7,40	0,50	32,80	3,70	16,50
Obesity	34	11,04 (7,99-14,09)	7,74	9,35	0,50	39,90	5,20	15,10
H=5,43 p=0,143								
Pelvis height difference (PHD in mm)								
BMI category	**N**	**Mean (95%CI)**	**SD**	**Me**	**Min.**	**Max.**	**Q1**	**Q3**
Underweight	33	9,27 (6,83-11,72)	5,57	7,70	0,10	23,20	3,60	12,50
Normal Body Mass	342	7,97 (7,25-8,68)	7,90	6,30	0,00	35,60	2,60	11,10
Overweight	55	9,96 (7,67-12,24)	8,62	7,40	0,10	37,40	4,50	14,70
Obesity	34	10,07 (7,37-12,77)	8,74	7,50	0,20	28,80	4,70	15,90
H=5,33 p=0,150								

H: Kruskall-Wallis test; SD: standard deviation; CI: confidence interval; Max: maximum value; Me: median; Min: minimum value; n: number of subjects; *p*: test probability value; Q1: quartile 25.; Q3: quartile 75.

Discussion

The start of school education marks a period when a child's posture is very sensitive to changes due to the new co-occurring environmental factors. The adverse risk factors include mainly the long periods when the child remains seated in class and during other school-related activities, wearing a heavy schoolbag, asymmetry of schoolbag straps, or asymmetric position of a schoolbag worn by the child, as well as more frequently occurring fatigue and stressful experiences at school. All of these may promote different postural habits involving more pronounced thoracic kyphosis and downward head positioning [29-30]. As a result, natural physical activity is restricted to a degree, and children tend to spend their free time in a passive way, in front of a computer or TV. This situation produces adverse effects because a sedentary lifestyle not only increases the risk of excessive body mass in the children but also contributes to the development of postural deficits.

The time when a child attends school may produce beneficial effects as it is likely to foster development of habits related to physical activity and sport, which are of extreme importance for ensuring the child's normal physical development [31-32]. It is important to enable early diagnosis, since body posture in adults to a large degree is a result of the early stages of development [33-34]. It should be emphasised that early and non-invasive body posture studies among school age children, with the use of the external diagnostic systems, are crucially important.

The current study enabled the assessment of body posture parameters in relation to the body mass index category identified in children attending primary and middle schools. In the study group 6.8% of the boys and in 7.4% of the girls were identified as being underweight. Normal body mass was found in 72.7% of the boys and 74.8% of the girls. 11.5% of the boys and in 12.2% of the girls were identified as being overweight. Obesity was found in 9% of the boys and in 5.7% of the girls. These values are similar to the data published by the WHO, according to which in 2016 overweight and obesity were found in 18% of children and adolescents between 5 and 19 years of age [35].

The current study shows a strong correlation between the BMI and the body posture parameters. Also, a correlation was found between the height of the left shoulder and excessive weight. Children with higher BMI were far more often found to have a decreased distance between the scapula and the frontal plane.

A study by Batistão et al., involving 288 school age children, reported asymmetry in the position of shoulders in 74.3% of the subjects; the problem was particularly pronounced among older children, aged 13-15, which supports the claim that this type of deficit may be associated with the rapid growth of specific segments of the body occurring during puberty. In fact, the problem appears to be more closely related to age than to body mass. These asymmetries in the position of the shoulders may also be explained by the varied overloads of the body linked with environmental factors, e.g. asymmetrical body posture in sitting position and carrying of schoolbags on one side, a habit frequently observed in teenagers [36]. As shown by the present study, incorrect body mass may also be a contributing factor, producing similar effects.

Many authors have discussed the relation of body posture and BMI. An important problem was pointed out by Pausić et al. as well as Barszczyk et al. who claim that both excessively low and excessively high body mass lead to negative changes in the position of the spine, lower extremities and feet [37-38]. Partly similar results were reported by Walicka- Cupryś et al. These authors examined children with genu valgum and found that the defect was most common in overweight children (28.6%), followed by children with normal weight (14.7%), and it was least frequent in underweight subjects (10.7 %) [25].

Bogucka et al. in their study examined the body posture of 227 school age children. The authors observed that in the subgroup of underweight girls, the protruding scapulae were present significantly more often than in their peers with normal weight and height. However, underweight boys more frequently than their peers with normal BMI were characterized by asymmetry of the scapulae towards the spine. It was suggested that faulty body postures in the scapulae area occurred more frequently in underweight subjects ($r = 0.359$; $p<0.001$) [39].

Likewise, Grivas et al. reported that excessively low BMI is more frequently associated with body asymmetry in teenagers [40]. Similar conclusions can be drawn from the study by Grabara et. al [41]. The present study identified the opposite tendency. Children with greater body mass (overweight and obesity) were found to have a larger distance between the scapulae and the frontal plane ($H=11.47$ $p=0.009$). However, all the above findings suggest that height- and weight-related abnormalities are closely linked with postural defects during developmental age.

People with overweight and obesity show higher abnormalities in the position of the shoulders and pelvis than people with normal weight. Age-related analysis of the study group showed a negative correlation between the subjects' age and oblique position of the pelvis ($r=0.09$, $p=0.049$). Similarly, Rosa et al. reported low rates of incorrect pelvis position in grade I-III children. No related abnormalities were identified in 68% of the girls and 72% of the boys [42]. Different findings were reported by Słoń, who performed similar measurements in a group of 162 primary school students (grades IV-VI) in Warsaw. The author observed incorrect position of the pelvis in 77% of the subjects [43].

The current study enabled the assessment of BMI in relation to the incidence of abnormalities in selected parameters measured in the trunk area. In the literature we can find data related to the growing number of children and teenagers with excessive body weight, as well as more and more evidence proving the adverse health related effects of overweight and obesity. Excessive body weight to a large extent contributes to postural defects, and adversely affects health condition, as well as body water and electrolyte balance. That is why it was justifiable to specify the body mass category based on BMI and to investigate its influence on body posture in school-age children. In view of the fact that obesity is more and more common among children, schools should provide instruction on healthy diet and encourage students to take up physical activity.

The results of the examinations made it possible to increase awareness among parents and primary school teachers related to the important role of body weight in a child's development, including the effects of this factor in body posture. Following the study, the headmasters of the relevant schools initiated cooperation with a Rehabilitation Centre offering specialist consultations and optional corrective exercise programs for children with postural defects. Overweight and obesity among children and adolescents should be prevented by introducing educational programs for whole families and showing them the negative impact of obesity on body posture.

Conclusions

Increase in children's BMI produces adverse effects in the position of the shoulder blades, reflected by their greater distance from the frontal plane. Increase in BMI is not significantly related to the position of the shoulder joints or pelvis; however, the subjects with overweight or obesity presented a greater difference in the position of the shoulder joints and pelvis.

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Authors' contributions

WR- conception and design, revising critically for intellectual content, final approval of the manuscript, JL- acquisition of data, drafting the article, final approval of the manuscript; JB-acquisition of data, revising critically for intellectual content, final approval of the manuscript; MA- analysis and interpretation of data, drafting the article, final approval of the manuscript; Weres Aneta,- analysis and interpretation of data, drafting the article, final approval of the manuscript; RB- acquisition of data, drafting the article, final approval of the manuscript, GI-acquisition of data, revising critically for intellectual content, final approval of the manuscript;

ECL- acquisition of data, revising critically for intellectual content, final approval of the manuscript, SP- acquisition of data, drafting the article, final approval of the manuscript; TP conception and design, revising critically for intellectual content, final approval of the manuscript.

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Conflicts of interest

None declared.

Data sharing statement

The datasets generated and/or analysed during the current study are not publicly available due to protect the students' privacy, but are available from the corresponding author on reasonable request.

Figure legend

Fig. 1 Topographic points marked on the body of patients

Fig. 2 The difference in the distance of the scapula in the sagittal projection

Fig. 3 Pelvic height difference and shoulder height difference in the frontal projection

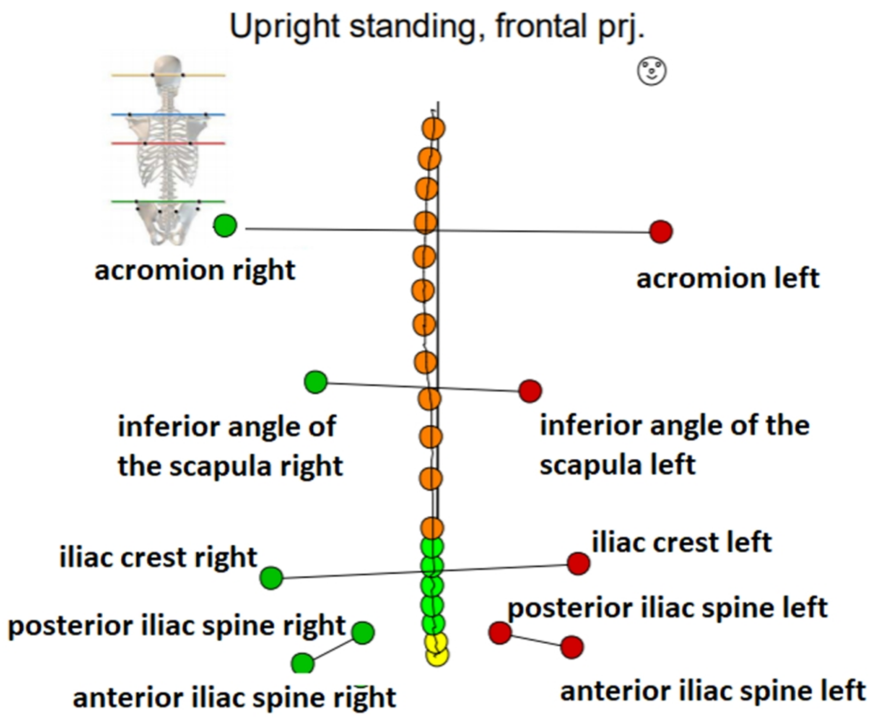

Fig. 1 Topographic points marked on the body of patients

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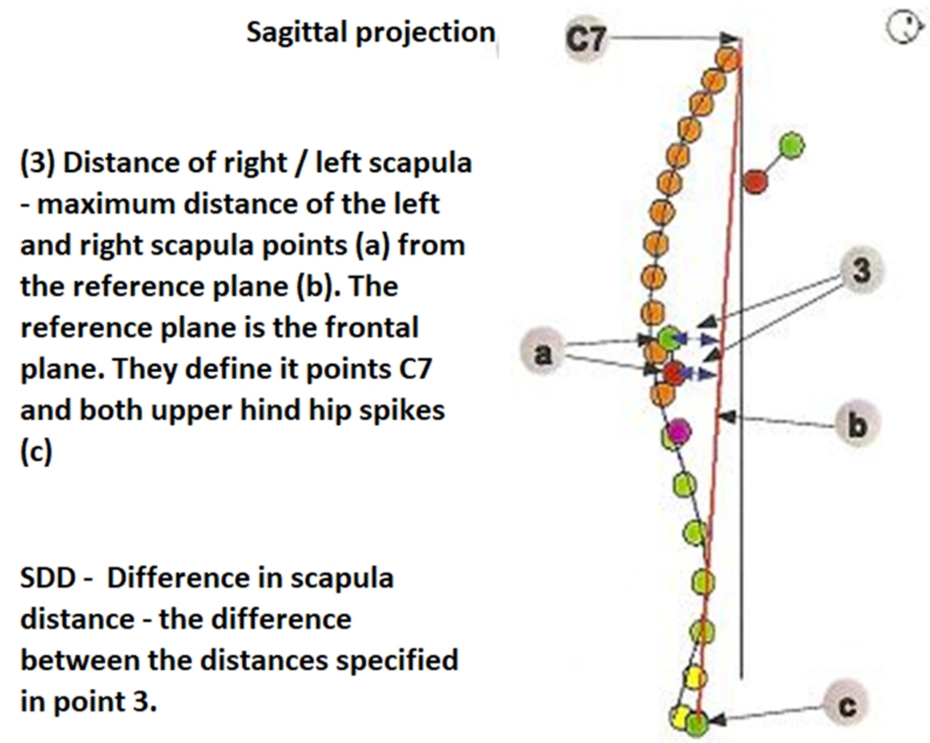

Fig. 2 The difference in the distance of the scapula in the sagittal projection.

128x95mm (300 x 300 DPI)

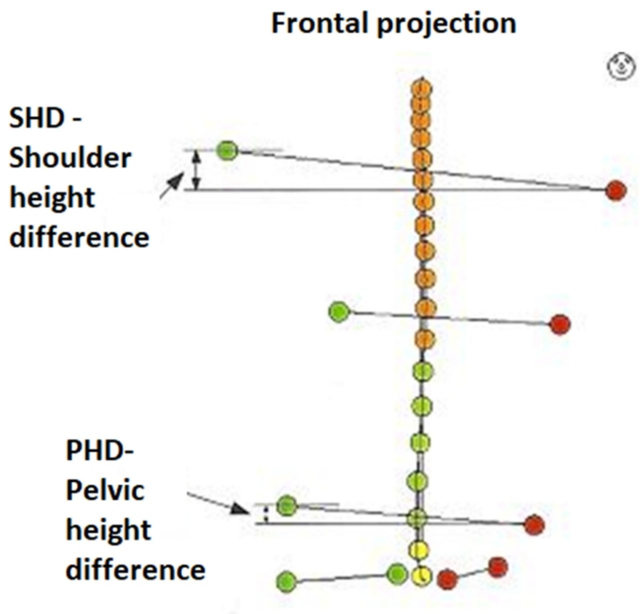

Fig. 3 Pelvic height difference and shoulder height difference in the frontal projection.

128x93mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	n/a
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	n/a
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	8
		(*e*) Describe any sensitivity analyses	8
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5
		(b) Give reasons for non-participation at each stage	5
		(c) Consider use of a flow diagram	n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	n/a
		(b) Indicate number of participants with missing data for each variable of interest	n/a
Outcome data	15*	Report numbers of outcome events or summary measures	n/a
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	10-12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-12
Generalisability	21	Discuss the generalisability (external validity) of the study results	10-12
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.