The shape of anterior-posterior spinal curvatures and body composition in school-children

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Abstract: The aim of the study was to assess the relationship between the shape of the anterior-posterior curvature of the spine and body composition in school-children. The study included 257 children, aged 11-12. Correct spinal curvature was established in 106 (41.08%) subjects. Other types included: decreased kyphosis and correct lordosis - 40 participants (15.50%), correct kyphosis and decreased lordosis - 24 individuals (9.30%), increased kyphosis and correct lordosis - 17 subjects (6.59%), correct kyphosis and increased lordosis - 22 children (8.53%), decreased kyphosis and decreased lordosis - 32 people (12.40%), decreased kyphosis and increased lordosis - 4 of the examined subjects (1.55%), increased kyphosis and lordosis - 13 people (5.04%). In addition, 134 (51.94%) demonstrated scoliotic posture and 8 (3.10%) scoliosis. There were significant relationships between the shape of the anterior-posterior curvatures and body composition in school-children. Those with a strong body build (predominance of mesomorphs) were generally characterised by the correct formation of these curvatures. In contrast, lean people (with the predominance of ectomorphic factors) were more likely to experience abnormalities. No correlations with body composition were observed in the group with scoliotic posture or scoliosis.
Keywords: body posture defects; the shape of anterior-posterior spinal curvatures; body composition, school-children

1. Introduction

Body posture, as a chain of numerous conditional and unconditional reflexes, is essentially a dynamic stereotype, a kind of movement habit [1]. The final determination of the anterior-posterior curvature of the spine in overcoming gravity is determined by sets of conditional reflexes and movement habits. They are created during the period of development on the basis of unconditional postural, positional, support, static-kinetic, motion-based reflexes [2]. Factors from the external environment also play an important role in the development of posture. This happens through the development of increasingly higher forms of functional adaptation of body posture and movement to the outside world [3]. Environmental influences are responsible for developmental variability, intra-individual variability and, as a result of inter-individual diversity, individuality in terms of body posture. Therefore, human body posture is similar for species, but developmentally variable and individually differentiated. Body posture of the same child who has just reached a standing position therefore differs from his/her posture in subsequent periods of development. However, it is always individual, to the extent that it is often a criterion for recognising a given person [4].

Before the final shaping of posture, appropriate mechanisms conditioning the development of the ability to resist gravity must work. Here, a specialised gravitational system plays a coordinating role. The correct posture of the body is an integrated system of osteoarticular and fascial-ligamentous-muscular structures controlled by the central nervous system to ensure optimal conditions for development and puberty [5].

Any deviations in the operation of this system should be treated as defects requiring correction on the basis of feedback and self-control or reconstruction enabling the development of more favourable stato-kinetic patterns. Hence, the criteria for correct posture cannot be constant and unambiguous for everyone, to the contrary, they should changed depending on the child's developmental period. In this assessment, factors such as constitutional type, sports disciplines and forms of recreation cannot be ignored [6].

The formation of anterior-posterior curvatures of the spine and body posture depend on both genetic determinants and the interaction of the nervous and endocrine systems. Hence, posture defects may have their cause in both nervous system dysfunctions as well as in hormonal disorders or in developmental and post-traumatic deformations of the trunk or limbs [7].

Changes in posture and shape of anterior-posterior spinal curvatures that occur during the growth of children are one of the manifestations of somatic development. However, the concept of body posture should be distinguished from its build. Admittedly, both properties, posture and build are an expression of the special condition of the osteoarticular and fascial-ligamentous-muscular system and image spatial arrangement of the body, mainly the locomotor system, but they are based on different mechanisms [8].

Body composition basically depends on somatic structure and body composition. Body posture, as a chain of numerous conditional and unconditional reflexes, is essentially a dynamic stereotype, a kind of movement habit. It is based on the neurophysiological function conditioning the state of proper tension in appropriate muscle groups. This leads to one and no other arrangement of individual body segments relative to each other, determining its overall balance [9].

The aim of the study was to assess the relationship between the shape of anterior-posterior curvatures of the spine and body composition in school-children.

2. Material and Methods

The study included 257 children aged 11-12 qualified for examination. The children were divided into groups according to age and sex. There were 66 girls aged 11, 67 girls aged 12 and 70 boys aged 11 and 60 boys aged 12. Research was conducted from December 2016 to the end of May 2017 at the Posturology Laboratory of the Jan Kochanowski University in Kielce. The study was conducted with the consent of the Bioethics Committee of the University of Economics in Kielce No. 20/2015.

Body posture and the spine were examined with the Diers formetric III 4D optoelectronic method. Three-dimensional analysis of body posture and the spine is a combination of digital data processing and the latest optical imaging technique. The test enables non-contact and fast 4D photogrammetric measurement. The measurement results are very precise, and thanks to sending the image to a computer, data analysis takes place immediately after the test. At a distance of about 3 m from the optical tripod, a dark background was mounted. During the measurement, the subject was positioned with his/her back to the camera at a distance of 2 m. S/he assumed a normal posture, with his/her feet placed in front of the marked line. The projector emitted horizontal stripes about 1 cm wide onto the subject's back. As recommended by the manufacturer of the Diers formetric III 4D, examination of body posture and spine was carried out with DiCAM program using the 'Average' measurement option. This consisted of executing a sequence of 12 film frames. Then, by creating an average value, the variance of posture was reduced and thus, improved the value of the study. Then the computer program analysed the data and determined a digital, photogrammetric image of the spine. The test was performed twice. The researcher decided which study more closely reflected the actual posture and only this examination was further analysed. Body posture testing with the Diers formetric III 4D device lasted about 15 minutes.

The following parameters describing the child's posture were analysed: kyphotic angle (°), lordotic angle (°), pelvic tilt (mm), lateral deviation (mm) and surface rotation (°). The norms for kyphotic and lordotic angles, on the basis of which body posture in the sagittal plane was assessed, are: kyphotic angle 47°-50°, lordotic angle 38° -42°. On their basis, 8 spinal types were distinguished in the sagittal plane: correct curvature of the spine (kyphotic angle 47°-50°, lordotic angle 38°-42°); decreased kyphosis and correct lordosis (kyphotic angle <47°, lordotic angle 38°-42 °); correct kyphosis and decreased lordosis (kyphotic angle 47°-50°, lordotic angle <42 °); increased kyphosis and correct lordosis (kyphotic angle >50°, lordotic angle 38°-42°); correct kyphosis and increased lordosis (kyphotic angle 47°-50°, lordotic angle >42°); decreased kyphosis and decreased lordosis (kyphotic angle <47°, lordotic angle <42°); decreased kyphosis and increased lordosis (kyphotic angle <47°, lordotic angle >42°); increased kyphosis and increased lordosis (kyphotic angle >50°, lordotic angle >42°) [10].

The occurrence of scoliotic posture and scoliosis was found by considering the values of 3 variables: pelvic tilt (mm), lateral deviation (mm) and surface rotation (°). The following division was adopted for the assessment:

• scoliotic posture:
- pelvic tilt less than 5 mm,
- lateral deviation (rms) less than 5 mm,
- rotation (rms) less than 5°.

• scoliosis:
- pelvic tilt equal to or greater than 5 mm,
- lateral deviation (rms) equal to or greater than 5 mm,
- rotation (rms) equal to or greater than 5°.

To assess the presence of scoliotic posture or scoliosis, all 3 conditions had to be met. If 3 requirements were not met, it was assumed that scoliosis or scoliosis did not occur [10]. Body composition was measured using Bioelectrical impedance analysis (BIA) with the Tanita MC-780 multi-frequency segment body composition analyser. This non-invasive testing method allows analysis of body composition using the electrical resistance of the body's tissues, so-called impedance. The Tanita MC-780 segment body composition analyser applies innovative Multi Frequency technology, i.e. currents with variable frequencies: 5, 50, 250 and 500 kHz. This allowed the assessment of resistance and conductivity of the tissues. The flow of alternating currents was possible due to different fluid contents in the tissues. Body composition analysis of individual segments (upper and lower limbs, trunk) was conducted taking into account the body side (right and left) and the distinction between tissue reactance and resistance (muscle, fat and visceral tissue). The patient was examined in a standing position, the feet (placed on the base of the analyser) in contact with the built-in electrodes. Patient data (age, gender, body height) were entered by the investigator. During the first stage, body mass was determined, at the next stage (patient's hands - on the handles with built-in electrodes), impedance was measured. Full segment analysis was carried out in 30 seconds. Values of segment measurements for the lower and upper limbs as well as the trunk are expressed in specific SI units: (kg), (kJ), (%), (°), (Ω), (kg/m²). The body analyser had a certificate confirming the possibility of its use in the medical field. The following variables were analysed in the study: body mass (kg), basal metabolic rate (BMR) (kJ), fat percentage (FATP) (%), fat mass (FATM) (kg), fat-free mass (FFM) (kg), total body water (TBW) (kg), predicted muscle mass (PMM) (kg), body mass index (BMI) (kg/m²), visceral fat level (VFATL), bone mass (BONEM) (kg), extracellular water (ECW) (kg), intracellular water (ICW) (kg) and metabolic age (METAAGE) (years).

The results of the survey were summarised using the statistical package PQStat version 1.6.4.121 statistical package. Normality of distribution regarding body posture and composition variables were assessed using the Kolmogorov-Smirnov test. Differences between variables according to sex and age of the subjects were compared by the Mann-Whitney U test. Analysis of the relationship between body posture defects and composition was carried out via the Kruskal-Wallis test and the Dunn-Bonferroni post-hoc test. The test probability of $p<0.05$ was considered statistically significant.

3. Results

Correct spinal curvature was noted in 106 (41.08%) persons. The remaining types were: decreased kyphosis and correct lordosis 40 - people (15.50%), correct kyphosis and decreased lordosis - 24 individuals (9.30%), increased kyphosis and correct lordosis, 17 subjects (6.59%), correct kyphosis and increased lordosis, 22 people (8.53%), decreased kyphosis and decreased lordosis, 32 patients (12.40%), decreased kyphosis and increased lordosis, 4 people (1.55%), increased kyphosis and increased lordosis, 13 participants (5.04%). In addition, 134 (51.94%) subjects demonstrated scoliotic posture and 8 (3.10%), scoliosis.

Body height (cm) in the group of 11-year-old boys was at an average of 151.44, with a standard deviation of 5.49. The median distribution of results was 151 and the range of results from 136 to 164. However, among girls, the average was 149.35 with a standard deviation of 8.23. The median distribution of results was 149.5 and the range of results was from 134 to 171. There were no significant differences between the results for both sexes (p=0.0973).

Height (cm) in the group of 12-year-old among boys was at an average of 158.18, with a standard deviation of 8.71. The median distribution of results was 158 and the range of results from 141 to 177. However, among girls, the average totalled 159.24 with a standard deviation of 6.63. The median distribution of results equalled 159 and the range of results was from 142 to 175. There were no significant differences between the results for both sexes (p=0.4440).

Body mass (kg) in the group of 11-year-old was at an average an 44.19 with a standard deviation of 10.56. The median distribution of results was 41.7 and the range of results from 27.6 to 81.1. While among girls, the average was 41.66 with a standard deviation of 10.23. The median distribution of results totalled 39.95 and the range of results was from 24.8 to 73.5. There were no significant differences between the results for both sexes (s=0.1681).

Body mass (kg) in the 12-year-old group of boys was, on average, 50.08, the standard deviation being 13.72. The median distribution of results was 47.9 and the range of results ranged from 31.7 to 103.6. However, among girls, the average was 49.11 with a standard deviation of 10.34. The median distribution of results equalled 48.2 and the range of results was from 29.3 to 83.3. There were no significant differences between the results for boys and girls (p=0.6565).

Fat (%) in the group of 11-year-old boys was at an average of 21.85 with the standard deviation amounting to 7.5. The median distribution of results was 20.75 and the range of results was from 2.1 to 43.7. In the case of girls, the average was 23.65 with a standard deviation of 5.06. The median distribution of results totalled 22.2 and the results ranged from 14.8 to 37.3. There were no significant difference between the results for both genders (p=0.1064). Fat (%) in the group of 12-year-olds for boys was at an average of 20.1 with a standard deviation of 7.43. The median distribution of results was 17.7 and the range of results from 8.7 to 43.2. However, among girls, the average was 23.82 with a standard deviation of 4.55. The median distribution of results equalled 23.8 and the range of results was from 14.1 to 37.8. A highly significant difference was found between the results for both sexes (p=0.0011).

Fat mass (kg) in the group of 11-year-old boys was, on average, 10.46, with a standard deviation of 6.07. The median distribution of results was 8.5 while the results ranged from 3.1 to 35.4. Among girls, the average was 10.23 with a standard deviation of 4.49. The median distribution of results totalled 8.3 and the range of results was from 4.3 to 22.7. There were no significant differences between the results for both sexes (p=0.5699).

Fat mass (kg) in the 12-year-old group of boys averaged at 10.75, with a standard deviation of 6.7. The median distribution of results was 8.7 and the range of results was from 3 to 31.8. However, among girls, the average was 12.07 with a standard deviation of 4.81. The median distribution of results being 11.5 and the range of results from 4.4 to 31.5. There was no significant difference between the results for both genders (p=0.2065) .

FFM (kg) in the group of 11-year-old boys was, on average, 33.72, with a standard deviation of 5.11. The median distribution of results was 33.7 and ranged from 23.2 to 47.6, while among girls, the average was 31.42, the standard deviation being 6.16. The median distribution of results was 30.8 and the range of results from 20.4 to 50.8. Significant gender related differences were noted (p=0.0211).

FFM (kg) in the group of 12-year-old boys was at an average of 39.33 with a standard deviation of 8.49. The median distribution of results was 37.5 and the range of results was from 26.4 to 72.2. However, among girls, the average was 37.04 with a standard deviation of 5.94. The median distribution of results equalled 36.7 and the range of results was between 24.2 and 51.8. There were no significant differences between the results for both sexes (p=0.0832).

Muscle mass (kg) in the group of 11-year-old boys was, on average, 31.9, with the standard deviation totalling 4.92. The median distribution of results was 31.9 and the range of results from 21.9 to 45.2. However, among girls, the average was 29.8 with a standard deviation of 5.85. The median distribution of results was 29.2 and the range of results was from 19.3 to 48.2. A significant difference was found between the results for both gender groups (p=0.0275).

Muscle mass (kg) for the 12-year-old group of boys was average at 37.28with a standard deviation of 8.1. The median distribution of results amounted to 35.5, while the range of results was from 24.9 to 68.6.In the case of girls, the average was 35.15 with a standard deviation of 5.65. The median distribution of results equalled 34.8 and the range of results was from 22.9 to 49.2. There were no significant differences between the results for both sexes (p=0.0907).

BMI among boys aged 11 was at an average of 19.13 with a standard deviation of 3.76. The median distribution of results was 18.1 and the range of results was from 14.5 to 30.9. However, among girls, the average was 18.48, the standard deviation totalling 3.26. The median distribution of results was 17.7 and the range of results is from 12.5 to 27.7. There were no significant differences between the results obtained for girls and boys (p=0.2974).

BMI in the 12-year-old male group was, on average, 19.77, with a standard deviation of 4.1. The median distribution of results was 18.7 and the range of results being from 13.5 to 35.8. In contrast, among girls, the average was 19.25 with a standard deviation of 3.28. The median distribution of results was 19.1 and ranged from 13.8 to 31.7. There were no significant differences between the results for either of the sexes (p=0.4267).

TBW (kg) in the group of 11-year-old boys reached an average of 24.69, with a standard deviation of 3.75. The median distribution of results was 24.7 and the range of results between 17 and 34.8. Among girls, the average was 23 and the standard deviation, 4.52. The median distribution of results reached 22.55 and the range of results was from 14.9 to 37.2. Significant differences were established between the results for achieved for the boys and girls (p=0.0211).

TBW (kg) in the group of 12-year-old boys was averaged at 28.79 with a standard deviation of 6.22. The median distribution of results as 27.5 and the range of results was from 19.3 to 52.9. However, among girls, the average was 27.11, and the standard deviation reaching 4.35. The median distribution of results was 26.9 and the range of results was from 17.7 to 37.9. There were no significant sex-related differences between the results (p=0.0822).

TBW (%) in the group of 11-year-odl boys was, on average, 56.96, with a standard deviation of 5.18. The median distribution of results was 57.8 while the range of results was from 41.2 to 65.5. However, among girls, this average was 55.9 with a standard deviation at the level of 3.69. The median distribution of results was 57 and the range from 46 to 62.4. There were no significant sex-related differences between the results (p=0.1766).

TBW (%) in the group of 12-year-olds was at an average of 58.49 with a standard deviation of 5.45 for boys. In this group, the median distribution of results was 60.3, their range from 41.5 to 66.7. Among the group of girls, the average was 55.77 while the standard deviation 3.31. The median distribution of results was 55.8 and the range of results from 45.5 to 62.9. A greatly significant difference was found between the results for both sexes (p=0.0011). BMR (kJ) among boys aged 11 was 6,029.91 with a standard deviation of 597.4. The median distribution of results was 5,964.5, ranging from 4,766 to 7,682. For the girls' group, the average was 5,220.55, with a standard deviation of 674.44. The median distribution of results totalled 5138 and the range of results being from 4,054 to 7,435. A significant difference (p<0.0001) was noted between the results for both sexes. of 970.67. The median distribution of results is 6,318 and the range of results is from 5,209 to 10,544. However, among girls the average is 5,733.16 with a standard deviation of 678.25. The median distribution of results equalled 5,686 and the ranged from 4,381 to 7,623. A highly significant difference was noted between the results for both sexes (p<0.0001).

BMR (kcal) in the 11-year-old group of boys was averaged 1,441.17, with a standard deviation of 142.78. The median distribution of results was 1,425.5while the range of results was from 1,139 to 1,836. However, among girls, the average was 1,252.75 with a standard deviation of 162.54. The median distribution of results amounted to 1,242.5 and the range of results was from 969 to 1,777. A significant difference was exhibited between the results for both gender groups (p<0.0001).

BMR (kcal) in the group of 12-year-old boys was, on average, 1,562.82 and the standard deviation totalled 231.99. The median distribution of results equalled 1,510 and the range of results was from 1,245 to 2,520. In the case of girls, the average was 1,370.25, with a standard deviation of

162.11. The median distribution of results amounted to 1,359 and the range of results was between 1,047 and 1,822. A greatly significant difference was highlighted between the results obtained for both sexes (*p*<0.0001).

In the group of 11-year-old boys, bone mass (kg) was, on average, 1.78, the standard deviation being 0.24. The median distribution of results achieved the level of 1.8 and the range of results was from 1.3 to 2.4. However, among girls, this average was 1.62 and the standard deviation 0.31. The median distribution of results was 1.6 and the range of results was from 1.1 to 2.6. A greatly significant difference was found between the results for both sexes (*p*=0.0013).

Bone mass (kg) for the 12-year-old group among boys was averaged at 2.06. The standard deviation was 0.39. The median distribution of results for this group 2 while their range was between 1.5 and 3.6. For the same variable, the average was 1.9 for girls. The standard deviation in this group totalled 0.29. The median distribution of results was 1.9 and the range of results was between 1.3 and 2.6. A significant difference was indicated regarding the results obtained for both sexes (*p*=0.0109).

Proteins (kg) in the group of 11-year-old boys were, on average, 7.23 and the standard deviation equalled 1.13. The median distribution of results was 7.2 and the range of results was between 4.9 and 10.4. However, among girls, the average was 6.8 and the standard deviation of.34. The median distribution of results amounted to 6.65 and the range of results was from 4.4 to 11. A significant difference was found between the results for both sexes (*p*=0.0461).

Proteins (kg) in the group of 12-year-old boys were, on average, 8.48, with a standard deviation of 1.88. The median distribution of results totalled 8 and the range of results was from 5.6 to 15.7. Among girls, the average was 8.04 with a standard deviation of 1.3. The median distribution of results reached 7.9 and the range of results was from 5.2 to 11.3. There were no significant gender-related differences with regard to this variable (*p*=0.1241) (Tab. 1).

Table 1. Results of analysed variables according to gender

Variables	Age	Sex	X	SD	Mann-Whitney U test	Student's *t*-test
Body height (cm)	11	Boys	151.44	5.49	Z=1.877	t=1.673
		Girls	149.35	8.23	p=0.060	p=0.097
	12	Boys	158.18	8.71	Z=0.886	t=-0.768
		Girls	159.24	6.63	p=0.375	p=0.444
Body mass (kg)	11	Boys	44.19	10.56	Z=1.420	t=1.386
		Girls	41.66	10.23	p=0.155	p=0.168
	12	Boys	50.08	13.72	Z=0.114	t=0.446
		Girls	49.11	10.34	p=0.908	p=0.656
Fat (%)	11	Boys	21.85	7.5	Z=2.225	t=-1.626
		Girls	23.65	5.06	p=0.026	p=0.106
	12	Boys	20.1	7.43	Z=3.993	t=-3.371
		Girls	23.82	4.55	p=0.000	p=0.001
Fat mass (kg)	11	Boys	10.46	6.07	Z=0.568	t=0.245
		Girls	10.23	4.49	p=0.569	p=0.806
	12	Boys	10.75	6.7	Z=2.600	t=-1.271
		Girls	12.07	4.81	p=0.009	p=0.206
FFM (kg)	11	Boys	33.72	5.11	Z=2.561	t=2.334
		Girls	31.42	6.16	p=0.010	p=0.021
	12	Boys	39.33	8.49	Z=1.333	t=1.749
		Girls	37.04	5.94	p=0.182	p=0.083
Muscle mass (kg)	11	Boys	31.9	4.92	Z=2.467	t=2.229
		Girls	29.8	5.85	p=0.0136	p=0.027
	12	Boys	37.28	8.1	Z=1.288	t=1.707

		Girls	35.15	5.65	p=0.197	p=0.090
BMI	11	Boys	19.13	3.76	Z=0.739	t=1.046
		Girls	18.48	3.26	p=0.459	p=0.297
	12	Boys	19.77	4.1	Z=0.345	t=0.797
		Girls	19.25	3.28	p=0.729	p=0.426
TBW (kg)	11	Boys	24.69	3.75	Z=2.554	t=2.334
		Girls	23	4.52	p=0.010	p=0.021
	12	Boys	28.79	6.22	Z=1.331	t=1.754
		Girls	27.11	4.35	p=0.183	p=0.082
TBW (%)	11	Boys	56.96	5.18	Z=1.965	t=1.358
		Girls	55.9	3.69	p=0.049	p=0.176
	12	Boys	58.49	5.45	Z=4.024	t=3.375
		Girls	55.77	3.31	p=0.000	p=0.001
BMR (kJ)	11	Boys	6029.91	597.4	Z=6.367	t=7.255
		Girls	5220.55	674.44	p<0.001	p<0.001
	12	Boys	6538.84	970.67	Z=5.021	t=5.393
		Girls	5733.16	678.25	p<0.001	p<0.001
BMR (kcal)	11	Boys	1441.17	142.78	Z=6.195	t=7.036
		Girls	1252.75	162.54	p<0.001	p<0.001
	12	Boys	1562.82	231.99	Z=5.021	t=5.394
		Girls	1370.25	162.11	p<0.001	p<0.001
Bone mass (kg)	11	Boys	1.78	0.24	Z=3.580	t=3.291
		Girls	1.62	0.31	p=0.001	p=0.001
	12	Boys	2.06	0.39	Z=2.227	t=2.588
		Girls	1.9	0.29	p=0.025	p=0.010
Proteins (kg)	11	Boys	7.23	1.13	Z=2.270	t=2.014
		Girls	6.8	1.34	p=0.023	p=0.046
	12	Boys	8.48	1.88	Z=1.114	t=1.550
		Girls	7.23	1.13	p=0.265	p=0.124

Body composition results differed significantly (p<0.05) and highly significantly (p<0.01) according to on the type of spine. Body height showed significant (p=0.041) differences regarding spine type in post-hoc analyses, nonetheless, no specific differences between the groups could be indicated (p>0.05). Body mass showed highly significant (p=0.0018) differences depending on spine type and in post-hoc analyses, a significant difference (p = 0.0230) concerned the comparison of the groups “decreased kyphosis and increased lordosis” and “increased kyphosis and increased lordosis”.

Fat (%) showed highly significant (p=0.005) differences depending on the type of spine in post-hoc analyses, and a significant difference was noted when comparing the groups "increased kyphosis and increased lordosis" with "decreased kyphosis and decreased lordosis" (p=0.003) and "decreased kyphosis and correct lordosis "(p=0.036).

Fat mass (kg) showed highly significant (p=0.004) differences depending on spine type in post-hoc analyses. Highly significant (p=0.007) were differences in the comparison of the groups "increased kyphosis and increased lordosis" with "decreased kyphosis and decreased lordosis".

FFM (kg) showed highly significant (p=0.002) differences with regard to the defect in the sagittal plane, and in post-hoc analyses, a significant (p=0.033) difference was found in the comparison of the groups "decreased kyphosis and increased lordosis" with "increased kyphosis and correct lordosis" (Tab. 2).

Table 2. Body posture defects according to body composition

Variables	N; %	Body mass (kg)		Fat (%)		Fat mass (kg)		FFM (kg)	
		X; SD	Kruskal-Wallis test	X;SD	Kruskal-Wallis test	X;SD	Kruskal-Wallis test	X;SD	Kruskal-Wallis test
Correct spinal curvatures in the sagittal plane	106 % 41.08	48.00 ± 13.29	H=22.81 p=0.001	22.46 ± 7.02	H=20.28 p=0.005	11.50 ± 6.42	H=20.49 p=0.004	36.50 ± 8.03	H=21.648 p=0.002
Decreased kyphosis and correct lordosis	40 % 15.50	44.62 ± 8.98		21.02 ± 5.03		9.62 ± 3.71		35.00 ± 5.97	
Correct kyphosis and decreased lordosis	24 % 9.30	42.58 ± 11.89		21.58 ± 5.82		9.75 ± 5.07		32.84 ± 7.14	
Increased kyphosis and correct lordosis	17 % 6.59	50.79 ± 9.53		23.42 ± 7.05		12.29 ± 5.24		38.50 ± 5.93	
Correct kyphosis and increased lordosis	22 % 8.53	44.64 ± 9.39		24.74 ± 5.29		11.40 ± 4.44		33.24 ± 5.48	
Decreased kyphosis and decreased lordosis	32 % 12.40	42.63 ± 7.86		19.94 ± 5.55		8.77 ± 3.75		33.87 ± 5.12	
Decreased kyphosis and increased lordosis	4 % 1.55	33.18 ± 6.16		20.93 ± 3.41		6.98 ± 1.79		26.20 ± 4.84	
Increased kyphosis and increased lordosis	13 % 5.04	54.31 ± 12.60		28.16 ± 6.62		15.90 ± 7.37		38.41 ± 6.24	
Correct posture in the frontal	116 % 44.96	47.06 ± 12.58	H=2.252 p=0.324	22.77 ± 6.58	H=1.055 p=0.589	11.28 ± 6.04	H=1.005 p=0.604	35.78 ± 7.67	H=3.011 p=0.22

plane									1
Scoliotic posture	134 % 51.94	45.86 ± 11.04		21.95 ± 6.40		10.61 ± 5.33		35.25 ± 6.61	
Scoliosis	8 % 3.10	40.14 ± 7.99		22.78 ± 5.08		9.31 ± 3.34		30.83 ± 5.60	

Muscle mass (kg) exhibited highly significant (p=0.002) differences depending on the type of spine in post-hoc analyses and significant (p=0.033) differences related to the comparison of the groups "decreased kyphosis and increased lordosis" with "increased kyphosis and correct lordosis".

BMI demonstrated significant (p=0.010) differences depending on the type of spine in post-hoc analyses, however, no specific differences between the groups could be indicated (*p*>0.05).

TBW (kg) demonstrated highly significant (*p*=0.0029) differences depending on spine type in post-hoc analyses, the significant (*p*=0.032) difference was in the comparison of the groups "decreased kyphosis and increased lordosis" with "increased kyphosis and correct lordosis".

TBW (%) showed highly significant (*p*=0.005) differences depending on the type of spine, and in post-hoc analyses, significant differences concerned the comparison of the group "increased kyphosis and increased lordosis" with "decreased kyphosis and decreased lordosis" (*p*=0.003) and "decreased kyphosis and correct lordosis" (*p* = 0.034) (Tab. 3).

Table 3. Body posture defects according to body composition

Variables	N; %	Muscle mass (kg)		BMI		TBW (kg)		TBW (%)	
		X; SD	Kruskal-Wallis test	X;SD	Kruskal-Wallis test	X;SD	Kruskal-Wallis test	X;SD	Kruskal-Wallis test
Correct spinal curvatures in the sagittal plane	106 % 41.08	34.61± 7.65	H=21.907 p=0.002	19.58 ± 4.08	H=18.397 p=0.011	26.72 ± 5.88	H=21.668 p=0.002	56.57 ± 4.91	H=20.247 p=0.005
Decreased kyphosis and correct lordosis	40 % 15.50	33.17± 5.69		18.36 ± 2.41		25.62 ± 4.36		57.85 ± 3.63	
Correct kyphosis and decreased lordosis	24 % 9.30	31.12± 6.80		18.70 ± 3.56		24.05 ± 5.22		57.42 ± 4.28	
Increased kyphosis and correct lordosis	17 % 6.59	36.51± 5.65		20.63 ± 3.31		28.20 ± 4.35		56.09 ± 5.14	

Correct kyphosis and increased lordosis	22 % 8.53	31.39± 5.32		18.99 ± 3.26		24.33 ± 4.01		55.10 ± 3.88	
Decreased kyphosis and decreased lordosis	32 % 12.40	32.09± 4.86		17.99 ± 2.66		24.79 ± 3.76		58.61 ± 4.08	
Decreased kyphosis and increased lordosis	4 % 1.55	24.83± 4.62		15.25 ± 2.25		19.15 ± 3.55		57.83 ± 2.54	
Increased kyphosis and increased lordosis	13 % 5.04	36.43± 5.93		21.64 ± 4.30		28.13 ± 4.57		52.62 ± 4.84	
Correct posture in the frontal plane	116 % 44.96	33.92± 7.30		19.43 ± 4.01		26.19 ± 5.62		56.51 ± 4.80	
Scoliotic posture	134 % 51.94	33.40± 6.31	H=3.041 p=0.218	19.01 ± 3.31	H=1.318 p=0.517	25.80 ± 4.83	H=3.038 p=0.218	57.04 ± 4.51	H=1.027 p=0.598
Scoliosis	8 % 3.10	29.20± 5.31		17.54 ± 2.71		22.55 ± 4.11		56.48 ± 3.72	

BMR (kJ) showed highly significant (p=0.001) differences depending on spine type, and in post-hoc analyses, significant differences were found regarding the comparison of the groups "decreased kyphosis and increased lordosis" with "correct posture" (p=0.047) and "increased kyphosis and increased lordosis"(p=0.046) as well as "increased kyphosis and correct lordosis" (p=0.005).

BMR (kcal) showed highly significant (p=0.002) differences according to type of spine in post-hoc analyses, and significant differences applied when comparing the groups "decreased kyphosis and increased lordosis" with "correct posture" (p=0.0473) as well as "increased kyphosis and increased lordosis" (p=0.0468) and "increased kyphosis and correct lordosis"(p=0.005).

Bone mass (kg) indicated highly significant (p=0.002) differences depending on spine type and in post-hoc analyses, a significant difference (p=0.018) concerned the comparison of groups "decreased kyphosis and increased lordosis" with "increased kyphosis and correct lordosis".

Proteins (kg) showed highly significant (p=0.003) differences depending on the type of spine in post-hoc analyses, the significant difference (p=0.037) highlighted in the comparison of the groups "decreased kyphosis and increased lordosis" with "increased kyphosis and correct lordosis" (Tab. 4).

In contrast, body composition results did not differ significantly (p>0.05) with regard to scoliosis (Tab. 4).

Table 4. Body posture defects according to body composition

Zmienne	N; %	BMR (kJ)		BMR (kcal)		Bone mass (kg)		Proteins (kg)	
		X; SD	Kruskal-Wallis test	X;SD	Kruskal-Wallis test	X;SD	Kruskal-Wallis test	X;SD	Kruskal-Wallis test
Correct spinal curvatures in the sagittal plane	106 % 41.08	6031.08 ± 992.07	H=23.04 p=0.001	1441.46 ± 237.11	H=22.33 p=0.002	1.89 ± 0.39	H=21.86 p=0.002	7.89 ± 1.77	H=21.35 p=0.003
Decreased kyphosis and correct lordosis	40 % 15.50	5787.25 ± 715.35		1383.18 ± 170.99		1.83 ± 0.29		7.55 ± 1.32	
Correct kyphosis and decreased lordosis	24 % 9.30	5625.00 ± 779.26		1356.92 ± 182.16		1.72 ± 0.35		7.08 ± 1.57	
Increased kyphosis and correct lordosis	17 % 6.59	6310.00 ± 742.34		1508.1 ± 177.42		1.99 ± 0.28		8.31 ± 1.30	
Correct kyphosis and increased lordosis	22 % 8.53	5525.55 ± 675.08		1320.6 ± 161.35		1.72 ± 0.27		7.19 ± 1.20	
Decreased kyphosis and decreased lordosis	32 % 12.40	5799.13 ± 649.85		1386.0 ± 155.28		1.78 ± 0.26		7.30 ± 1.11	
Decreased kyphosis and increased lordosis	4 % 1.55	4620.00 ± 433.80		1104.2 ± 103.66		1.38 ± 0.22		5.68 ± 1.07	
Increased kyphosis and increased lordosis	13 % 5.04	6155.08 ± 807.30		1471.08 ± 192.93		1.98 ± 0.31		8.30 ± 1.37	
Correct posture in the frontal plane	116 % 44.96	5948.72 ± 941.73	H=2.807 p=0.245	1421.78 ± 225.08	H=2.755 p=0.252	1.86 ± 0.37	H=2.853 p=0.240	7.73 ± 1.68	H=3.065 p=0.215
Scoliotic posture	134 % 51.94	5860.98 ± 800.24		1403.06 ± 189.95		1.83 ± 0.32		7.61 ± 1.46	

Scoliosis	8 % 3.10	5333.00 ± 792.07		1274.63± 189.31		1.63± 0.29		6.65 ± 1.20	

4. Discussion

Correct posture is a decisive factor for body stability based only on small planes of two feet [11]. It is also a condition for the economic expenditure of energy for body balance, also affecting the proper positioning of internal organs and their functions [12]. Slight adaptation deviations in posture may prove to be beneficial from the point of view of effort-related economics. However, far-reaching adaptations to a given activity are already unfavourable [13]. They lead to defects in posture and, consequently, in body build. Therefore, compensatory procedures are recommended for people who tend to maintain one position for a long time, among others, students spending many hours sitting in front of a school desk [14].

Correct posture is also a body system that provides proper conditions for all body functions, and at the same time, enables active human behaviour towards the environment [15]. This behaviour requires a certain state of alert, which is associated with greater metabolism and significant energy expenditure [16]. This is true when measuring muscle EMG for correct and improper posture. In correct posture, EMG shows more intensive muscle work [17].

Fatigue, quickly occurring with the involvement of muscles in static efforts, effectively prevents the system by frequent change of position, by relieving one of the muscles, and burdening the others with work [18]. This happens not only while standing, during the phenomenon of so-called deflection, but also in other positions, even while sleeping [19]. Thus, the economic importance of correct posture lies not in the fact that the body is released from effort, but in the fact that it is not exposed to excessive expenditure, which occurs with incorrect body balance [20,21].

Most often, however, the health importance of correct body posture is emphasized. Its relationship with health and the proper functioning of the system is expressed in many forms [22]. Defective formation of the anterior-posterior curvatures of the spine causes worse ventilation of the tops of the lungs, and as a result, a tendency towards respiratory diseases; often leading to head tilt and compression of vessels in the neck region, which impairs cerebral blood supply; lumbar hyperlordosis is the cause of low back pain, neurological disorders and orthostatic proteinuria [23]. With excessive lumbar lordosis, protruding abdomen often occurs. The flaccid abdominal muscles, which do not give proper support to the viscera, lead to incorrect arrangement of organs, mainly the digestive system and abnormal movements of the diaphragm [24]. This weakens digestive and respiratory functions as well as circulation in the abdomen. Disabilities are manifested in digestive disorders, constipation, stabbing sensations, and often irritability and nervousness due to intestinal pressure on nerve plexuses. In girls, the phenomenon of lumbar hyperlordosis sometimes results in menstrual cycle disorders [25,26].

In the authors' research, there were significant relationships between the formation of sagittal curvatures of the spine and body composition in school-children. People with a strong build (with a predominance of mesomorphs) were generally characterised by the correct shape of the sagittal curvatures of the spine. In contrast, lean people (with the predominance of the ectomorphic factor) were more likely to have abnormalities in curvatures, while body composition results did not differ significantly (p>0.05) depending on scoliosis.

In a another similar study, the authors stated that anthropometry and body composition are plausible influences on pediatric sagittal standing posture. Girls showed increased values of lumbar angle, head and neck flexion, as well as craniocervical angle with the largest mean (standard deviation) difference in lumbar angle. In both genders, body mass and body mass index were weakly associated with lumbar angle: $0.24 \geq r \leq 0.31$ in girls and $0.16 \geq r \leq 0.26$ in boys, all $p < 0.001$. Fat, fat-free mass and bone mineral density were weakly associated with lumbar angle in both genders. Girls showed increased values of lumbar angle, head and neck flexion, and craniocervical angle with the largest mean (standard deviation) difference in lumbar angle among boys. In both genders, body mass and body mass index were weakly associated with lumbar angle in girls and boys. Fat and fat-free mass as well as bone mineral density were weakly associated with lumbar angle in both genders [27].

The aim of a different study was to assess the relationship between children's body mass composition and body posture. The relationship between physical activity level of children and the parameters characterising their posture, was also evaluated. The study included 120 school-children between the age of 11 and 13, comprising 61 girls and 59 boys. Each study participant underwent posture evaluation via the photogrammetric method using the projection moiré phenomenon. Moreover, body mass and the level of physical activity were evaluated. Children with the lowest content of muscle tissue showed the highest differences in the height of the inferior angles of the scapulas in the frontal plane. Children with excessive body fat had less curvature of the thoracic-lumbar spine, greater differences in the depth of the inferior angles of the scapula, and greater angles of the shoulder line. The individuals with higher levels of physical activity had smaller angle body inclination angles. The content of muscle tissue, adipose tissue, and physical activity level determines the variability of the parameter characterising body posture [28].

The objective of another study was to assess the relationship between body mass index (BMI) and the incidence of abnormalities in selected parameters measured in the trunk area. It was noticed that obese and overweight children tended to have incorrect position of the shoulders and pelvis in comparison to children with normal body mass. It was found that greater body mass (higher BMI) coincided with a larger distance of the scapulae from the frontal plane (p=0.009). An incease in BMI among children causes detrimental effects in scapula positioning, reflected in their greater distance from the frontal plane. The increase in BMI is not significantly correlated with positioning of the shoulder or pelvic joints, however, overweight or obese individuals demonstrated greater differences in their positioning [29].

In another study, the authors aimed to determine which somatic features and parameters of spinal curvatures in the sagittal plane show statistically significant differences among children with given types of body posture. The size-related parameters and indices of anterior-posterior spinal curvatures appeared to be the least differentiating factors among posture types. The strongest similarity of posture types was found in somatic features and weight-height ratios. The size parameters and indices of anterior-posterior spinal curvatures appeared to be the least differentiating factors among posture types. The strongest similarity of posture types was found in somatic features and weight-height ratios [30].

Knowledge regarding the ontogenetic variability of body composition will result in more precise information on the physiological and biochemical processess taking place in the body of a child with postural defects.

5. Conclusions

There were significant relationships between the shape of the anterior-posterior curvatures and body composition in school-children. Individuals with a strong build (predominance of mesomorphs) were generally characterised by the correct formation of these curvatures. In contrast, lean people (with the predominance of the ectomorphic factor) were more likely to have abnormalities within them. In the group of children with scoliotic posture and scoliosis, no relationships with body composition were observed.

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Motivation for the publication
This paper deserves to be published for a variety of reasons. Significant relationships were found between the shape of spinal curvatures in the sagittal plane body composition in school-children. Knowledge of these issues may significantly help determine the causes of postural defects.

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Ethical approval and consent for participation

Research was conducted with the consent of the Bioethical Committee of Jan Kochanowski University in Kielce, No. 20/2015.

Consent for publication

We have obtained consent for publication from the legal guardians of all the participants with individual patient data.

Competing interests

The authors declare no competing interests.

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