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Correlations of somatic traits and postural defects in girls and boys aged 10–12

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Background: The aim of the study was to analyse correlations between somatic features and variables of postural defects in girls and boys aged 10–12. *Methods:* The study included 301 children aged 10–12. Variables of somatic features were assessed using the method of bioelectrical impedance analysis – BIA, which consists of the evaluation of resistance to the flow of an electric current. Body posture was examined via the optoelectronic method – Diers formetric III 4D – using raster stereography. *Results:* The majority of participants demonstrated proper somatic features. Over half of the studied children had scoliotic posture, while a small group comprised those with scoliosis. Cases of reduced kyphosis and shallowed lordosis were also observed. Significant relationships were noted between somatic features and postural defect variables. *Conclusion:* Body posture is a psychomotor habit that is associated with somatic development, composition and body structure. Along proper body composition and somatic structure, shaping the habit of correct posture is much easier. Both in the prevention and correction of postural defects, one should gradually move away from the unilateral, usually single-component therapeutic effect. An approach considering both somatic and morphological as well as neurophysiological, emotional-volitional and environmental factors seems to be appropriate.

Key words: *somatic features, variables of postural defects, bioelectrical impedance analysis, Diers formetric III 4D*

1. Introduction

The unsatisfactory effects of posture and scoliosis therapy are an inspiration to verify relevant programmes and to look for new diagnostic methods [3], [8]. Among postural defects, scoliosis treatment is long-term, sometimes extending even into adulthood [20], [23]. This disease determines the choice of the future profession and the type of work performed. Therefore, preventative procedures, screening tests and postural reeducation are necessary [4], [19]. Attention to proper posture among children should absorb therapists from the time of pre-school or even infancy [7], [16], [24]. Despite many studies, the etiology of postural and scoliosis defects has still not been established. The general classification distinguishes defects regarding innate and acquired posture. Both can be osteogenic, muscle-derived or neurogenic [6], [9], [13]. Sometimes the aetiology of these defects is not known or they develop as a secondary effect of a different disorder. Their decisive percentage are acquired habitual defects [11], [14]. In the pathogenesis of postural defects, genetic, neurophysiological, somatic, morphological and environmental factors are isolated [10], [28]. The main goal of postural reeducation is to eliminate an existing defect or to hinder its progression. According to currently accepted views, the primary issue in postural and scoliosis therapy is shaping and improving the habit of correct posture [21], [22]. Great importance is also placed on stretching and strengthening appropriate muscle groups [15], [17], [18]. Some authors argue that in genetic re-education, genetic factors, somatic and morphological features are the most important [3], [16], [30]. Others, nevertheless, consider neurophysiological and environmental factors as the most significant [27], [28]. The research analysed the relationships between the somatic sphere

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of the subjects and the variable body posture. The aim of the study was to analyse correlations between somatic features and variables of postural defects in girls and boys aged 10–12.

2. Methods

Research was conducted at the beginning of 2016 in the Laboratory of Posturology at the Faculty of Medicine and Health Sciences in Kielce (Poland). The selection of study participants was random. The criteria for inclusion in the study group were age 10 to 12 years, place of residence in the Świętokrzyskie Voivodeship, lack of chronic illnesses and diseases that could affect posture, consent of the parent/legal guardian for participation in the study. Before the test, children and their parents were informed about the purpose of the study, its course and duration. All parents gave written consent for their child to participate in the study. All research procedures were carried out in accordance with the 1964 Declaration of Helsinki and with the consent of the University Bioethics Board for Scientific Research affairs at Jan Kochanowski University in Kielce (Poland) (Resolution No. 5/2015). The study involved 301 children aged 10–12 from 3 primary schools. The total number of studied girls was 142 (47.18%), and boys 159 (52.82%). Body composition was assessed using the method of bioelectrical impedance analysis – BIA, which consists in the evaluation of resistance to the flow of an electric current. As a research instrument, the Tanita MC 780 MA body composition analyser was used. As the result of measurements, the following variables were obtained: body height [cm], body mass [kg], body mass index (BMI), fat mass [kg], fat mass [%], fat free mass [kg], fat free mass [%], muscle mass [kg], muscle mass [%], total body water (kg), total body water (%). Body posture was examined bia the optoelectronic method – Diers formetric III 4D – using raster stereography. The examination was performed by means of the DiCAM software using the average measurement. This consisted in taking a sequence of 12 snapshots, which, by creating the mean value, reduce variances of the posture, and consequently, improve the clinical value of the test. The computer averages the snapshots and registers one of them. The following parameters describing body posture were analysed: trunk length VP-DM [mm], trunk length VP-DM [%], dimple distance DL-DR [mm], trunk length VP-SP [mm], trunk inclination VP-DM [mm], trunk inclination VP-DM [°], pelvic tilt DL-DR [°], pelvic tilt DL-DR [mm], inflection point ICT [mm], inflection point ITL [mm], kyphotic angle VP-ITL [°], kyphotic angle ICT-ITL max [°], pelvic inclination [°] (dimples), surface rotation (rms) [°], lateral deviation VP-DM (rms) [mm], lateral deviation VP-DM (max) [mm], trunk imbalance VP-DM [mm], trunk imbalance VP-DM [°], pelvic tilt in degrees [°], pelvic torsion DL-DR [°], kyphotic apex KA (VP-DM) [mm], inflection point ILS [mm], lordotic angle ITL-ILS [max°], lordosis angle ITL-DM [°], trunk imbalance VP-DM [°], lordosis apex LA (VP-DM) [mm], pelvic inclination (symmetry line) [°], trunk torsion [°] (Table 1). On the basis of chest kyphosis and lumbar lordosis angles, 9 types of posture were distinguished in the sagittal plane:

- spine with proper physiological curvature: chest kyphosis angle 42–55°; lumbar lordosis angle 33–47°;
- reduced kyphosis and reduced lordosis (flat back): chest kyphosis angle < 42°; lumbar lordosis angle <33°;
- reduced kyphosis and proper lordosis: chest kyphosis angle < 42°; lumbar lordosis angle 33–47°;
- reduced kyphosis and increased lordosis: chest kyphosis angle < 42°; lumbar lordosis angle >47°;
- proper kyphosis and increased lordosis (concave back): chest kyphosis angle 42–55°; lumbar lordosis angle >47°;
- proper kyphosis and reduced lordosis: chest kyphosis angle 42–55°; lumbar lordosis angle <33°;
- increased kyphosis and reduced lordosis: chest kyphosis angle >55°; lumbar lordosis angle <33°;
- increased kyphosis and proper lordosis (convex back): chest kyphosis angle >55°; lumbar lordosis angle 33–47°;
- increased kyphosis and increased lordosis (convex-concave back): chest kyphosis angle: >55°; lumbar lordosis angle > 47° [12].

In the case of the remaining body posture variables, the norms were the following: trunk inclination VP-DM: ≤5 mm, trunk inclination VP-DM: ≤5°, pelvic tilt DL-DR: ≤4° pelvic tilt DL-DR: ≤4 mm, pelvic inclination (dimples): ≤4°, surface rotation (rms): ≤4°, lateral deviation VP-DM (rms): ≤ 4 mm, lateral deviation VP-DM (max): ≤4 mm, trunk imbalance VP-DM: ≤4 mm, trunk imbalance VP-DM: ≤4°, pelvic tilt in degrees: ≤4°, pelvic torsion DL-DR: ≤2°, trunk imbalance VP-DM: ≤4° [12]. According to manufacturer guidelines of the Diers formetric III 4 D apparatus, the incidence of scoliotic posture and scoliosis was determined by considering the values of 3 variables: pelvic slant [mm], lateral deviation [mm] and the surface rotation [°]. Scoliotic posture occurred when pelvic slant and lateral deviation were less than 5 mm and surface rotation was less than 5 degrees. Scoliosis was present when pelvic slant and lateral deviation were greater than 5 mm and the surface rotation was greater than 5 degrees. To assess the occurrence of scoliotic posture or scoliosis, all 3 conditions must be met. In the absence of these 3 requirements, it is assumed that scoliosis or scoliotic posture is also absent [12]. Based on these norms, the following groups were distinguished: scoliotic posture, scoliosis, posture with proper physiological curvature of the spine, reduced kyphosis, reduced lordosis (flat back), reduced kyphosis, normal lordosis, reduced kyphosis, increased lordosis, normal kyphosis, reduced lordosis, normal kyphosis, increased lordosis (concave back), increased kyphosis, normal lordosis (convex back), increased kyphosis, increased lordosis (convex – concave back) [12]. Individuals with postural disorders generally show higher values for all of the listed parameters. The independent variables regarded somatic parameters, while the variables were dependent on postural features. Variables were verified for normality of distribution using the Shapiro–Wilk test and the Kolmogorov–Smirnov test. The differences between variables of body composition and posture in boys and girls were determined using the Student's *t*-test, while differences between types of body posture in the sagittal and frontal planes were estimated using the *p* structure test and the χ^2 test (of highest reliability). In order to distinguish variables without correlations, factor analysis was conducted. Relationships between somatic and posture defect variables were determined as canonical correlations. The $p < 0.05$ level of significance was assumed.

3. Results

Most of the subjects demonstrated normal somatic features. Between the boys and girls, there was significant differentiation regarding body mass, BMI, lean tissue index FFM [kg], muscle mass [kg] and total body water content [kg] (Table 1).

In the examined group, 87 (28.9%) children we observed demonstrated proper curvature of the spine, 67 children (22.26%) had increased kyphosis but proper lordosis, 48 (15.95 %) showed decreased kyphosis and decreased lordosis (flat back), 35 (11.63%) had proper kyphosis but increased lordosis (concave back), 21 (6.98%) demonstrated increased kyphosis and increased lordosis (convex-concave back), 17 (5.65%) had proper kyphosis but decreased lordosis, 14 (4.65%) had decreased kyphosis but increased lordosis and 12 (3.99%) showed increased kyphosis but proper lordosis (convex back) (Table 2). A significant relationship

Table 1. Differences between the variables of the body composition of girls and boys

Variables of somatic features	Girls						Boys					
	10 years		11 years		12 years		10 years		11 years		12 years	
	n	*x*	*n*	*x*	*n*	*x*	*n*	*x*	*n*	*x*	*n*	*x*
Body height [cm]	65	143.446	47	150.702	30	160.200	67	144.567	60	154.933	32	158.344
Body mass [kg]	65	36.328	47	40.177	30	47.663	67	38.146	60	46.913	32	48.256
Body mass index (BMI)	65	17.618	47	17.530	30	18.480	67	18.128	60	19.373	32	19.113
Fat mass [kg]	65	8.666	47	8.962	30	11.733	67	8.807	60	10.635	32	10.750
Fat mass [%]	65	23.128	47	21.485	30	23.790	67	22.288	60	21.753	32	21.341
Fat free mass [kg]	65	27.662	47	31.215	30	35.963	67	29.339	60	36.278	32	37.506
Fat free mass [%]	65	76.879	47	78.544	30	76.190	67	77.722	60	26.568	32	78.655
Muscle mass [kg]	65	26.222	47	29.619	30	34.117	67	27.745	60	34.380	32	35.541
Muscle mass [%]	65	72.870	47	74.495	30	72.270	67	73.476	60	74.129	32	74.521
Total body water [kg]	65	72.870	47	22.853	30	26.320	67	21.479	60	26.568	32	27.453
Total body water [%]	65	56.438	47	57.506	30	55.767	67	56.899	60	57.243	32	57.569

Table 2. Characteristics of body posture

Characteristics of body posture in the sagittal plane							
Types of body posture in the sagittal plane	Girls		Boys		Total		Structure indicator test *p*
	n	%	*n*	%	*n*	%	
Reduced kyphosis and reduced lordosis (flat back)	22	15.49	26	16.35	48	15.95	0.83893
Reduced kyphosis and proper lordosis	41	28.87	26	16.35	67	22.26	**0.00914**
Reduced kyphosis and increased lordosis	12	8.45	2	1.26	14	4.65	**0.00309**
Correct kyphosis, reduced lordosis	1	0.70	16	10.06	17	5.65	**0.00045**
Spine with proper physiological curvature	36	25.35	51	32.08	87	28.90	0.19896
Proper kyphosis and increased lordosis (concave back)	18	12.68	17	10.69	35	11.63	0.59189
Increased kyphosis and proper lordosis (convex back)	2	1.41	10	6.29	12	3.99	**0.03072**
Increased kyphosis and increased lordosis (convex-concave back)	10	7.04	11	6.92	21	6.98	0.96637
Increased kyphosis and reduced lordosis	–	–	–	–	–	–	–
Total	142	47.18	159	52.82	301	100	
$\chi^2 = 35.14282$; *df* = 7; *p* = **0.0001**							

Characteristics of body posture in the frontal plane							
Types of body posture in the frontal plane	Girls		Boys		Total		Structure indicator test *p*
	n	%	*n*	%	*n*	%	
Body posture correct	58	40.85	71	44.65	129	42.86	0,50501
Scoliotic posture	76	53.52	85	53.46	161	53.49	0,99141
Scoliosis	8	5.63	3	1.89	11	3.65	0,08372
Total	142	47.18	159	52.82	301	100	
$\chi^2 = 3.213308$; *df* = 2; *p* = **0.20056**							

between the gender of the subjects was also noted concerning the occurrence of reduced kyphosis and proper lordosis ($p = 0.00914$), decreased kyphosis and increased lordosis ($p = 0.00309$), proper kyphosis and reduced lordosis ($p = 0.00045$) (concave back) and increased kyphosis and proper lordosis (convex back) ($p = 0.03072$). There were no cases of increased kyphosis and decreased lordosis (Table 2). More than half of the children, 161 (53.49%), were characterised by the occurrence of scoliotic posture, while 11 (3.65%) had scoliosis. Children without scoliotic posture or scoliosis totalled 129 (42.86%) (Table 2). There were no significant differences noted in the frontal plane between the boys and girls (Table 2).

Furthermore, in the group of girls and boys, there was significant differentiation in deviation from vertical VP-DM [°] ($p = 0.01563$), deviation from vertical VP-DM [mm] ($p = 0.01536$), pelvic tilt [°] ($p = 0.00002$), inflection point ICT [mm] ($p = 0.00464$), kyphosis apex KA (VPDM) [mm] ($p = 0.00198$), inflection point ITL [mm] ($p = 0.04847$), kyphosis angle ICT-ITL (max) [°] ($p = 0.00610$), kyphosis angle VP-ITL [°] ($p = 0.00855$), lordosis angle ITL-ITS (max) [°] ($p = 0.00453$), lordosis angle ITL-DM [°] ($p = 0.00742$) and pelvic tilt (line of symmetry) [°] ($p = 0.00001$) (Table 3).

Some of the somatic variables were strongly correlated. Correlations were also demonstrated in the case of postural defect variables. On the other hand, canonical correlation analysis requires that each canonic variable (left and right sets) be an independent one. Therefore, in order to identify variables that do

Table 3. Differences between other variable postures of girls and boys

Variables of body posture	Girls			Boys			T	*df*	*p*
	n	*x*	*s*	*n*	*x*	*s*			
Trunk inclination VP-DM [°]	142	–0.110	1201	159	–0.457	1.266	2.431	299	**0.01563**
Trunk inclination VP-DM [mm]	142	–0.716	7.696	159	–2.966	8.252	2.438	299	**0.01536**
Pelvic inclination [°]	142	24.507	5.613	159	21.709	5.652	4.301	299	**0.00002**
Inflection point ICT [mm]	142	1.562	9.922	159	–1.678	9.764	2.852	299	**0.00464**
Kyphosis peak (VPDM) [mm]	142	–126.348	30.352	159	–136.233	24.543	3.120	299	**0.00198**
Inflection point ITL [mm]	142	–228.560	37.802	159	–237.133	37.172	1.981	299	**0.04847**
Kyphotic angle ICT-ITL (maks) [°]	142	41.781	9.210	159	44.748	9.388	–2.762	299	**0.00610**
Kyphotic angle VP-ITL [°]	142	38.757	9.332	159	41.708	9.935	–2.647	299	**0.00855**
Lordotic angle ITL-ITS (maks) [°]	142	41.870	9.177	159	38.827	9.241	2.861	299	**0.00453**
Lordotic angle ITL-DM [°]	142	38.145	9.032	159	35.322	9.102	2.696	299	**0.00742**
Pelvic tilt DL-DR [°]	142	24.235	7.785	159	20.308	7.052	4.592	299	**0.00001**

not show dependence, factor analysis was used. As a result of exploratory factor analysis with Varimax rotation among 11 normalized somatic variables, 2 orthogonal factors were found which did not correlate with one another. The proportion of these 2 factors in the total variance was significantly higher than the others. For the individual factors, the absolute values of the factorial load were as follows: Factor 1: body height (LC = 0.994), Factor 2: muscle mass [%] (LP = 0.960). The distinguished orthogonal factors comprised 81.6% of the total variance. The selected variables did not correlate with each other despite the range: (R = –0,102; R = 0.102). As a result of exploratory factor analysis using Varimax rotation among the 12 normalised variables characterising body posture, orthogonal factors not showing correlations with one another were found. The share of these 12 factors in the total variance was significantly higher than the others. For individual factors, the absolute values of the factorial load were found in the following factors: Factor 1: trunk length VP-SP [mm] (LC = 0.935), Factor 2: kyphotic angle VP-ITL [°] (LC = –0.940), Factor 3: surface rotation (max) [°] (LC = 0.940), pelvic inclination [°] (LC = 0.905), lateral deviation VP-DM (rms) [mm], (LC = 0.878), trunk inclination VP-DM [°] (LC = –0.974), pelvic tilt DL-DR [°] (LC = –0.974), trunk inclination VP-DM [°] (LC = –0.964), dimple distance DL-DR [%] (LC = 0.926), inflection point ICT [mm] (LC = 0.821), trunk length VP-SP [%] (LC = –0.916). The selected orthogonal factors constituted 88.3% of the total variance. The selected variables did not correlate with each other despite the range: (R = –0.309; R = 0.325). In canonical correlation, on the side of somatic variables, the greatest shares (absolute value of canonical weight) were linked to: body height (–0.988) and muscle mass [%] (0.086). On the side of posture defect variables, the greatest contributions (absolute value of canonical weight) regarded: trunk length VP-SP [mm] (–0.938), trunk length VP-SP [%] (0.069), dimple distance DL-DR [%] (0.160), trunk inclination VP-DM [°] (–0.079), pelvic tilt DL-DR [°] (–0.028), inflection point ICT [mm] (–0.240), kyphotic angle (VP – 0.121), pelvic inclination [°] (–0.084), surface rotation (rms) (–0.004), lateral deviation VP-DM (rms) [mm] (0.035) (Table 4). Of the two essential elements (solutions), the first one was selected for the greatest substantive value (sensibility of canonical variables determined by the weights of individual constituent variables). The canonical analysis of selected somatic variables (left set) and postural stability variables (right set) allowed to create significant and correlated variables at the level of (R = 0.83233) ($p < 0.001$) (Table 4).

Table 4. Canonical weights of somatic and postural variables

Canonical weights						
Variables of somatic features				Variables of body posture		
2				12		
Isolated variation	100.00%			19.49%		
Total redundancy	48.39%			9.33%		
Variables of somatic features	Elem 1	Elem 2	Elem 3	Postural variables	Elem 1	Elem 2
Body height [mm]	**–0.988**	–0.188	–0.355	Trunk length VP-SP [mm]	**–0.938**	–0.274
Muscle mass [%]	**0.086**	–1.002	0.917	Trunk length VP-SP [%]	**0.069**	0.178
				Dimple distance DL-DR [%]	**–0.160**	0.365
				Trunk inclination VP-DM [°]	**–0.126**	0.635
				Trunk imbalance VP-DM [°]	**–0.079**	0.102
				Pelvic tilt DL-DR [°]	**–0.028**	–0.067
				Inflection point ICT [mm]	**–0.240**	0.697
				Kyphotic angle VP-ITL [°]	**–0.121**	0.090
				Pelvic inclination [°]	**–0.084**	0.086
				Surface rotation (rms) [°]	**–0.004**	0.043
				Lateral deviation VP-DM (rms) [mm]	**0.031**	–0.015
				Lateral deviation VP-DM (max) [mm]	**0.035**	–0.009
$R = 0.83233$; χ^2 (24) = 434.5605; $p < 0.001$						

4. Discussion

Unsatisfactory results of the corrective procedure in the cases of postural defects and scoliosis were the inspiration to undertake research aimed at understanding the mechanisms of their pathogenesis. Both in the prevention and correction of postural defects, one should gradually move away from the unilateral, usually single-component therapeutic effect. An approach that takes both genetic, somatic, morphological as well as environmental and neurophysiological factors into account seems appropriate [29]. Another, similar study aimed to investigate the association between bone physical properties and sagittal standing postural patterns in 7-year-old children. The relationship between lean and non-fat mass and postural patterns was also examined. In this population-based paediatric setting, there was an inverse association between bone physical properties and flat posture. Bone and posture were more strongly positively linked in a rounded posture. Our results support the observation that both bone properties and posture mature in a shared and interrelated mechanical environment, probably modulated by pattern-specific anthropometrics and body composition [1]. In similar research, the aim 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. Children with the lowest content of muscle tissue showed the highest difference in the height of the inferior angles of the scapulas in the coronal plane. Children with excessive body fat had less slope of the thoracic-lumbar spine, greater difference in the depth of the inferior angles of the scapula and greater angle of the shoulder line [30]. The purpose of subsequent studies was to determine which somatic features and curvature of the spine in the sagittal plane show statistically significant differences between children with specific types of posture. The size-related parameters and indices of anterior-posterior spinal curvature 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 [2]. Another study aimed to investigate body composition and its correlation with leptin and soluble leptin receptor (sOB-R) levels in girls with adolescent idiopathic scoliosis (AIS), compared to healthy controls. The results suggested that the lower body mass in AIS girls was contributed to both lower skeletal muscle mass and lower body fat. Altered leptin bioavailability also exists in AIS girls and could lead to lower body mass, lower BMI and abnormal body composition that were manifested in AIS simultaneously [25]. Other studies show a negative association between body mass index (BMI)/body mass at age 10 and scoliosis at age 15. This association with BMI/body mass reflects associations with both fat mass and lean body mass. After adjustment to age, gender, leg length and fat mass, SD increased in lean mass, there was by 20% reduced risk of scoliosis and per SD increase in fat mass, there was by 13% reduced risk of scoliosis. In terms of adipocyte function, an inverse association was seen between leptin at age 10 and scoliosis, and a positive association between adiponectin at age 10 and scoliosis [5]. In our present research, significant correlations between some of the somatic features and postural defect variables were shown. In the canonical correlation regarding somatic variables, the largest shares concerned: body height and muscle mass [%]. However, on the side of postural defect variables, the largest shares were related to: trunk length VP-SP, trunk length VP-SP, dimple distance DL-DR, trunk inclination VP-DM, pelvic tilt DL-DR, inflection point ICT [mm], kyphotic angle VP-ITL, pelvic inclination, surface rotation (rms), lateral deviation VP-DM (rms) [mm] and lateral deviation VP-DM (max). Knowledge about the ontogenetic variability of somatic traits and body composition contributes to a more accurate understanding of the physiological and biochemical processes taking place in the body of a child with defective posture. Knowledge of these issues can significantly help in the treatment of scoliotic posture and scoliosis [26].

5. Conclusion

Body posture is a psychomotor habit associated with somatic development as well as body composition and structure. Along with proper body composition and build, shaping the habit of the correct posture is much easier. Both in the prevention and correction of postural defects, one should gradually move away from the unilateral, usually single-component therapeutic effect. An approach considering both somatic, morphological as well as neurophysiological, emotional-volitional and environmental factors seems to be appropriate.

Ethics approval and consent to participate

All research procedures were carried out in accordance with the 1964 Declaration of Helsinki and with the consent of the University Bioethics Board for Scientific Research affairs at Jan Kochanowski University in Kielce (Poland) (Resolution No. 5/2015).

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