SEXUAL DIMORPHISM IN SIGNIFICANT CORRELATIONS FREQUENCY BETWEEN THE CHARACTERISTICS OF BODY TRUNK AND FEET IN CHILDREN AGED 4 TO 6 YEARS

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Abstract Relatively few publications have concerned characteristics of body trunk and feet. It is generally suggested that correlations exist between the characteristics of the developing foot and the spinal column. The purpose of the study was to show sexual dimorphism in frequency of incidence, as well as significant correlations concerning selected body trunk and feet parameters in the group of 4–6-year-old children.

The examinations conducted in a group of children aged 4 to 6 allowed for recording 2,988 observations, including 1,482 girls and 1,506 boys, and values of 87 characteristics that described body trunk and feet. The test stands for the measurement of the selected parameters using the photogrammetric method consisted of a personal computer, software, screen and printer, and a projection-reception device with a camera.

The general number of body trunk characteristics having significant correlations with feet parameters in females was slightly higher. The number of relationships in sagittal and frontal planes was the same in both sexes. The characteristics that differentiated males from females were found mainly in transverse and frontal planes. The number of feet characteristics that most often showed significant correlations with body trunk parameters was higher in girls than in boys. These were mainly characteristics concerning width and length, longitudinal arch and disorders in the position of the feet. The characteristics that differentiated boys described only the longitudinal arch of the feet.

Key words relationships, dimorphism, characteristics of body posture, feet, sex

Introduction

The issue of sexual dimorphism in the field of somatic traits has occurred in numerous publications and seems to be obvious, well-described and undisputed (Górniak, 2000; Webster-Gandy, Warren, Henry, 2003; Wolański, 2005, Gosh, Choudhary, Chowdhury, Ghosh, 2009; Perenc, Radochońska, 2012; Koudelová, Brůžek, Cagáňová,

Krajíček, Velemínská, 2015; Wojciechowska-Maszkowska, Wieloch, 2015). However, there have been very few publications regarding the impact and correlations of body trunk and foot parameters. M. Steinmetz (1984) assumes there is interdependence between the type of the forming foot and the shape of the spine. The suggestion that if the spinal traits can be corrected by modifying the foot parameters, the foot parameters can be influenced by changing the spinal characteristics, raises a number of objections. However, the results of the studies presented below, at least theoretically, allow such a possibility. M. Steinmetz (1984) also emphasizes legitimacy of wearing corrective footwear since a correctly positioned foot in a special footwear can cause spinal deformation which is consistent with the views expressed by the authors of this paper. The pilot studies by J. Drzał-Grabiec and S. Snela (2012) in the population of 7−9-year-old girls and boys allowed to find relationships between the longitudinal arch of the right and left foot, measured with Clarke's angle, and length parameters describing body posture. According to the research, there was a significant correlation between the longitudinal arch of both feet, measured using Clarke's angle and the spine height between points C7 and S1. This dependence was confirmed when considering the division into subgroups of boys and girls as well as age subgroups. As far as age groups are concerned, a significant correlation was observed only in the group of 9-year-olds.

The purpose of the study was to show sexual dimorphism in frequency of incidence, as well as significant correlations concerning selected body trunk and feet parameters in the group of 4−6-year-old children.

Material and method

The studies conducted in the Warmińsko-Mazurskie Voivodeship enabled to record 2,988 observations including 1,482 girls and 1,506 boys. Body posture was assessed by means of the photogrammetric method with regard to generally adopted principles (Mrozkowiak, 2015). The statistical analysis covered 87 angular and linear parameters of the spine, pelvis, trunk and feet in the sagittal, frontal and transverse planes, in particular age and environment categories (Table 1, Table 2). The empirical data were the quantitative and qualitative characteristics (gender, domicile, etc.). The conducted calculations covering the values of position statistics (arithmetic mean, quartiles), the dispersion parameter (standard deviation) and symmetry indicators (asymmetry and concentration indicators) provided a full view of the distribution of the studied features considering gender, environment and age ranges. The correlations and their significance were assessed using p-value and frequency expressed in percentage. Due to editorial requirements related to article volume, the authors deliberately did not include the detailed description and a full statistical analysis of the findings, citing only partial results ensuing from the subject of the paper.

Table 1. Body trunk parameters

No.	Symbol	Parameters		
		unit	name	description
1	2	3	4	5
Sagittal plane				
1.	Alfa	degree	Inclination of lumbo-sacral region	
2.	Beta	degree	Inclination of thoracolumbar region	
3.	Gamma	degree	Inclination of upper thoracic region	
4.	DCK	mm	Total length of the spine	Distance between C7 and S1, measured in vertical axis
5.	KPT	degree	Angle of extension	Defined as a deviation of the C7-S1 line from vertical position (backwards)

1	2	3	4	5
6.	KPT–	degree	Angle of body bent	Defined as a deviation of the C7-S1 line from vertical position (forwards)
7.	DKP	mm	Thoracic kyphosis length	Distance between LL and C7
8.	KKP	degree	Thoracic kyphosis angle	KKP = 180 – (Beta + Gamma)
9.	RKP	mm	Thoracic kyphosis height	Distance between points C7 and PL
10.	GKP	mm	Thoracic kyphosis depth	Distance measured horizontally between the vertical lines passing through points PL and KP
11.	DLL	mm	Lumbar lordosis length	Distance measured between points S1 and KP
12.	KLL	degree	Angle of lumbar lordosis	KLL = 180 – (Alfa + Beta)
13.	RLL	mm	Lumbar lordosis height	Distance between points S1 and PL
14.	GLL–	mm	Lumbar lordosis depth	Distance measured horizontally between the vertical lines passing through points PL and LL
				Frontal plane
15.	KNT–	degree	Angle of body bent to the side	Defined as deviation of the C7-S1 line from the vertical axis to the left
16.	KNT	degree		Defined as deviation of the C7-S1 line from the vertical axis to the right
17.	LBW–	mm	Right shoulder up	Distance measured vertically between horizontal lines passing through points B_2 and B_4
18.	LBW	mm	Left shoulder higher	
19.	KLB	degree	Shoulder line angle, right shoulder up	Angle between the horizontal line and the straight line passing through points B_2 and B_4
20.	KLB–	degree	Shoulder line angle, left shoulder up	
21.	ŁŁW	mm	Left scapula up	Distance measured vertically between horizontal lines passing through points Ł1 and Łp
22.	ŁŁW–	mm	Right scapula up	
23.	UL	degree	Angle of scapula line, right scapula up	Angle between the horizontal line and the straight line passing through points Ł1 and Łp
24.	UL–	degree	Angle of scapula line, left scapula up	
25.	OL	mm	Lower angle of left scapula more distant	Difference of the distance of lower angles of the scapula from the line of spinous processes measured horizontally along the lines passing through points Łl and Łp
26.	OL–	mm	Lower angle of right scapula more distant	
27.	TT	mm	Left waist triangle up	Difference of the distance measured vertically between points T_1 and T_2, T_3 and T_4.
28.	TT–	mm	Right waist triangle up	
29.	TS	mm	Left waist triangle wider	Difference of the distance measured horizontally between straight lines passing through points T_1 and T_2, T_3 and T_4
30.	TS–	mm	Right waist triangle wider	
31.	KNM	degree	Pelvis tilt, right ilium up	Angle between the horizontal line and the straight line passing through points M1 and Mp
32.	KNM–	degree	Pelvis tilt, left ilium up	
33.	UK	mm	Maximum inclination of the spinous process to the right	Maximal deviation of the spinous process from the line from S1. The distance is measured in horizontal line.
34.	UK–	mm	Maximum inclination of the spinous process to the left	
35.	NK	–	Number of the vertebra maximally distanced to the left or to the right	Number of the vertebra most distanced to the left or to the right in the asymmetric line of the spinous process, counting as 1 the first cervical vertebra (C_1). If the arithmetic mean takes the value e.g. from 12.0 to 12.5, it is Th_5, if from 12.6 to 12.9 it is Th_6
				Transverse plane
36.	ŁB–	mm	Lower angle of the right scapula more convex	Difference of the distance of lower scapula angles from the surface of the back
37.	ŁB	mm	Lower angle of the scapula more convex	
38.	UB–	degree	Angle of projection line of lower scapula angles, the left one more convex	Difference in the angles $UB_1 – UB_2$. Angle UB_2 between: the line passing through point Łl and at the same time perpendicular to the camera axis and the straight line passing through points Łl and Łp. Angle UB_1 between the line passing through point Łp and perpendicular to the camera axis and the straight line passing through points Łp and Łl
39.	UB	degree	Angle of projection line of lower scapula angles, the right one more convex	

1	2	3	4	5
40.	KSM	degree	Pelvis rotated to the right	Angle between the line passing through point M1 and perpendicular to the camera axis and the straight line passing through points M1 and MP
41.	KSM–	degree	Pelvis rotated to the left	Angle between the line passing through point Mp and perpendicular to the camera axis and the straight line passing through points Ml and MP

Source: author's own research.

Table 2. Foot parameters

No.	Symbol	Parameters		
		unit	name	description
1	2	3	4	5
1.	DL p	mm	Length of the right foot (P), left foot (L)	Distance between points akropodion and pternion in a plantogram
2.	DL l			
3.	Sz p		Length of the right foot (P), left foot (L)	Distance between points metatarsale fibulare and metatarsale tibiale in a plantogram
4.	Sz l			
5.	Alfa p m	degree	Valgus angle of the hallux of the right foot: AlfaPp, of the left foot: AlfaLp. Angle of varus deformity in the right foot: AlfaPm, left foot: AlfaLm	Angle between the straight line passing through points metatarsale tibiale and the most inner one on the medial edge of the heel and the straight line passing through points metatarsale tibiale and the most inner one on the medial edge of the great toe
6.	Alfa p p			
7.	Alfa l m			
8.	Alfa l p			
9.	Beta p m		Angle of varus deformity of the 5th toe of the right foot: Beta Pp, of the left foot: BetaLp. Valgus angle of the fifth toe of the right foot: BetaPm, left foot: BetaLm.	Angle between the straight line passing through points metatarsale fibulare and the most outer one on the lateral edge of the heel and the straight line passing through points metatarsale fibulare and the most outer one on the lateral edge of the fifth toe in a plantogram
10.	Beta p p			
11.	Beta l m			
12.	Beta l p			
13.	Gamma p (Gam.P)		Heel angle of right foot (P), of left foot (L)	Angle between the straight line passing through points metatarsale tibiale and the most inner one on the medial edge of the heel and the straight line passing through points metatarsale fibulare and the most outer one on the lateral edge of the heel in a plantogram
14.	Gamma l (Gam.L)			
15.	PS p	mm^2	Plantar surface of right foot (P), left foot (L)	Plantar surface of the foot
16.	PS l			
17.	DP 1	mm	Length of longitudinal arch 1, 2, 3, 4, and 5 of right foot (P), left foot (L)	Length of the arch from 1, 2, 3, 4 and 5 metatarsale foot to point pternion
18.	DP 2			
19.	DP 3			
20.	DP 4			
21.	DP 5			
22.	DL 1			
23.	DL 2			
24.	DL 3			
25.	DL 4			
26.	DL 5			
27.	WP 1		Height of the arch 1, 2, 3, 4 and 5 of right foot (P), left foot (L)	Distance from the bottom to the highest point of arch 1, 2, 3, 4 and 5
28.	WP 2			
29.	WP 3			
30.	WP 4			
31.	WP 5			
32.	WL 1			
33.	WL 2			
34.	WL 3			
35.	WL 4			
36.	WL 5			

1	2	3	4	5
37.	SP 1	mm	Width of the arch 1, 2, 3, 4 and 5 of right foot (P), left foot (L)	Bowstring of the distance of the arch 1, 2, 3, 4 and 5
38.	SP 2			
39.	SP 3			
40.	SP 4			
41.	SP 5			
42.	SL 1			
43.	SL 2			
44.	SL 3			
45.	SL 4			
46.	SL 5			

The fundamental assumption of the study was to always assess the habitual posture as a relatively constant individual characteristic of a human being. This posture reflected an individual emotional, psychical and social condition of the subject. Moreover, the posture provided the most reliable description of the subject's silhouette at a given time and in a place. The conducted diagnostics did not determine whether an individual's posture was correct or not, it only identified the condition of its ontogenetic development. Objectified and comparable test results were able to ensure that the postural parameters adopted for the analysis were recorded with possible to determine compensations. The combined assessment of the trunk and feet allowed to objectively determine the quality of the postural model applied in a given environment, gender and age category. The measuring instrument used in the study determined several tens of parameters describing body posture (Table 1, Table 2). Obtaining the spatial picture was possible thanks to displaying the line of strictly defined parameters on back and feet. The lines falling on the skin of a child got distorted depending on the configuration of the surface screen. The applied lens ensured that the imaging of a subject could be received with the use of the MORA 4G HD diagnostics set, the picture can be received and transmitted onto a computer by a special optical system with a camera. The distortions of the line imaging recorded in the computer memory were processed through a numerical algorithm on the topographic map of the investigated surface. When conducting the study, one should be aware of the fact that the taken photo records an image of the silhouette displayed on a child's skin (Mrozkowiak, 2015). The acceptance of the Research Ethics Committee at the Kazimierz Wielki University in Bydgoszcz had been obtained before the research were conducted[1].

Results

The analysis of the findings headed in two directions. The first one was to determine how often and which body trunk parameters most frequently revealed a significant correlation with feet parameters within sexual dimorphism. The second, to explain which feet parameters most often significantly correlated with the body trunk parameters, also within sexual dimorphism.

The analysis of the study results with regard to sexual dimorphism, concerning feet parameters with which body trunk parameters correlated most frequently, showed the following parameters in girls: width of both feet (SZP,

[1] A written consent of parents or guardians was received, for their children to participate in a scientific project, as well acceptance of preschool principals and the Research Ethics Committee at the Kazimierz Wielki University in Bydgoszcz – KEBN 2/2018.

SZL), length of the left foot (DLL), valgus angle of the fifth toe in the right foot (BetaPp), and of the Plantar surface of left foot (PSL), height and length of the first arch in the right foot (WP1, DP1), width of the first and fifth longitudinal arch of the left foot (SL1, SL5). As regards boys, these were the values of such parameters as height of the second and third longitudinal arch in the right foot (WP2, WP3), width of the third and fourth arch in the right foot (SP3, SP4), height of the fourth and length of the fifth arch (WL4, DL5) and width of the third arch in the left foot (SL3) (Table 3).

Table 3. Sexual dimorphism of the characteristics of feet with the most frequent significant correlation with the characteristics of body trunk; (n) = 1,482 girls and 1,506 boys

Parameter	Gender		Parameter	Gender	
	girls	boys		girls	boys
SZP	13.4	0.0	SP1	6.5	17.3
SZL	13.4	0.0	SP3	0.0	8.6
DLP	17.3	17.3	SP4	0.0	6.5
DLL	17.3	0.0	WL4	0.0	10.8
BetaP	6.5	0.0	WL5	6.5	8.6
GamP	8.6	6.5	DL2	21.7	6.5
GamL	17.3	15.2	DL5	0.0	6.5
PSL	8.6	0.0	SL1	22.6	0.0
WP1	6.5	0.0	SL2	17.3	6.5
WP2	0.0	13.4	SL3	0.0	8.6
WP3	0.0	8.6	SL4	6.5	6.5
DP1	10.8	0.0	SL5	6.5	0.0

The analysis of the study results in terms of sexual dimorphism of body trunk parameters that most frequently differentiated the relationships with feet parameters revealed that among girls these were the values of the following parameters: the angle, height and depth of lumbar lordosis (KLL, RLL, GLL), angle of body trunk bent to the left side in the frontal plane (KNT−), angle of body bent to side in the sagittal plane (KPT−), asymmetry of waist triangles height with the right triangle up (TT−), asymmetry of the distance of lower angles from the spinous process with the angle of the left scapula being more distanced (OL), maximum inclination of one spinous process to the left (UK−). Among boys, these characteristics included: height of thoracic kyphosis (RKP), angle of body trunk bent to the right side in the frontal plane (KNT), asymmetry of the projection line of lower scapula angles with the left one more convex (UB), angle of pelvis rotated to the right (KSM), number of the vertebrae maximally distanced to the left from the spinous process (NK−) (Table 4).

No research similar to those presented in this study had been found in source literature. Statistical analysis revealed a number of dependencies significant for posture equilibrium disorders. Despite evident results of statistical analysis, the above presented relations should not be approached uncritically, for what logical connection can there occur between depth and height of thoracic kyphosis and varus or valgus angle of the fifth toe? While planning a correction procedure, one should take into consideration the above presented correlations not only between values of feet parameters and spine-pelvis system, but also between spine-pelvis system and feet, as well as weight and height, as presented in other research of the authors. The analysed relations between spine-pelvis and feet characteristics at boys and girls aged 4−18 demonstrate that the most often a significant correlation occurs in spinal sagittal longitudinal features, less often in frontal or transverse ones. These features most often

Table 4. Sexual dimorphism of the frequency of significant correlations between the characteristics of body trunk and feet; (n) = 1,482 girls and 1,506 boys

Parameter	Gender		Parameter	Gender	
	girls	boys		girls	boys
DCK	13.72	5.88	KPT−	19.6	0.0
Alfa	9.8	5.88	TT−	7.84	0.0
Beta	7.84	3.92	TS	3.92	7.84
Gamma	3.92	7.84	ŁB	3.92	11.76
KKP	3.92	7.84	UB	0.0	7.84
RKP	0.0	23.52	UB−	3.92	13.72
DKP	5.88	15.68	UL	5.88	7.84
GKP	5.88	13.72	ŁŁW	11.76	5.88
KLL	21.56	0.0	KLB	7.64	11.76
DLL	13.72	3.92	KLB−	7.84	11.76
RLL	15.68	0.0	OL	5.88	0.0
GLL	3.92	0.0	KNM	3.92	13.72
KNT	0.0	3.92	KSM	0.0	3.92
KNT-	5.88	0.0	UK−	13.72	0.0
			NK	0.0	9.8

showed dependency between right and left foot width, and valgus angle of the right foot's fifth toe. A significant correlation between feet parameters and spine-pelvis characteristics most often occurred with reference to width of both feet. Another correlation was repeatedly revealed between the height and length of lumbar lordosis and thoracic kyphosis, in the angle of upper thoracic part bent (Mrozkowiak, Jazdończyk, 2015). Among the analysed correlations between selected feet characteristics and trunk features in children and youth aged 4−18 years, those most popular and frequent occurred, as expected, at the age of 7−13 years, less frequent – at the age of 14−18 years, and the least frequent – at the age of 4−6 years. It should also be noted that, though in the first age group no meaningful relations with morphological features of feet (length and width) appear, in the remaining two – they do. Within sexual dimorphism at the age of 4−6 years, more numerous and frequent correlations occur among boys than girls. At the age of 7−13 years this disparity levels out, yet still boys maintain a slight dominance. In the last age group, 14−18-year-olds, girls display more numerous and frequent correlations than boys, which was also expected. No quantitative disparity of features occurred within environmental dimorphism in age group 4−6-year-olds, while frequency of significant correlations is slightly higher among boys. However, in the age group of 7−13-year-olds, individuals from urban environment display greater dominance in both, quantity and frequency of correlations with trunk features. In the last analysed age group, of 14−18-year-olds, mutual quantitative and frequency-related disparities disappear, approaching levels of the age group of 4−6-year-olds (Sokołowski, Mrozkowiak, 2017). The frequency analysis of essential correlations between feet and trunk features in youth aged 14−18 years revealed that values of left foot display more frequent correlation with trunk features than right foot. Feet characteristics display more frequent correlations with trunk features in sagittal plane, less in frontal one, and sporadic in transverse one. The features which feet characteristics most often correlate with are: angle of trunk bent to the left in frontal plane and height of lumbar lordosis, angle of upper thoracic bent, length of lumbar lordosis, height of thoracic kyphosis, scapulas height asymmetry, with the right one placed higher (Mrozkowiak et al., 2018).

Conclusions

1. The general number of body trunk parameters that significantly correlated with feet parameters was slightly higher in females. The number of dependencies regarding sagittal and frontal parameters was the same in both female and male subjects. The traits that differentiated males from females mainly concerned sagittal and frontal planes.

2. The number of feet characteristics that most often showed significant correlations with body trunk parameters was higher in girls than in boys. These were mainly characteristics concerning width and length, longitudinal arch and disorders in the position of toes. The characteristics that differentiated boys described only the longitudinal arch of the feet.

References

Drzał-Grabiec, J., Snela, S. (2012). The influence of rural environment on body posture. *Ann Agric Environ Med*, *19* (4), 846−850.

Górniak, K. (2000). Body posture in rural girls and boys. In: M. Skład (ed.), *The selected biological development rates of rural girls and boys from Podlasie* (pp. 303−336). Biała Podlaska: The Institute of Physical Education and Sport.

Gosh, A., Choudhary, S., Chowdhury, S.D., Ghosh, T. (2009). Fat and fat-free mass in Nepalese children: an assessment of nutritional status. *Eur J Pediatr*, *168*, 1513−1517.

Koudelová, J., Brůžek, J., Cagáňová, V., Krajíček, V., Velemínská, J. (2015). Development of facial sexual dimorphism in children aged between 12 and 15 years: a three-dimensional longitudinal study. *Orthod Craniofac Res*, *18* (3), 175−84.

Mrozkowiak, M. (2015). *Modulation, impact and correlations of selected postural parameters in children and adolescents aged 4−18 years in the light of projection mora*. Bydgoszcz: Publishing House of Kazimierz Wielki University.

Mrozkowiak, M., Jazdończyk, P. (2015). Związki zespołu cech kręgosłupa, miednicy i stóp dziewcząt i chłopców w wieku od 4 do 18 lat. *J Educ Health Sport*, *5* (7), 226−250.

Mrozkowiak, M., Posłuszny, M., Sokołowski, M., Kaiser, A. (2018). The incidence of significant relationships between selected parameters of feet and parameters of trunk in adolescents aged 14−18 years. *J Educ Health Sport*, *8* (2), 305−319.

Perenc, L., Radochońska, A. (2012). Dymorfizm płciowy wybranych cech antropometrycznych u dzieci i młodzieży rzeszowskiej w wieku 3−18 lat badanych w latach 1978 2004. *Prz Med Uniw Rzesz Inst Leków*, *10* (1), 38–49.

Sokołowski, M., Mrozkowiak, M. (2017). Correlations between selected characteristics that describe body trunk and feet in children and young people aged 4 to 18 years. *J Educ Health Sport*, *7* (6), 281−316.

Steinmetz, M. (1984). Le pied, le rachis, la course et la chaussure. *Medicine du Sport*, *58* (1), 34–45.

Webster-Gandy, J., Warren, J., Henry, C.J.K. (2003). Sexual dimorphism in fat patterning in a sample of 5 to 7-year-old children in Oxford. *Int J Food and Nutr*, *54* (6), 467−471.

Wojciechowska-Maszkowska, B., Wieloch, M. (2015). Muscular endurance and strength in boys aged from 11 to 13 years. *Journal of Physical Education & Health*, *4* (6), 23−30.

Wolański, N. (2005). The human biological development. Warszawa: Wydawnictwo Naukowe PWN.

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