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Sexual dimorphism of the incidence of significant relationships between selected parameters of feet and characteristics of trunk in adolescents aged 14 – 18 years

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Key words: relationships, dimorphism, parameters of body posture, feet, sex

Summary

Introduction. Symmetry, asymmetry, mutual relationships and concomitance have become a subject of interest of numerous researchers. The analysis of the findings obtained in the own study conducted among adolescents aged 14-18 years revealed an incidental nature and randomness of the distribution of significant correlations in each age and gender range, which made it impossible to show any regularities or dependencies between the measured parameters.

Material and method. The examinations carried out in the group of teenagers aged 14 to 18 years recorded 2343 observations, including 1148 girls and 1195 boys, concerning the size of 89 parameters describing trunk and feet. The station for an assessment of selected features using the photogrammetric method consisted of a computer, a card, software, a display monitor, a printer and a projection-reception device with a camera.

Findings

1. The number of feet parameters revealing significant relationships with trunk parameters which differentiated the female gender from the male one was greater; likewise, the features in women revealed a more frequent relationship. Additionally, female sex was differentiated by morphological traits, the abnormal positioning of toes and the longitudinal arch of feet.
2. The number of trunk parameters correlating with foot parameters was observed to be bigger in the female gender than in the male one. The parameters in female subjects showed more relationships and the parameters which differentiated female sex included the frontal plane and the sagittal plane to a lesser extent, whereas male gender was characterized by the sagittal plane.

1. **Introduction**

The studies conducted by Proszkowiec et al. among 192 teenagers of primary and lower secondary schools showed that the examined angular parameters were observed to have a significant sexual dimorphism. The girls with marked pubertal traits were reported to reveal significantly greater inclination angles of particular spinal regions and their total value in comparison to their peers of the other sex who were at the same stage of biological development [1]. Sulicz et al. carried out the research in the group of about 1,000 girls and boys aged 11-15 years which revealed differentiated individual postural indicators in the sagittal plane characteristic for puberty. During this period both girls and boys were observed to have a considerable progression of physiological curvatures, especially in the habitual posture [2]. The research results obtained by Zeyland-Malawka by the measurement of sagittal curvatures using the measuring wheel showed that an accurate indication of determining factors is difficult and rather unlikely to achieve considering the multitude of possible form creating influences including the genetic ones and individual psycho-emotional and environmental circumstances of the shape of physiological spinal curves [3]. The overall examination of human body reveals an apparent symmetry, however, more detailed measurements present numerous asymmetries in the frontal plane as well as different values of anteroposterior curvatures of the axial locomotor system. Morphological asymmetry which comes down to the difference in weight between the left and the right body half, the length and circumference of limbs and the positioning of the even body parts is supported by the

spacing of internal organs. The right body half is usually characterized by bigger mass, longer right limbs, larger circumference of typical locations of the upper right limb, more muscular left shin and the right side of the shoulder girdle [4, 5, 6]. Therefore, symmetry, asymmetry, mutual relationships and concomitance have become a subject of interest of numerous researchers [7-12]. The analysis of 2,343 observations obtained in the study conducted among adolescents aged 14-18 years revealed that the distribution of significant correlations in each age and gender range, their incidental nature and randomness, which impended a demonstration of any regularities and dependencies between the measured parameters at all. Only their concomitance can be actually determined.

Among the parameters describing the spine-pelvis complex and most frequently correlating with foot parameters observed at the age of 14-18 years, the features of the frontal and sagittal planes prevail and the transverse plane to a lesser extent. In the examined age ranges, the most frequent and the strongest relationships and concomitance with the parameters of feet were observed in 18-year-old girls and in boys aged 15 and 18 years [13].

The main objective of the study was to prove sexual dimorphism with regard to the incidence of significant correlations of the selected parameters of feet and the features of trunk in adolescents aged 14-18 years. The analysis of the research findings headed in two directions. The first one was to provide an answer to the question: which parameters of the foot reveal a significant relationship with the parameters of trunk within sexual dimorphism? The second one was to give an answer to the question: with which parameters of trunk do the parameters of the foot most often reveal a significant correlation also within sexual dimorphism?

2. **Material and method**

The examinations carried out in the group of teenagers aged 14 to 18 years recorded 2343 observations, including 1148 girls and 1195 boys. 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, sex and environmental categories, see Table 1. Due to the article constraints, the detailed description of the somatic features of the study material and the obtained results are available in the author's monography [14]. 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 comprehensive view of the distribution of the studied

features considering age ranges, gender and environment. The relationships and their significance were assessed using p-value and frequency expressed in percentage.

The fundamental assumption of the study was to 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 ensured 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. The statistical analysis covered 89 angular and linear parameters of the spine, pelvis, trunk and feet in the sagittal, frontal and transverse planes, see Table 1. Obtaining the spatial picture was possible thanks to displaying the line of strictly defined parameters on a teenager's back and feet. The lines falling on the skin of a person got distorted depending on the configuration of the surface. The applied lens ensured that the imaging of a subject could be received by a special optical system with a camera, then transmitted to the computer monitor. 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 an individual's skin [14].

Table 1.

List of parameters measured for trunk and foot system

Trunk parameters

No.	Symbol	Parameters		
		Unit	Name	Description
Sagittal plane				
1	Alfa	degrees	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)
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 C_7
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 B2 and B4
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 B2 and B4
20	KLB –	degrees	Shoulder line angle, left shoulder up	

21	LŁW	mm	Left scapula up	Distance measured vertically between horizontal lines passing through points Ł1 and Łp
22	LŁW	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 scapulas 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 T1 and T2, T3 and T4.
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 T1 and T2, T3 and T4
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- NK	_	Number of the vertebra maximally distanced to the	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 (C1).

			left (NK-) or to the right (NK)	If the arithmetic mean takes the value e.g. from 12.0 to 12.5, it is Th5, if from 12.6 to 12.9 it is Th6.
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 UB1 – UB2. Angle UB2 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 UB1 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	
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

Foot parameters

Symbol			Parameters	
No.		Unit	Name	Description
42	DL p	mm	Length of the right foot (p), left foot (l)	Distance between points acropodion and pterion in a plantogram
43	DL l			
44	Sz p		Width of the right foot (p), left foot (l)	Distance between points metatarsal fibular and metatarsal tibial in a plantogram
45	Sz l			
46	W p		"W" Indicator (Wejsflog indicator) of the right foot (p), of the left foot (l)	The relationship of foot length to its width DL p/Sz p = W p, DL l/Sz l = Wl
47	W 1			
48	Alfa P m	degree	Valgity angle of big toe of the right foot: Alfa p p, of the left foot: Alfa l p. Angle of varus deformity in the right foot:	Angle between the straight line passing through points metatarsal tibial and the most inner one on the medial edge of the heel and the straight line passing through points metatarsal tibial and the most inner one on the medial edge of the great toe
49	Alfa P p			
50	Alfa L m			
51	Alfa L p			

			Alfa p m, left foot: Alfa l m.	
52	Beta p m		Angle of varus deformity of the 5th toe of the right foot: Beta p p, of the left foot: Beta l p. Valgity angle of the fifth toe of the right foot: Beta p m, left foot: Beta l m.	Angle between the straight line passing through points metatarsal fibular and the most outer one on the lateral edge of the heel and the straight line passing through points metatarsal fibular and the most outer one on the lateral edge of the fifth toe in a plantogram
53	Beta p p			
54	Beta l m			
55	Beta l p			
56	Gamma P (Gam.P)		Heel angle of right foot (p), of left foot (l)	Angle between the straight line passing through points metatarsal tibial and the most inner one on the medial edge of the heel and the straight line passing through points metatarsal fibular and the most outer one on the lateral edge of the heel in a plantogram
57	Gamma l (Gam. L)			
58	PS p	mm^2	Plantar surface of right foot (p), left foot (l)	Plantar surface of the foot
59	PS 1			
60	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 metatarsal foot to point pterion
61	DP 2			
62	DP 3			
63	DP 4			
64	DP 5			
65	DL 1			
66	DL 2			
67	DL 3			
68	DL 4			
69	DL 5			
70	WP 1		Height of 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.
71	WP 2			
72	WP 3			
73	WP 4			
74	WP 5			
75	WL 1			
76	WL 2			
77	WL 3			
78	WL 4			
79	WL 5			
80	SP 1		Width of arch 1, 2, 3, 4 and 5 of right foot (P), left foot	Bowstring of the distance of arch 1, 2, 3, 4 and 5.
81	SP 2			
82	SP 3			

83	SP 4		(L)	
84	SP 5			
85	SL 1			
86	SL 2			
87	SL 3			
88	SL 4			
89	SL 5			

Source: author's own research

3. **Results**

Table 2. Sexual dimorphism of the biggest incidence of significant relationships between selected features of feet and trunk

(n) K=1148, M=1195 (K – Female, M – Male)

Parameter	Gender		Parameter	Gender	
	K	M		K	M
DLP	14.28	7.14	SP2	11.9	
DLL	9.52	4.76	SP3	11.9	
SZP	28.56		SP5	4.76	
SZL	4.76	4.76	WL1	11.9	
AlfaL		14.28	WL2	11.9	
BetaP	7.14	7.14	WL5	7.14	
BetaL	11.9	4.76	DL1		19.4
GamL	7.14	7.14	DL2		9.52
PSP	19.04	4.76	DL3	4.76	
PSL	4.76	11.9	DL4		9.52
WP1	9.52		DL5		16.66
WP2	9.52		SL1	9.52	
WP3	9.52		SL2	19.04	
DP3	14.28		SL3	16.66	
SP1	7.14				

Source: author's own research

The analysis of the study results with regard to sexual dimorphism, concerning trunk parameters most frequently differentiating the relationships with foot parameters revealed the following parameters in girls: width of right foot (SZP), height of the first, second and third arch (WP1, WP2, WP3), length of arch 1 (DP1), width of arch 1, 2, 3 and 5 of the right foot (SP1, SP2, SP3, SP5), height of arch 1, 2 and 5 (WL1, WL2, WL5), length of arch 4 (DL4), width of arch 1, 2, 3 of the left foot (SL1, SPL2, SL3). The following parameters were revealed in boys: valgity angle of big toe, length of longitudinal arch 1, 2, 4 and 5 of the left foot (DL1, DL2, DL4, DL5), Table 2, Fig. 1.

Table 3. Sexual dimorphism of trunk parameters having the biggest incidence of significant relationship with the features of feet

(n) K=1148, M=1195 (K – Female, M – Male)

Parameter	Gender		Parameter	Gender	
	K	M		K	M
Alfa	4.34	17.38	TS	10.86	4.34
Beta	13.03	4.34	LŁW-	26.08	6.52
Gamma	36.95		KLB	13.04	
DKP	17.38	15.21	KLB-	8.69	17.38
RKP	17.38	15.21	UB	10.86	4.34
GKP	4.34	15.21	UB-	13.04	10.86
DLL	30.42	8.69	UL	4.34	
RLL	28.25	23.9	KSM	4.34	6.52
GLL		23.91	UK-	10.86	6.52
KPT-	6.52	43.47	NK-	6.52	
KNT-	10.86	8.69	TT-	13.04	

Source: author's own research

The analysis of the study results with regard to sexual dimorphism concerning foot parameters with which trunk parameters most often correlated, revealed the following parameters in girls: upper thoracic inclination (Gamma), thoracic kyphosis length (DKP), asymmetric height of waist triangles with right waist triangle up (TT-), asymmetric shoulder line angle with the right shoulder up (KLB), asymmetric scapula line angle with the right scapula up (UL). The following parameters were revealed in boys: lumbar lordosis depth (GLL), Table 3, Fig. 2.

5. **Findings**

1. The number of feet parameters revealing significant relationships with trunk parameters which differentiated the female gender from the male one was greater; likewise, the features in women revealed a more frequent relationship. Additionally, female sex was differentiated by morphological traits, the abnormal positioning of toes and the longitudinal arch of feet.
2. The number of trunk parameters correlating with foot parameters was observed to be bigger in the female gender than in the male one. The parameters in female subjects showed more relationships and the parameters which differentiated female sex included the frontal plane and the sagittal plane to a lesser extent, whereas male gender was characterized by the sagittal plane.

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(Description of the Figures)

Fig. 1 Sexual dimorphism of significant relationships of the parameters of trunk with the parameters of feet in adolescents aged 14 – 18 years (n) K=1148 M=1195

Incidence (%)

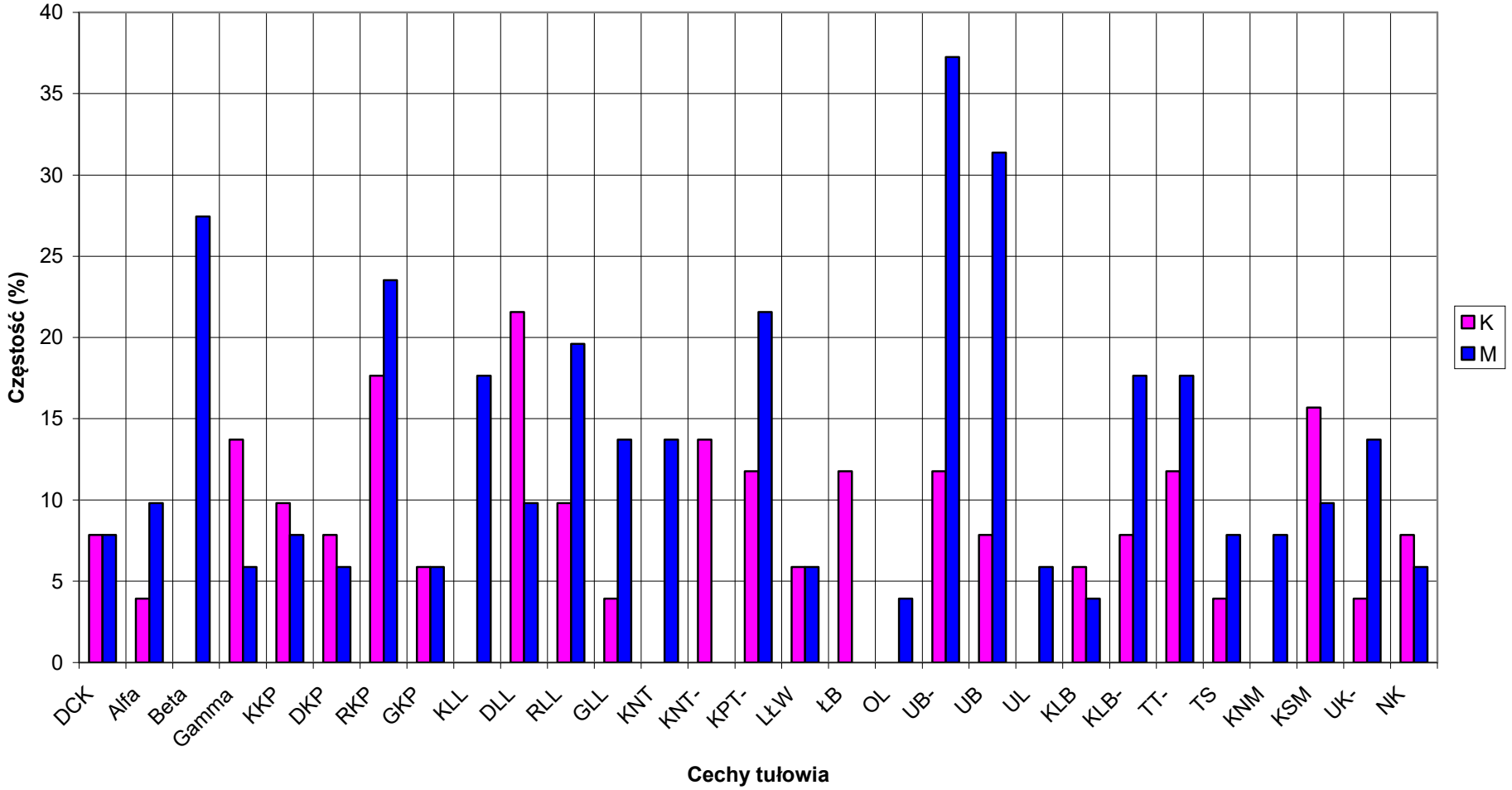
Parameters of feet	K (female)	M (male)

Fig. 2 Sexual dimorphism of significant relationships of the parameters of feet with the parameters of trunk in adolescents aged 14 – 18 years (n) K=1148 M=1195

Incidence (%)

Parameters of trunk	K (female)	M (male)

Ryc. 1. Dymorfizm płciowy istotnych związków cech tułowia z cechami stóp wśród 14 - 18-letniej młodzieży (n) K=1148, M=1195



Ryc. 2. Dymorfizm płciowy cech stóp o najczęstszym istotnym związku z cechami tułowia wśród młodzieży 14 - 18-letniej obojga środowisk (n) K=1148,M=1195