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An attempt to identify significant correlations between parameters of body trunk and parameters of feet and their frequency in adolescents aged 14-18 years

Mrozkowiak Mirosław

Physiotherapy Office, Poznań, Poland

Abstract

Introduction. All disorders are temporary as a natural consequence of ontogenetic processes usually disappearing after puberty. Therefore, it is important to provide incentives in this period in order to maintain physical activity at a previously achieved level and try to shape the parameters of feet through exerting a conscious influence on body trunk parameters.

Material and method. The study conducted with the group of adolescents aged 14 to 18 years enabled to record 2,343 observations with regard to the measurement of 90 parameters describing trunk and feet. The station for an assessment of body posture and feet using the photogrammetric method consisted of a computer, a card, software, a display monitor, a printer, and a projection-reception device with a camera to measure the selected parameters.

Conclusions

1. The values of frontal and sagittal body trunk parameters revealed a significant correlation

with the parameters of feet. An increased frequency of these correlations was observed between the sagittal parameters of the body trunk and feet. The relationship between transverse parameters was much less significant.

2. Feet parameters most often significantly correlated with: trunk flexion angle in the sagittal plane, height of thoracic kyphosis, angle of the projection line of lower scapula angles with the right or the left angle being more convex, lumbar lordosis length, asymmetry in the height of scapula triangles with the right scapula up, inclination of the thoracic and lumbar spine, shoulders line angle with the left one up and the angle of pelvic flexion to the right in the transverse plane.
3. Feet parameters with which trunk parameters most frequently correlated included: width of longitudinal arch 1, length of longitudinal arch 2 in the right foot, varus angle of the fifth toe and width of the right foot and length of the first arch in the left foot and length of the right and left foot.

Key words: correlation, spine, pelvis, feet.

1. **Introduction**

All disorders are temporary as a natural consequence of ontogenetic processes usually disappearing after puberty. Therefore, it is important to provide incentives in this period in order to maintain physical activity at a previously achieved level.

In its final stage, adolescence leads to the shaping of lifestyle and thus the attitude to physical culture. After the onset of puberty, especially in girls, changes can be observed in body weight, height, and proportions, mainly by increasing inactive body fat, and the changing scope of interest and feelings does not encourage constant care for the development of the physical activity. Puberty clearly crystallizes sexual dimorphism in the field of physical fitness, cares about body posture, its appearance, and attractiveness [1]. A characteristic feature of disorders in the musculoskeletal system is their irreversibility and no possibility to return to the initial state. Hence, the need for not only symptomatic but also prophylactic physiotherapy [2].

There are relatively few publications on the correlations of parameters within the region of feet and lap belts. This issue has been investigated by Męsowicz [3, 4, 5], Drzał-Grabiec, Snela [6], Mrozkowiak, Sokołowski, and Jazdończyk [7, 8]. The development of information technologies has contributed to a comprehensive approach to the assessment of body posture, allowed the placement of particular elements in time and space, and capturing the spatial balance of vertical body posture [9]. The multitude of procedures for assessing the body posture and the lack of an objectionable method means that the choice must arise from the objective of the research. Modern diagnostics allows to determine the number of most common postural parameters, and thus the relationships between them. This problem has not been often mentioned in the available domestic and foreign literature.

The purpose of the studies was to determine the frequency of coexistence and significant correlations between parameters of body trunk and parameters of feet in 14-18-year-old adolescents.

2. **Material and methods**

The study conducted with the group of teenagers aged 14 to 18 years enabled to record 2,343 observations. The statistical analysis included 90 angular and linear parameters of the spine, pelvis, trunk, and feet in the sagittal, frontal and transverse planes, Table 1. Due to the article constraints, the detailed description of the somatic features concerning the research material and the obtained results can be found in the author's monography [10]. The empirical data were quantitative and qualitative characteristics (gender, domicile, etc.). 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 picture of how the studied features were distributed. The correlations and their significance were assessed using p-value and their frequency was expressed by means of the arithmetic mean.

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 the 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 studies did not determine whether an individual’s posture was normal, they only identified the state of ontogenetic realization.

Objectified and comparable test results ensured that the postural parameters adopted for the analysis were recorded. The combined assessment of the trunk and feet allowed us to objectively determine the quality of the postural model. The applied measuring apparatus allowed to determine several dozen postural parameters. The statistical analysis included 90 angular and linear parameters of the spine, pelvis, trunk, and feet in the sagittal, frontal and transverse planes, Table 1. The station for the assessment of body posture and foot parameters using the photogrammetric method consisted of a computer, a card, software, a display monitor, a printer, and a projection-reception device with a camera to measure selected parameters of the pelvis, spine, trunk, and feet. 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 child 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 photo records an image of the silhouette displayed on a child's back. Uneven distribution of subcutaneous adipose tissue along the back makes it difficult to reliably assess body posture in children, especially those with BMI 25 – 30 and over. It is much more difficult to determine the selected anthropometric measurements used in statistical analysis [10].

Table 1. List of parameters measured for trunk and feet.

Trunk parameters

No.	Symbol	Parameters		
		Unit	Name	Description
Sagittal plane				
1	Alfa	degrees	Inclination of lumbo-sacral region	
2	Beta	degree	The inclination of thoracolumbar region	
3	Gamma	degree	The inclination of upper thoracic region	
4	Delta	degree	The sum of angles	Delta = Alfa + Beta + Gamma
5	DCK	mm	The total length of the spine	Distance between C_7 and S_1, measured in the vertical axis
6	KPT	degree	Angle of extension	Defined as a deviation of the C_7-S_1 line from a vertical position (backward)
7	KPT -	degree	The angle of the body bent	Defined as a deviation of the C_7-S_1 line from a vertical position (forwards)
8	DKP	mm	Thoracic kyphosis length	Distance between LL and C_7
9	KKP	degree	Thoracic kyphosis angle	KKP = 180 – (Beta+Gamma)
10	RKP	mm	Thoracic kyphosis height	Distance between points C_7 and PL
11	GKP	mm	Thoracic kyphosis depth	The distance measured horizontally between the vertical lines passing through points PL and KP

12	DLL	mm	Lumbar lordosis length	The distance measured between points S_1 and KP
13	KLL	degree	The angle of lumbar lordosis	KLL = 180 – (Alfa + Beta)
14	RLL	mm	Lumbar lordosis height	Distance between points S_1 and PL
15	GLL -	mm	Lumbar lordosis depth	The distance measured horizontally between the vertical lines passing through points PL and LL
Frontal plane				
16	KNT -	degree	The angle of the body bent to the side	Defined as the deviation of the C_7-S_1 line from the vertical axis to the left
17	KNT	degree		Defined as the deviation of the C_7-S_1 line from the vertical axis to the right
18	LBW -	mm	Right shoulder up	The distance measured vertically between horizontal lines passing through points B2 and B4
19	LBW	mm	Left shoulder higher	
20	KLB	degree	Shoulder line angle, right shoulder up	The angle between the horizontal line and the straight line passing through points B2 and B4
21	KLB –	degrees	Shoulder line angle left shoulder up	
22	LŁW	mm	Left scapula up	The distance measured vertically between horizontal lines passing through points Ł1 and Łp
23	LŁW-	mm	Right scapula up	
24	UL	degree	The angle of scapula line, right scapula up	The angle between the horizontal line and the straight line passing through points Ł1 and Łp
25	UL -	degree	The angle of scapula line left scapula up	
26	OL	mm	The 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
27	OL -	mm	The lower angle of right scapula more distant	

28	TT	mm	Left waist triangle up	Difference of the distance measured vertically between points T1 and T2, T3 and T4.
29	TT –	mm	Right waist triangle up	
30	TS	mm	Left waist triangle wider	Difference of the distance measured horizontally between straight lines passing through points T1 and T2, T3 and T4
31	TS -	mm	Right waist triangle wider	
32	KNM	degree	Pelvis tilt, right ilium up	The angle between the horizontal line and the straight line passing through points M1 and Mp
33	KNM -	degree	Pelvis tilt left ilium up	
34	UK	mm	The maximum inclination of the spinous process to the right	Maximal deviation of the spinous process from the line from S_1. The distance is measured in a horizontal line.
35	The UK -	mm	The maximum inclination of the spinous process to the left.	
36	NK	_	Number of the vertebra maximally distanced to the left (NK-) or to the right (NK)	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 (C_1). 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				
37	ŁB -	mm	The lower angle of the right scapula more convex	Difference in the distance of lower scapula angles from the surface of the back
38	ŁB	mm	The lower angle of the scapula more convex	
39	UB –	degree	The angle of projection line of lower scapula angles, the left one more convex	The 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

40	UB	degree	The angle of projection line of lower scapula angles, the right one more convex	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.
41	KSM	degree	Pelvis rotated to the right	The angle between the line passing through point M1 and perpendicular to the camera axis and the straight line passing through points M1 and MP
42	KSM -	degree	Pelvis rotated to the left	The 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
43	DL p	mm	Length of the right foot (p), left foot (l)	Distance between points acropodion and pterion in a plantogram
44	DL l			
45	Sz p		Width of the right foot (p), left foot (l)	Distance between points metatarsal fibular and metatarsal tibial in a plantogram
46	Sz l			
47	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
48	W 1			
49	Alfa p m	degree	Valgity angle of the big toe of the right foot: Alfa p p, of the left foot: Alfa l p. Angle of varus deformity in the right foot: Alfa p m, left foot: Alfa l m.	The 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
50	Alfa p p			
51	Alfa l m			
52	Alfa l p			
53	Beta p m		The 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.	The 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
54	Beta p p			
55	Beta l m			
56	Beta l p			
57	Gamma P (Gam.P)		Heel angle of right foot (p), of left foot	The angle between the straight line passing through points metatarsal tibial

			(l)	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
58	Gamma l (Gam. L)			
59	PS p	mm^2	The plantar surface of right foot (p), left foot (l)	The plantar surface of the foot
60	PS 1			
61	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
62	DP 2			
63	DP 3			
64	DP 4			
65	DP 5			
66	DL 1			
67	DL 2			
68	DL 3			
69	DL 4			
70	DL 5			
71	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.
72	WP 2			
73	WP 3			
74	WP 4			
75	WP 5			
76	WL 1			
77	WL 2			
78	WL 3			
79	WL 4			
80	WL 5			
81	SP 1		Width of arch 1, 2, 3, 4, and 5 of right foot (P), left foot (L)	Bowstring of the distance of arch 1, 2, 3, 4, and 5.
82	SP 2			
83	SP 3			
84	SP 4			
85	SP 5			
86	SL 1			
87	SL 2			
88	SL 3			
89	SL 4			
90	SL 5			

Source: author's own research

3. **Results**

The analysis of research results focusing on two directions. The first one was to answer which trunk parameters and how often revealed a significant correlation with feet parameters. The second one was to answer the following question: with which foot parameters did trunk parameters reveal a significant relationship?

Table 2. Incidence of significant relationships between the parameters of feet and the parameters of the trunk (n) 2,343.

Parameter and incidence of its correlation with feet parameters											
DCK	15.68	**GKP**	11.76	**KNT-**	13.72	**OL**	3.92	**UB-**	11.76		
Alfa	13.72	**KLL**	17.64	**TT-**	29.4	**UL**	5.88	**NK**	13.72		
Beta	27.44	**DLL**	31.36	**TS-**	11.76	**KLB**	9.8				
Gamma	19.6	**RLL**	29.4	**LłW-**	11.76	**KLB-**	25.48				
KKP	17.64	**GLL**	17.64	**UB**	39.21	**KNM**	7.84				
DKP	13.72	**KPT-**	45.08	**UB-**	47.05	**KSM**	25.48				
RKP	41.16	**KNT**	13.72	**łB**	11.76	**The UK-**	17.64				

Source: author's own research

The greatest correlation, that is over 25% of trunk parameters with feet parameters was revealed by the trunk flexion angle in the sagittal plane (45.08%), the height of thoracic kyphosis (41.16%), the angle of the projection line of lower scapula angles with the right angle (39.21%) and the left one (47.05%) being more convex, the length of lumbar lordosis (31.36%), asymmetry in the height of scapula triangles with the right scapula up (29.4%), the inclination of the thoracic and lumbar spine (27.44%), shoulders line angle with the left one up and the angle of pelvic flexion to the right in the transverse plane (25.48%).

The incidence of trunk parameters with feet parameters at the level of 19.6% was observed in the upper thoracic inclination, and 17.64% in the inclination of thoracic kyphosis, lumbar lordosis, and the maximal deviation of the spinous process from the line. The total length of the

C_7-L_5 spine showed a 15.68% frequency of correlations with feet parameters. The incidence of correlations between feet parameters and the remaining parameters was lower than 15%, Table 2, Fig. 1.

Table 3. Feet parameters with which trunk parameters revealed the most frequent significant correlation (n) 2343

Feet parameters most frequently significantly influenced by trunk parameters									
SZP	25.9	**WP1**	8.6	**WL1**	8.6	**DP1**	23.8	**AlfaL**	6,5
SZL	19.5	**WP2**	15.1	**WL2**	8.6	**DP2**	36.7		
DLP	23.7	**WP4**	6.5	**WL4**	8.6	**DP3**	6.5		
DLL	21.7	**WP5**	13.4	**DL1**	24.2	**DP1**	23.8		
BetaP	30.3	**SP1**	41.6	**DL4**	13.0	**SL3**	17.2		
GamP	15.1	**SP3**	13.0	**SL1**	13.0	**PSP**	19.9		
GamL	8.6	**SP5**	8.6	**SL5**	6.5	**PSL**	8.6		

Source: author's own research

The further analysis of research results found those trunk parameters most often significantly correlated, at a level higher than 20%, with the value of the width of longitudinal arch 1 (41.6%), the length of longitudinal arch 2 in the right foot (36.7%), varus angle of the fifth toe (30.3%) and the width of the right foot (25.9%) as well as a 24.2% incidence with the length of arch 1 in the left foot. The trunk features showed a 23.8% frequency of significant correlation with the length of the first arch and the width of the left foot (19.5%), and frequency at the level of 23.7% with the length of the right foot and 21.7% with the length of the left foot. The level of frequency of significant correlation with the value of a plantogram of the right foot was 19.9%, with the width of longitudinal arch 3 in the left foot was 17.2%, with the heel angle and height of the longitudinal arch 2 in the right foot was 15.1%. A similar incidence, that is 13.0%, was observed in relation to the length of arch 4 and the width of arch 1 in the left foot. The incidence of significant correlations revealed by trunk parameters with other feet parameters was lower than 10%, Table 3, Fig. 2.

4. **Discourse**

The analysis of multiple regression of body trunk and feet parameters showed that sagittal parameters of physiological curvatures correlated much more frequently with feet parameters. It should be assumed that even though the alliance of these parameters is very frequent and large, it is less reasonable than in the case of frontal or even transverse parameters. In addition, the influence of all features in the age range of 4-6 and 14-18 years is significantly smaller than in 7-13-year-olds and biomechanically justified in many cases [10, 11] as it is impossible to demonstrate a logical and significant relationship of the inclination of the upper thoracic spine with the varus angle or valgity angle of the fifth toe in both feet. With respect to frontal parameters of the body trunk, the biomechanical effect of the asymmetric burden on the feet, as it should be supposed, should be reflected mainly in longitudinal and transverse arches.

5. **Findings**

1. The values of frontal and sagittal body trunk parameters revealed a significant correlation
   with the parameters of feet. An increased frequency of these correlations was observed between the sagittal parameters of the body trunk and feet. The relationship between transverse parameters was much less significant.
2. Feet parameters most often significantly correlated with: trunk flexion angle in the sagittal plane, height of thoracic kyphosis, angle of the projection line of lower scapula angles with the right or the left angle being more convex, lumbar lordosis length, asymmetry in the height of scapula triangles with the right scapula up, inclination of the thoracic and lumbar spine, shoulders line angle with the left one up and the angle of pelvic flexion to the right in the transverse plane.
3. Feet parameters with which trunk parameters most frequently correlated included:
   width of longitudinal arch 1, length of longitudinal arch 2 in the right foot, varus angle of the fifth toe and width of the right foot and length of the first arch in the left foot and length of the right and left foot.

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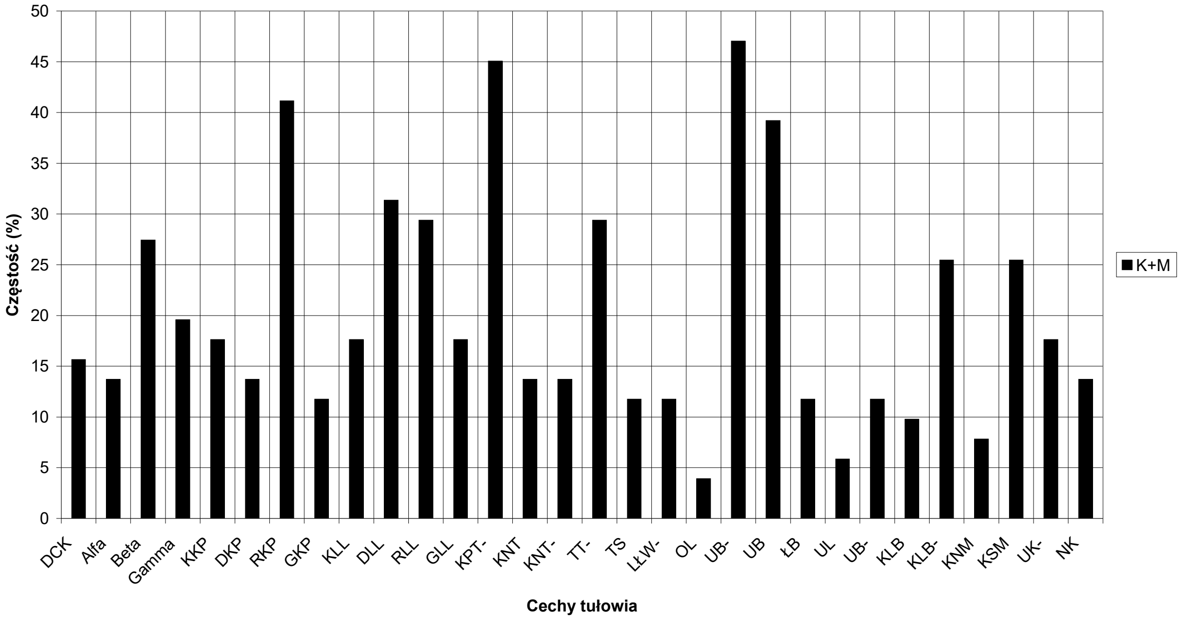
Ryc. 1. Częstość istotnych związków cech tułowia z cechami stóp wśród młodzieży 13 - 18-letniej obojga płci i środowisk (n) 2343



Ryc. 2. Cechy stóp, z którymi cechy tułowia wykazują najczęstszy istotny związek wśród młodzieży 14 - 18-letniej obojga płci i środowisk (n) 2343