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Sexual dimorphism of the incidence of significant relationships between selected foot parameters and trunk parameters in children aged 7 – 13 years

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Summary

Introduction. Despite the development of alternative means of transport and consequential sedentary lifestyle, two-legged locomotion has remained important during phylogenetics. Lower limbs are still the main and ultimate means of human mobility which is transforming the mutual influences, dependencies and relationships between the features of trunk and feet.

Material and method. The study with the group of children aged 7-13 years enabled to record 12943 observations including 6983 girls and 5960 with regard to the measurement of the 87 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 foot parameters revealing significant relationships with the trunk characteristics differentiating both sexes was the same and the correlation between the examined properties was found stronger in boys. The differentiating features included parameters describing disorders of toe positioning and the longitudinal arch of feet among male adolescents and only the longitudinal arch in female subjects.
2. The number of trunk parameters with which the features of feet correlated most significantly was found to be bigger in male subjects than in their female counterparts. The features in boys revealed a more frequent significant relationship whereas the differentiating features were observed only in the frontal plane.

1. **Introduction**

Upright standing in phylogenetics of body posture resulted in a range of morphological changes within the entire body.

The development of spinal curvatures in the sagittal plane and perhaps the architecture of feet, we know today, over which the centre of body gravity has shifted was an immediate consequence of a multi-annual process of verticalization. As a result, the foot and the entire pelvic girdle were transformed. Foot and to some extent spinal curvatures have begun to fulfil supportive, locomotor, shock-absorbing and sensory functions. Despite the development of alternative means of transport and consequential sedentary lifestyle, two-legged locomotion has remained important during phylogenetics. Lower limbs are still the main and ultimate means of human mobility which is transforming the mutual influences, dependencies and relationships between the features of trunk and feet.

Yasser and Kasperczyk, while studying the relationships between the height of longitudinal medial arch and Clarke's arch, concluded that there was a relationship confirmed by significant correlation between both parameters [1]. Own studies carried out in the group of children and adolescents aged 7-13 years enabled to record 12943 observations consisting in the measurements of 87 features describing body posture and feet in particular age groups and sexes. The analysis of the results regarding the relationships between the parameters of trunk and feet revealed that the most frequent and the strongest relationships and interaction with the features of feet in the assessed age groups were observed in girls aged 11 and 12, boys at the age of 11, 12 and 13. No regularities or logical relationships between the parameters of the spine-pelvis complex and feet were found in all age ranges and sexes. The features of the sagittal, frontal and transverse planes to a lesser extent were predominant among the characteristics describing the spine-pelvis complex and most often correlating with the parameters of feet. It appears, however, that among the features of feet, the parameters concerning the fifth toe varus and valgus deformity and the first toe varus deformity in the right foot most frequently correlated with the parameters of the spine-pelvis complex [2]. Marciniak, in his biomechanical deliberations concerning the correction of foot defects and failures, mentions the controversies about the ways of influencing the correct development of feet in children in case of static flat-valgus foot deformities. According to the author, the incidence is not widespread and refers to ca. 10-15% of the population. He also claims that the formation of the longitudinal arch of foot is largely affected by the positioning of heel and consequently by the strength of spinator muscles [3]. Steinmetz assumes there is an interaction between the type of the formation of foot and the spinal formation. The suggestion that if the spine can be corrected by the foot, the foot can be corrected by the spine, arouses a number of reservations, but the results of the studies presented below, at least theoretically, envisage such a possibility. Steinmetz also emphasises the reasons for wearing corrective footwear as the properly positioned foot in special footwear may be the cause of spinal deformity [4].

The main objective of the study was to prove sexual dimorphism with regard to the frequency of significant correlations of the selected trunk parameters and the features of feet in the group of children and teenagers aged 7-13 years. The analysis of the study results headed in two directions. The first one was to provide an answer to the question: which parameters of trunk most frequently revealed a significant relationship with the parameters of feet within sexual dimorphism? The second one was to give an answer to the question: which parameters of trunk most often correlated with the parameters of feet within sexual dimorphism?

2. Material and methods

The study with the group of children aged 7-13 years enabled to record 12943 observations including 6983 girls and 5960 with regard to the measurement of 87 features describing the trunk and feet. 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 [5]. 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 87 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 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 taken photo records an image of the silhouette displayed on a child's back [5].

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 C7
8	KKP	degrees	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	Number of the vertebra	_	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 (C1). 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	Alfa p m	degree	Valgity angle of the hallux of the right foot: Alfa p, of the left foot: Alfa l p. Angle of varus	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
47	Alfa p p			
48	Alfa l m			
49	Alfa l p			

			deformity in the right foot: Alfa p m, left foot: Alfa l m.	most inner one on the medial edge of the great toe
50	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
51	Beta p p			
52	Beta l m			
53	Beta l p			
54	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
56	PS p	mm^2	Plantar surface of right foot (p), left foot (l)	Plantar surface of the foot
57	PS 1			
58	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
59	DP 2			
60	DP 3			
61	DP 4			
62	DP 5			
63	DL 1			
64	DL 2			
65	DL 3			
66	DL 4			
67	DL 5			
68	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.
69	WP 2			
70	WP 3			
71	WP 4			
72	WP 5			
73	WL 1			
74	WL 2			
75	WL 3			
76	WL 4			
77	WL 5			
78	SP 1		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.
79	SP 2			
80	SP 3			
81	SP 4			
82	SP 5			

83	SL 1			
84	SL 2			
85	SL 3			
86	SL 4			
87	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=6983, M=5960 (K – Female, M – Male)

Parameter	Gender		Parameter	Gender	
	K	M		K	M
DLP	16.66	4.76	DP4	9.52	4.76
DLL	23.8	14.28	DP5	7.14	7.14
SZP	26.18	28.56	SP1	7.14	9.52
SZL	23.8	28.56	SP2	7.14	7.14
Alfa P		16.66	SP3	11.9	4.76
Alfa L	23.8	19.04	SP4	4.76	9.52
BetaP	7.14	4.76	SP5		23.8
BetaL	26.18	23.8	WL1	9.52	23.8
GamP	11.9	4.76	WL2	14.28	23.8
GamL	19.04	4.76	WL3	7.14	19.04
PSP	19.04	14.28	WL4	16.66	9.52
PSL	7.14	4.76	WL5	9.52	9.52
WP1	14.28	16.66	DL1	4.76	
WP2	11.9	28.56	DL2	9.52	16.66
WP3	9.52	9.52	DL3		4.76
WP4	9.52	14.28	DL4	9.52	
WP5	7.14	7.14	DL5	4.76	
DP1	19.04	16.66	SL1	7.14	11.9
DP2	16.66	16.66	SL2	11.9	11.9
DP3	19.04	11.9			

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: length of arch 1, 4 and 5 of left foot (DL1, DL4, DL5). In boys, the following parameters were found: valgity angle of the hallux of right foot (Alfa), width of the longitudinal arch 5 of right foot (SP5), length of arch 3 of left foot (DL3), Table 2, Figure 1, 2.

Table 3. Sexual dimorphism of the biggest incidence of significant relationships between selected features of feet and trunk

(n) K=6983, M=5960 (K=female, M=male)

Parameter	Gender		Parameter	Gender	
	K	M		K	M
Alfa	15.21	15.21	TS	8.69	8.69
Beta	23.9	37.47	KLB	6.52	
Gamma	28.25	23.9	KLB-	6.52	
DKP	21.73	45.64	OL	8.69	13.03
RKP	26.07	45.65	UL		21.72
GKP	15.21	45.64	UB	10.86	4.34
DLL	30.42	49.99	UB-	15.2	10.96
RLL	23.9	76.08	LŁW-		4.34
GLL	34.77	21.73	KNM		26.07
KPT-	34.77	34.77	KSM	6.52	8.69
KNT-	15.2		UK-	6.52	
TT-	17.39	13.04			

Source: author's own research

The analysis of the study results with regard to sexual dimorphism of foot parameters with which the parameters of trunk most frequently correlated, revealed the following parameters in girls: angle of body bent to the right side in the frontal plane (KNT-), shoulder line angle with right shoulder or left up (KLB, KLB-), maximum inclination of the spinous process to the left in the vertical line (UK-). The parameters identified in the boys included: asymmetric angle of scapula line with right scapula is up, asymmetry of scapulas with right scapula up (LŁW-), pelvis tilt to the left in the frontal plane (KNM), Table 3, Fig. 3.

5. **Conclusions**

1. The number of foot parameters revealing significant relationships with the trunk characteristics differentiating both sexes was the same and the correlation between the examined properties was found stronger in boys. The differentiating parameters included parameters describing disorders of toe positioning and the longitudinal arch of feet in male adolescents, and in female subjects it was only the longitudinal arch.
2. The number of trunk parameters with which the features of feet correlated most significantly was found to be bigger in male subjects than in their female counterparts. The features in boys revealed a more frequent significant relationship whereas the differentiating features were observed only in the frontal plane.

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(Description of the Figures)

Fig. 1 Sexual dimorphism of significant relationships of the parameters of feet with the parameters of trunk in children aged 7 – 13 years (n) K=6983 M=5960

Incidence (%)

Parameters of feet	K (female)	M (male)

Fig. 2 Sexual dimorphism of significant relationships of the parameters of longitudinal arch with the parameters of trunk in children aged 7 – 13 years (n) K=6983 M=5960

Incidence (%)

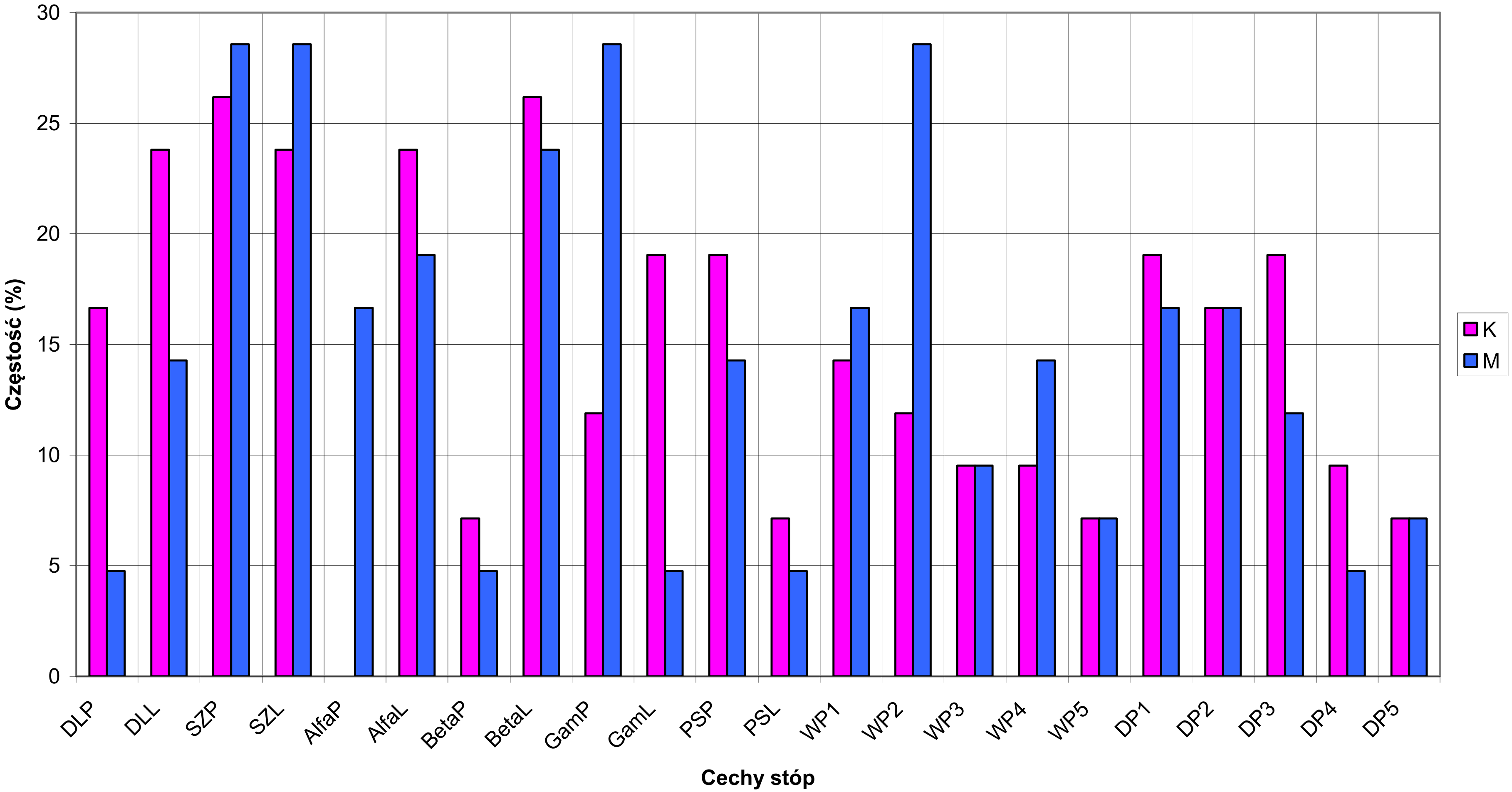
Parameters of longitudinal arch	K (female)	M (male)

Fig. 3 Sexual dimorphism of significant relationships of the parameters of trunk with the parameters of feet in children aged 7 – 13 years (n) K=6983 M=5960

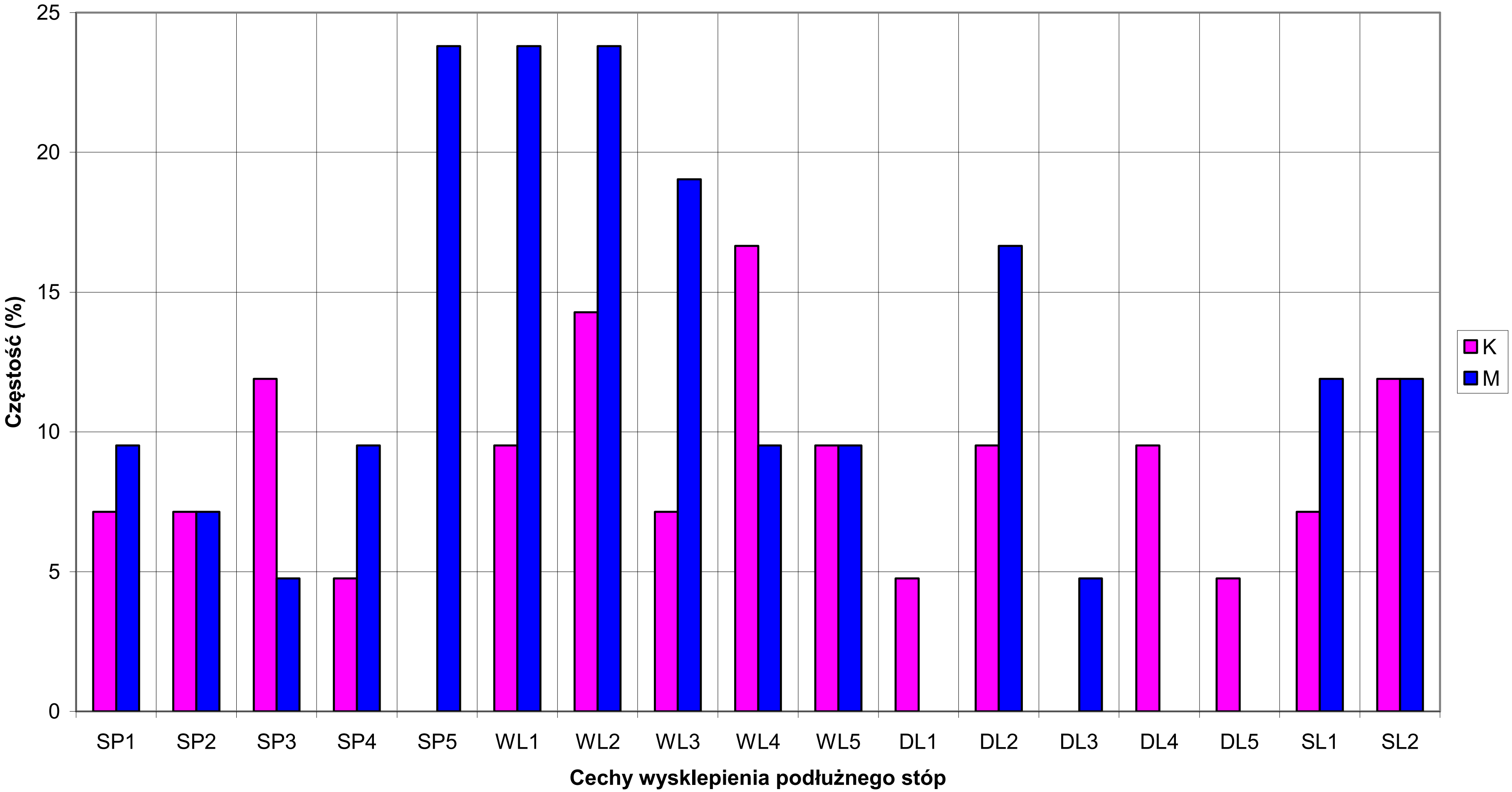
Incidence (%)

Parameters of trunk K (female) M (male

Ryc. 1. Dymorfizm płciowy istotnych związków wybranych cech stóp z cechami tułowia wśród 7 - 13-letniej młodzieży (n) K=6983, M=5960



Ryc. 2. Dymorfizm płciowy istotnych związków wybranych cech wysklepienia podłużnego stóp z cechami tułowia wśród 7 -13-letniej młodzieży (n) K=6983, M=5960



Ryc. 3. Dymofizm płciowy cech tułowia, z którymi cechy stóp wykazują najczęstszy istotny związek wśród 7 - 13-letniej młodzieży (n) K=6983, M=5960