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The frequency of significant relationships of selected features describing feet with the torso features among youth aged 7-13

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A – preparation of research project
B – data collection
C – statistical analysis
D – data reading
E – preparation of manuscript
F – literature elaboration
G – funds obtaining

Summary

Introduction. Research on the relationships and co-occurrence of the feet and torso features in a group of 4-6-year-old children showed that the values of the left foot features show a significantly more frequent relationship with the features of the torso than the right foot features.

Material and method. The research was carried out in the group of adolescents aged 7 to 13 and registered 12,898 observations of the value of 90 features describing torso and feet. The working stand for measuring the features of body posture and feet using the photogrammetric method consists of a computer and a card, a programme, a monitor, a printer, and a projection-receiving device with a camera for measuring selected features.

Conclusions

1. A similar number of features of the right and left foot is often associated with the torso features. The following features like width of the feet, the angle of the 5th hallux valgus and the left foot big toe, the heel angle and height of the right foot second arch, the height of the second longitudinal arch and the length of the left foot, and the length of the first arch of the right foot show especially frequent relationships.

2. The feet features show the most frequent significant relationship with the torso features of the frontal plane, whereas less of sagittal plane and occasionally of transversal plane. Torso features, which the most common features of the feet are significantly related to are the height and length of lumbar lordosis, the height of thoracic kyphosis, the angle of the torso flexion in the sagittal plane, the length of the thoracic kyphosis, the bent angle of the thoracic-lumbar spine, the depth of thoracic kyphosis, the depth of lumbar lordosis, and the inclination angle of the upper thoracic segment of the spine. The features of the feet are whereby most frequently related to the features of lumbar lordosis.

Keywords: relationship, feet, spine, pelvis

1. Introduction

The development of information technology resulted in the development of normative ranges of features describing the posture of the human body, which enabled further research on their mutual influence, relationships, and coexistence. This problem was dealt with, among others, by Łubkowska [1] and Mrozkowiak [2]. Grabara's research on body posture in a group of 207 girls and 200 boys of primary schools showed that a perfectly symmetrical body structure was rarely found, and asymmetries were common. The author believes that the reasons for this state can be found in the morphological and functional asymmetry, as well as in the lateralization process. The assessment of body posture in the sagittal plane showed a significant deepening of the anteroposterior curvatures of the spine, especially among the elderly, which led to a conclusion that such defects may occur more frequently in the sagittal plane in adolescence, and that creates the need to develop new patterns. The reason for such a frequent occurrence of body posture defects in children and adolescents may be related to the limited availability of corrective and compensatory activities or practicing more asymmetric sports like tennis. Adolescence also carries a risk of postural defects, which are associated with rapid growth changes. Therefore, it is important to provide children and adolescents with corrective and compensatory gymnastics, especially during periods of intensive growth, and to pay attention to proper body posture [3]. The result analysis of the correlation of 12898 observations of own research showed that in the selected age groups the most strongest relationships and coexistence appear among girls at the age of 11 and 12 and among boys at the age of 11, 12, and 13. There were no accuracy and logical relationships between the parameters of the pelvic-spine syndrome and feet in all age groups and each sex. The features of the sagittal and frontal plane are more dominant among the features describing the pelvic-spine syndrome and most often correlating with feet features, whereas transversal plane dominates less. On the other hand, features describing the 5^{th} hallux

valgus and varus and hallux varus of the right foot are the most dominant among the feet features in correlation with the parameters of the pelvic-spine syndrome [4].

There is relatively little publication about static-dynamic relations of features within the feet and torso area. The problem was explored by Mięsowicz [5-6], Drzał-Grabiec, Snela [7], Mrozkowiak, Sokołowski, and Jazdończyk [8, 9]. The author's research on relationships and the coexistence of feet and torso features in a group of 4-6-year-old children showed that the values of the left foot features showed a significantly more frequent relationship with the features of the torso than the right foot features. The most common features of the torso, which the features of the feet are related to are the size of the asymmetry in the height of the shoulder blades, where the right one is higher, the angle of inclination of the thoracolumbar segment of the spine and the asymmetry of the height of the waist triangles, where the right one is higher. Feet features show the most common significant relationship with torso features of sagittal and frontal plane rather than of the transversal plane [10].

The aim of the research is to determine the frequency of significant relationships of selected features describing the feet and torso features in the group of 7 - 13-year-old adolescents. The result analysis of the research was going in two directions. The first was the answer to the question: which feet features do most often show significant relationships with the features of the torso? The second was the answer to the question: which torso features are most often significantly related to the feet features?

2. Material and methods

The research was carried out in the group of children and adolescents aged 4 to 6 and registered 12,898 observations. For statistical analysis, 90 angular and linear parameters of the spine, pelvis, torso, and feet were selected in the sagittal, frontal, and transversal planes, in individual age categories, sex and environment, tab. 1. Due to the limited volume of the

work, a detailed description of the somatic features of the research material and the obtained research results can be found in the author's monograph [2]. Empirical data were based on quantitative and qualitative features (gender, place of residence, etc.). The values of positional statistics were calculated (arithmetic mean, quartiles), as well as dispersion parameter (standard deviation) and symmetry indicators (asymmetry coefficient, cluster coefficient), which give a full overview of the distribution of the researched features considering age groups, gender, and environment. Relationships and significance were determined using p as a value, and frequency as percentage.

The basic assumption in the research was to always assess habitual attitude as a relatively permanent individual characteristic of a human being. This attitude reflects the individual emotional, mental, and social state of the respondent. It is the most accurate in describing their silhouette in time and place. The obtained diagnostics does not determine whether the individual's posture is correct, but it only affirms the state of its ontogenetic realization. Objectivized and comparable test results will make it possible to register the parameters adopted for the analysis with possible to define compensations. The combination of a torso and feet examination made it possible to objectively determine the quality of the posture pattern realized in each environment, gender, and age category as well as the level of rehabilitation because of physical exercises. The working stand for measuring the features of body posture and feet using the photogrammetric method consists of a computer and a card, a programme, a monitor, a printer, and a projection-receiving device with a camera for measuring selected features. A spatial image is possible to obtain thanks to lines displayed with strictly defined parameters on the child's back and feet. The lines falling on the skin are distorted depending on the configuration of the surface. Thanks to the use of a lens, the image of the examined person can be received by a special optical system with a camera, and then transferred to a computer monitor. Line image distortions recorded in the computer memory

are processed by a numerical algorithm into a contour map of the tested surface. While the examination, one should be aware that the taken picture records the image of the silhouette visible on the child's skin. The uneven distribution of adipose tissue on the back surface makes it difficult to reliably assess the body posture in children, especially with BMI index above 25.0 - 30.0. This is the reason why it is much more difficult to determine the selected anthropometric points used in the calculations. [2].

Tab. 1. List of registered features of the torso and feet

Within torso area

No.	Symbol	Parametres		
		Label	Name	Description
Sagittal plane				
1	Alfa	degrees	Inclination of the lumbosacral segment	
2	Beta	degrees	Inclination of the thoracolumbar segment	
3	Gamma	degrees	Inclination of the upper thoracic segment	
4	Delta	degrees	The sum of the angle values	Delta = Alfa + Beta. + Gamma
5	DCK	mm	Total length of the spine	Vertical distance between C_7 and S_1 points
6	KPT	degrees	Torso extension angle	It is determined by the deviation of C_7-S_1 points from the vertical line (backwards)
7	KPT -	degrees	Torso bent angle	It is determined by the deviation of C_7-S_1 points from the vertical line (forwards)
8	DKP	mm	Length of thoracic kyphosis	Distance between LL a C_7 points
9	KKP	degrees	The angle of thoracic	KKP = 180 – (Beta+Gamma)

			kyphosis	
10	RKP	mm	Height of thoracic kyphosis	Distance between C_7 a PL points
11	GKP	mm	Depth of thoracic kyphosis	The distance measured horizontally between vertical lines passing through PL and KP points
12	DLL	mm	Length of lumbar lordosis	The distance between S_1 and KP points
13	KLL	degrees	Lumbar lordosis angle	KLL = 180 – (Alfa + Beta)
14	RLL	mm	Height of lumbar lordosis	Distance between S_1 and PL points
15	GLL -	mm	Depth of lumbar lordosis	The distance measured horizontally between vertical lines passing through PL and LL points
Frontal plane				
16	KNT -	degrees	The angle of the torso bend to the side	It is determined by the deviation of the C_7-S_1 line from the vertical to the left.
17	KNT	degrees		It is determined by the deviation of the C_7-S_1 line from the vertical to the right.
18	LBW -	mm	The right shoulder higher	The distance measured vertically between the horizontal lines going through the B_2 and B_4 points.
19	LBW	mm	The left shoulder higher	
20	KLB	degrees	The angle of shoulders line, where the right one is higher	The angle between the horizontal and the straight line going through the B_2 and B_4 points.
21	KLB –	degrees	The angle of shoulders line, where the	

			left one is higher	
22	LŁW	mm	Left shoulder blade higher	The distance measured vertically between horizontal lines going through Ł1 and Łp points.
23	LŁW –	mm	Right shoulder blade higher	
24	UL	degrees	The angle of shoulder blades line, where the right one is higher	The angle between the horizontal and the straight line going through the Ł1 and Łp points.
25	UL -	degrees	The angle of shoulder blades line, where the left one is higher	
26	OL	mm	The lower, more distant angle of the left shoulder blade	The difference in the distance of the lower angles of the shoulder blades from the line of the spinous processes of the spine, measured horizontally at the straight lines going through the Ł1 and Łp points.
27	OL -	mm	The lower, more distant angle of the right shoulder blade	
28	TT	mm	The left waist triangle is	The difference in the distance measured vertically between the T_1 and T_2 points and between T_3 and T_4

			higher	points.
29	TT –	mm	The right waist triangle is higher	
30	TS	mm	The left waist triangle is wider	The difference in the distance measured horizontally between the straight lines going through the T_1 and T_2 points and T_3 and T_4 points.
31	TS -	mm	The right waist triangle is wider	
32	KNM	degrees	The pelvic tilt angle, the right ala of ilium is higher	The angle between the horizontal and straight line going through the M1 and Mp points.
33	KNM -	degrees	The pelvic tilt angle, the left ala of ilium is higher	
34	UK	mm	The maximum deviation of the spinous process of the vertebra to the right	The greatest deviation of the spinous process from the vertical coming from S_1. The distance is measured on the horizontal axis.
35	UK -	mm	The maximum deviation of the spinous process of the vertebra to the left	

36	NK	_	The number of the vertebrae deviating as far as possible to the left or right	The number of the vertebrae most deviating to the left or right in the asymmetrical course of the spinous process, counting as 1, first cervical vertebra (C1) If the arithmetic mean is, for example, from 12.0 to 12.5 it is Th_5, if from 12.6 to 12.9 it is Th_6.
Transversal plane				
37	ŁB -	mm	The lower angle of the right shoulder blade more oblique	The difference in the distance (convexity) of the lower angles of the shoulder blades from the back surface.
38	ŁB	mm	The lower angle of the left shoulder blade more oblique	
39	UB –	degrees	The angle of the line of convexity of the lower angles of the blades, more convex on the left	Angle difference UB_1 - UB_2. The UB_2 angle between: the line passing through the point Łl and being simultaneously perpendicular to the camera axis and the straight line passing through Łl and Łp. The UB_1 angle included between the line passing through the point Łp and being simultaneously perpendicular to the camera axis and the straight line passing through Łp and Łl.
40	UB	degrees	The angle of the line of convexity of the lower angles of	

			the blades, more convex on the right	
41	KSM	degrees	Pelvis twisted to the right	The angle between a line passing through Ml point and being simultaneously perpendicular to the camera axis and a straight line passing through Ml and MP points
42	KSM -	degrees	Pelvis twisted to the left	The angle between a line passing through Mp point and being simultaneously perpendicular to the camera axis and a straight line passing through Ml and MP points

Within feet area

No.	Symbol	Features		
		Label	Name	Description
43	DL p	mm	Length of the right foot (p), and left foot (l)	The distance between akropodion and pterion points on the platnogram
44	DL l			
45	Sz p		The width of the right foot(p), and left foot (l)	The distance betwenn metatarsale fibulare and metatarsale tibiale points on the plantogram
46	Sz l			
47	W p		Wejsflog index "W" of the right foot (p) and the left foot (l)	The ratio of the foot length to its width DL p / Sz p = W p, DL l / Sz l = Wl
48	W l			
49	Alfa p m	degrees	The angle of the hallux valgus of the right foot: Alfa p p, and left: Alfa l p. The angle of hallux vargus of the right foot: Alfa p m, and left: Alfa l m.	The angle between the straight line passing through the metatarsale tibiale and the innermost points at the medial edge of the heel and the straight line passing through the metatarsale tibiale and the innermost points at the medial edge of the toe
50	Alfa p p			
51	Alfa l m			
52	Alfa l p			
53	Beta p m		The angle of the 5th hallux vargus of the right foot: Beta p p, and left: Beta l p.	The angle between the straight line passing through the metatarsale fiburale points and the outermost point on the lateral edge of the heel and the straight line passing
54	Beta p p			
55	Beta l m			

56	Beta l p		The aangle of the 5th hallux valgus of the right foot: Beta p m, and left: Beta l m.	through the metatarsale fiburale points and the outermost straight line on the lateral edge of the V toe on the plantogram
57	Gamma p (Gam.P)		Heel angle of the right foot (p), and left foot (l)	The angle between the straight line passing through the metatarsale tibiale and the innermost points on the medial edge of the heel and the straight line passing through the metatarsale fiburale points and the outermost line on the lateral edge of the heel in the plantogram
58	Gamma l (Gam.L)			
59	PS p	mm^2	Surface of the right foot (p), and left foot (l)	Foot plantogram surface
60	PS l			
61	DP 1	mm	Length of longitudal arch of the right foot 1, 2, 3, 4, and 5 (P), and the left foot (L)	The length of the arch from the 1st, 2nd, 3rd, 4th and 5th metatarsal bones to the pterion point
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 the right foot (P), and left foot	Distance from the ground 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 the right foot (P), and left foot (L)	Bowstring of the arch length 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: own research

4. Results

Tab. 2. The frequency of significant correlation of feet features with torso features (n) 12898

The feature name and the frequency of its significant correlation									
DLP	21,42	BetaP	11,9	WP1	30,94	DP2	33,32	SP3	16,66
DLL	38,08	BetaL	48,98	WP2	40,46	DP3	30,94	SP4	14,28
SZP	54,74	GamP	40,46	WP3	19,04	DP4	14,28	SP5	23,8
SZL	52,36	Gam L	23,8	WP4	23,8	DP5	14,28	WL1	33,32
Alfa	16,66	PSP	33,32	WP5	14,28	SP1	16,66	WL2	38,08
Alfa	42,84	PSL	11,9	DP1	35,7	SP2	14,28	WL3	26,18
WL4	26,18	DL2	26,18	DL5	4,76	SL3	19,04	SL5	14,28
WL5	19,04	DL3	4,76	SL1	19,04	SL4	30,94	SL2	23,8
DL1	4,76	DL4	9,52						

Source: own research

The most common association of the feet features with the torso features, in the value over 20% is in the width of the right (54.74%) and left (52.36%) foot, the angle of the fifth hallux valgus (48.98%) and the big toe (42.84% of the left), the heel angle (40.46%) and the height of the second arch (40.46%) of the right foot. Slightly less value, at the level of 38,08% is noticeable in the height of the second longitudinal and the length of the left foot, and the length of first the arch of the right foot 35.7%. The frequency of correlation between the plantocountourgraph and the length of the second arch of the right feet as well as between the height of the first arch of the right foot in the value of 33,32% together with the height of the first arch and the length of the third arch of the right foot and the width of the fourth arch of the left foot in the value of 30,94%. The following features are also correlated with a frequency of more than 20% in the height of the third and fourth arch and the length of the fifth arch of the left foot (26.18%), and with a frequency of 23.8% in the heel angle of the left

foot, the height of the fourth arch of the right foot and the width of the second arch of the left foot. Other features are below this threshold, tab. 2, fig. 1, 2.

Tab. 3. The torso features, which the feet features are most often related to (n) 12898

The name of torso features and the frequency of the significance of feet features									
Alfa	30,42	GKP	60,85	KNT-	15,2	OL	21,71	KNM	26,07
Beta	61,37	DLL	80,41	TT-	30,42	UL	21,71	KSM	15,21
Gamma	52,15	RLL	95,21	TS	17,37	UB	15,2	UK-	6,52
DKP	67,37	GLL	56,5	KLB	6,52	UB-	26,16		
RKP	71,72	KPT-	69,54	KLB-	6,52	LŁW-	4,34		

Source: own research

Further result analysis of the research showed that the value of the feet features was most often, more than 20%, significantly associated with the height (95.21%) and length (80.41%) of lumbar lordosis, the height of thoracic kyphosis (71.72%), sagittal torso flexion (69.54%), length of thoracic kyphosis (67.37%), inclination angle of the thoracolumbar segment of the spine (61.37%), depth of thoracic kyphosis (60.85%), depth of lumbar lordosis (56.5%), the inclination angle of the upper thoracic segment of the spine (52.15%), the inclination angle of the lumbosacral segment of the spine and the asymmetry of the height of the waist triangles, where the right one is higher (30.42%), the angle of pelvis inclination to the left in the frontal plane the and asymmetry of the angle of the convexity of the angles of lower shoulder blades, where the left one is more convex (26.16%), the asymmetry of the distance of the angles of the lower shoulder blades from the line of the spinous processes, where the lower angle of the left shoulder blade is further away, and the asymmetry line of the height of the angles of lower shoulder blades where the right angle is higher (21.71%). The relationship between the feet and other features of the torso is below 10%, Table 3, Fig. 3.

5. Discussion

The literature describing the relationship between the characteristics of the torso and feet is extremely poor. Research by Gonzales et al. [11] showed that the external morphology of the torso is related to running efficiency. Low thoracic kyphosis with a more flattened chest may positively affect respiratory biomechanics, while increased lordosis affects torso posture and may be beneficial to biomechanics of lower limbs related to the legs return. Assuming, if 45-50% HRR running load is within aerobic metabolism, our results may suggest that the outward shape of the torso is unrelated to the evolution of endurance in long-distance running. Research by Puszczałowska-Lizis [12] showed that the majority of the examined girls and boys had properly longitudinally and transversely arched feet and correctly positioned toes. Overweight was a factor deforming the foot shape in children; it caused the deterioration of the longitudinal and transversal arches of the right foot in girls, and the flattening of the left foot in boys.

6. Conclusions

1. A similar number of features of the right and left foot is often associated with the torso features. The following features like width of the feet, angle of the 5th hallux valgus and the left foot toe, heel angle and height of the second arch of the right foot, height of the second longitudinal arch and the length of the left foot, and the length of the first arch of the right foot show especially frequent relationships.

2. The features of the feet show the most frequent significant relationship with the features of the torso of the frontal plane, less with features of sagittal plane and occasionally with transversal plane. Torso features, which the most common features of the feet are significantly related to are the height and length of lumbar lordosis, the height of thoracic kyphosis, the angle of the torso flexion in the sagittal plane, the length of the thoracic kyphosis, inclination

angle of the thoracic-lumbar segment of the spine, the depth of thoracic kyphosis, depth of lumbar lordosis, inclination angle of the thoracic segment of the upper spine. The features of the feet are whereby most frequently related to the features of lumbar lordosis.

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Fig.1 The frequency of significant correlations of selected feet features with torso features among 7-13 years old adolescents of both sexes and environments (n) 12898

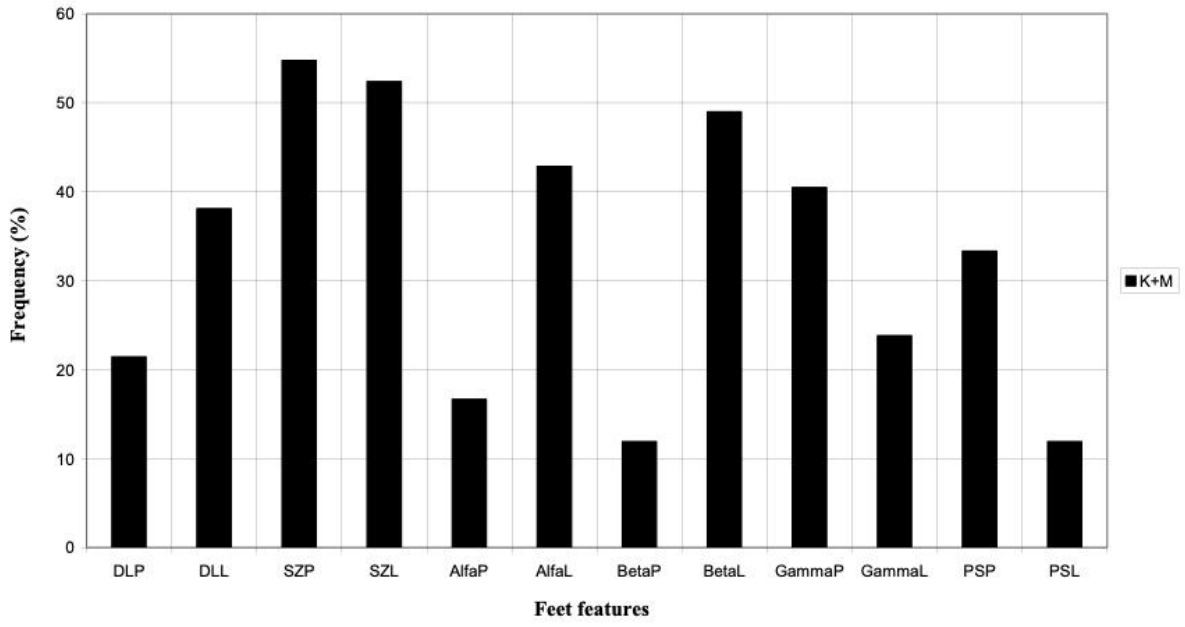

Fig.2 The frequency of significant correlations of feet features with torso features among 7-13 years old adolescents of both sexes and environments (n) 12898

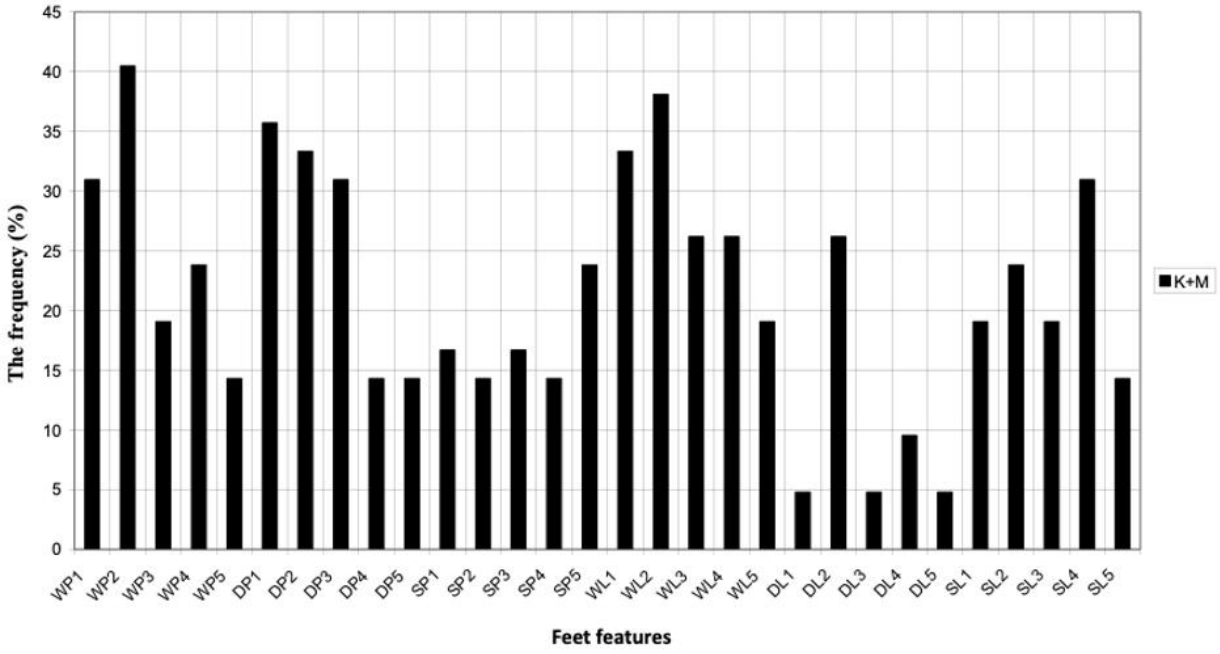

Fig.3 Torso features, which feet features are most significantly correlated with among 7-13 years old adolescents of both sexes and environments (n) 12898