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The influence of the angle of the trunk flexion and extension in the sagittal plane and flexion in the frontal plane on the value of features describing the spine and pelvis among 7 to 15-year-old youth of both sexes

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Keywords: projection moiré, features of spine and pelvis

Summary

The aim of the study was to demonstrate the significant effect of the value of the angle of trunk flexion and extension in the sagittal plane and the flexion to the left and right in the frontal plane on the value of selected features describing the spine.

Material and methodology. The research was conducted in a group of 2,361 people aged 7 to 15, in 6 semi-annual successive editions. This made it possible to record 16,608 observations using the photogrammetric method: 29 features describing spatially body posture.

Results. Four features influencing the value of features describing the posture were selected for the analysis like an angle of trunk flexion and extension in the sagittal plane, an angle of flexion to the left and right in the frontal plane on selected sagittal and frontal features.

Conclusions. (1) The influence of trunk flexion and extension angles in the sagittal plane and

left and right flexion in the frontal oplane on the spine features is multidirectional and differential. (2) Spine characteristics are significantly and positively affected in particular by the value of the trunk extension angle in the sagittal plane and the value of the left flexion angle in the frontal plane, and negatively the value of the flexion angle in the sagittal plane. (3) None of the examined angles affect the characteristics of the pelvis.

1. Introduction

Everything that violates the basics of health and disrupts the harmony of the musculoskeletal system is a potential threat to good posture and should be combated [1]. Compared to other diseases, e.g., of infectious etiology, body static disorders do not have geoclimatic conditions. Postural disorders occur in a similar percentage in the population of children and adolescents on other continents [2, 3]. The available literature in this field shows that the problem is not thoroughly investigated. However, high rates of postural disorders and scoliosis are observed in children in economically developed countries. School education is compulsory, and the physical activity of children and teenagers is much below the norm (from 6 to 15 hours of organized activities per week). The factor that increases the percentage of body posture violations is urbanization, unfavorable housing conditions, frequent and long illnesses, poor school scores and low physical activity [4]. All factors shaping a human being come from the surrounding, local, and family environment [5] as well as anatomical and physiological conditions. The image of posture is constantly changing during the day, under the influence of emotions, mental and physical state. However, the most lasting changes occur as the body ages.

The axis of the trunk, to a large extent determining the figure and locomotion, is the axial organ, supported by the sacrum. Body posture is an individual variable feature, and the beginning of the individual posture-forming process dates back to the prenatal period. Relative stabilization occurs at the age of 3. The subsequent significant growth of the torso with weak muscles stabilizing the spine causes a constant modification of curvatures. Their formation, and thus the type of posture, can be discussed at the age of about 7 years. They are unstable until older school age. This is of great importance in the child's posturogenesis, and thus in shaping the habitual posture of the body. At the age of 7 - 8 years, the anterior lumbar curve is clearly formed. The belly, despite the clear flattening, is still slightly bulging. In addition, according to the accepted opinion, the body posture in generally healthy children tends to symmetry in the frontal and transversal planes and to optimize the physiological curvatures in the sagittal plane with age [6].

The aim of the study was to demonstrate a significant effect of the value of the angle of flexion and extension in the sagittal plane and the flexion in the frontal plane of the trunk to the left and right on the value of features describing the spine.

2. Research material and methods

Body posture tests were carried out in randomly selected kindergartens and schools in the Warmian-Masurian and Pomeranian Regions. There were 46.84% of boys (1106 people) and 53.15% of girls (1255 people), who participated in the study. The advantage of girls was at the level of 149 people, which is 6.31%. The division of the respondents into those from the rural and urban environment was abandoned, due to the fact that this feature will never determine the homogeneity of the group and the cultural and economic border of both environments is blurring. tab. 1. In total, the research was conducted in the population of 2,361 children aged 7 to 15, in 6 consecutive semi-annual editions, and allowed to register 16,608 observations of 29 features of the spine-pelvic complex as well as body height and weight in individual age categories, tab. 1.

Tab. 1. Number of observations by age and gender

	Numer of observations		
Age (years)	Sex		Total (N)
	K(N	M (N)	
7	610	597	1207
8	1341	1255	2596
9	1839	1677	3516
10	1752	1542	3294
11	1047	901	1948
12	670	549	1219
13	569	462	1031
14	582	436	1018
15	424	355	779
Total	8834	7774	16608

Source: own research

The measurement stand for the value of selected body posture features consists of a computer, card, program, monitor, printer, projection and receiving device with a camera for measuring selected parameters of the spine-pelvis complex. The place of the examined person and the camera were spatially oriented according to the contour lines on the camera and in relation to the line of the child's toes. Obtaining a spatial image was possible by displaying lines with strictly defined parameters on the child's back, pic. 1. Lines falling on a body are distorted depending on the configuration of its surface. The image of the subject was received by a special optical system with a camera by the use of a lens, and then transferred to a computer monitor. Distortions of the line image recorded in the computer's memory are processed by a numerical algorithm into a contour map of the examined surface. The obtained image of the back surface enables a multi-faceted interpretation of body posture. In addition to the assessment of trunk asymmetry in the frontal plane, it is possible to determine the value of angular and linear features describing the pelvis and physiological curvatures in the sagittal and transversal planes, tab. 2, pic. 2, fig. 1-7. The most important aspect of the method was the simultaneous measurement of all the actual values of the spatial location of individual body sections [7, 8]. The research was carried out by a physiotherapist with 20 years of experience in diagnosing body posture using the photogrammetric method.

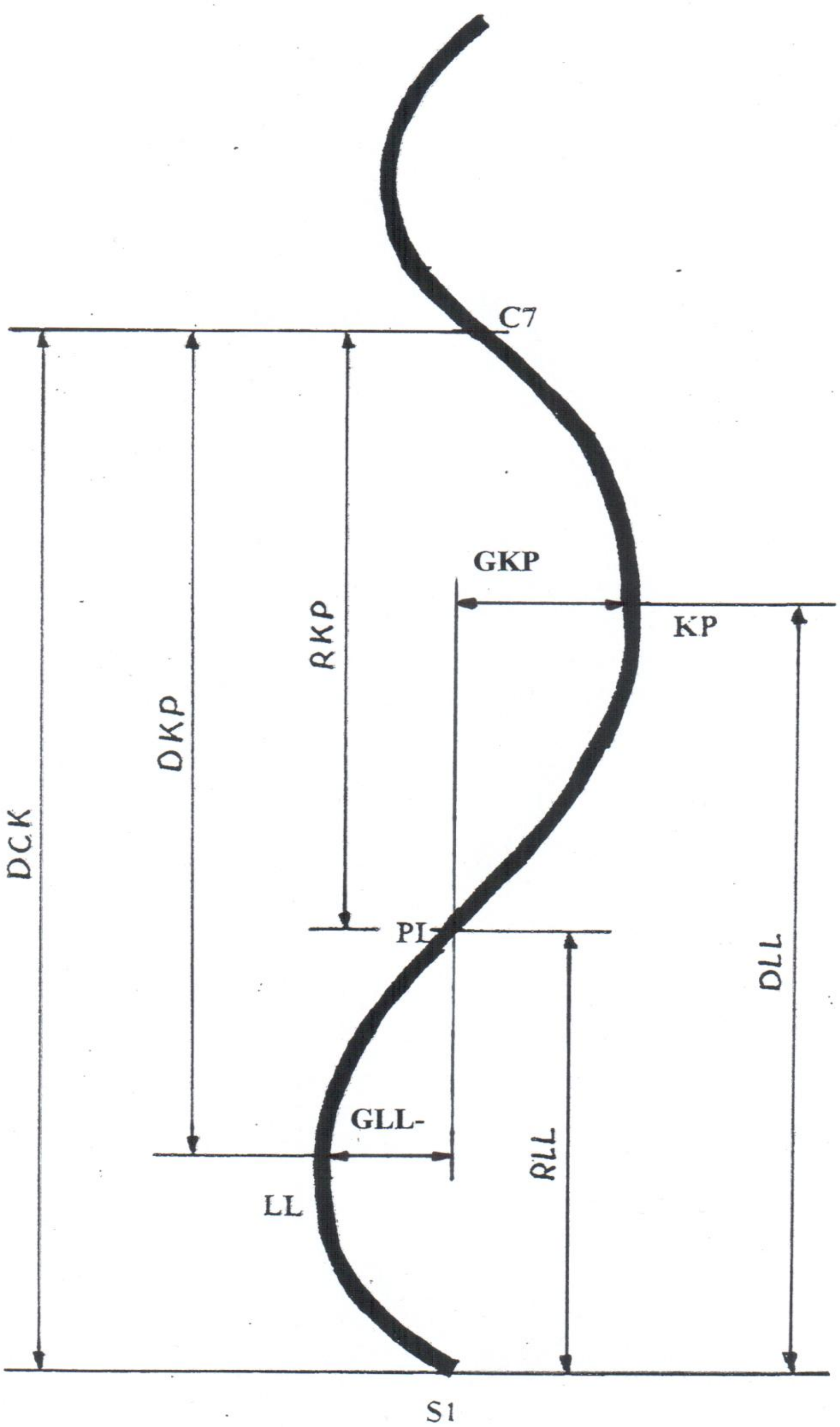
Pic. 1. Position 1: Habitual posture.

Tab. 2. List of registered parameters

No.	Parametres			
	Symbol	Unit of measure	Name	Description
Sagittal plane				
1	Alfa	degrees	Sacrolumbar tilt	
2	Beta	degrees	Thoracolumbar tilt	
3	Gamma	degrees	Upper thoracic tilt	
4	Delta	degrees	The sum of the angular values	Delta = Alfa + Beta + Gamma
5	DCK	mm	Total length of the spine	Distance between C7 and S1points measured in vertical axis
6	DCK	%		Percentage of body height
7	KPT	degrees	Angle of trunk extension	It is determined by the deviation of the C7-S1 line from the vertical
8	KPT -	degrees	Angle of trunk flexion	
9	DKP	mm	Length of thoracic kyphosis	Distance between C7 and LL points
10	DKP	%		Percentage of DCK
11	KKP	degrees	Angle of thoracic kyphosis	KKP = 180 – (Beta + Gamma)
12	RKP	mm	Height of thoracic kyphosis	Distance between C7 and PL points
13	RKP	%		Percentage of DCK
14	GKP	mm	Depth of thoracic kyphosis	Distance measured horizontally between vertical lines passing through the PL and KP points, at the level of the KP point
15	DLL	mm	Length of lumbar lordosis	Distance between KP and S1 points
16	DLL	%		Percentage of DCK
17	KLL	degrees	Angle of lumbar lordosis	KLL = 180 – (Alfa + Beta)
18	RLL	mm	Height of lumbar lordosis	Disyance between PL and S1 points
19	RLL	%		Percentage of DCK
20	GLL -	mm	Depth of lumbar lordosis	Odległość mierzona poziomo między liniami pionowymi przechodzącymi przez punkty PL i LL, na poziomie punktu LL
Frontal plane				
21	KNT -	degrees	Torso flexion angle in the frontal plane	It is determined by the deviation of the line C7 - S1 from the vertical to the left
22	KNT	degrees		It is determined by the deviation of the line C7 - S1 from the vertical to the right
23	KNM	degrees	Angle of pelvis tilt	The angle between the horizontal line and the straight line through the points M1 and Mp. Right ala of ilium higher "+". Left hip plate higher "-".
24	KNM -	degrees		
25	UK	mm	Max. deviation of the 1st vert. of the sp. processes to the	The greatest deviation of the spinous process from the vertical derived from S1. The distance is measured along the horizontal axis.
26	UK -	mm	Max. deviation of the 1st vert. of the sp. processes to the left	
27	NK	-	No. of the vertebra maximally deviated to the left or right	Vertebra number, counting as 1, first cervical vertebra (C1)

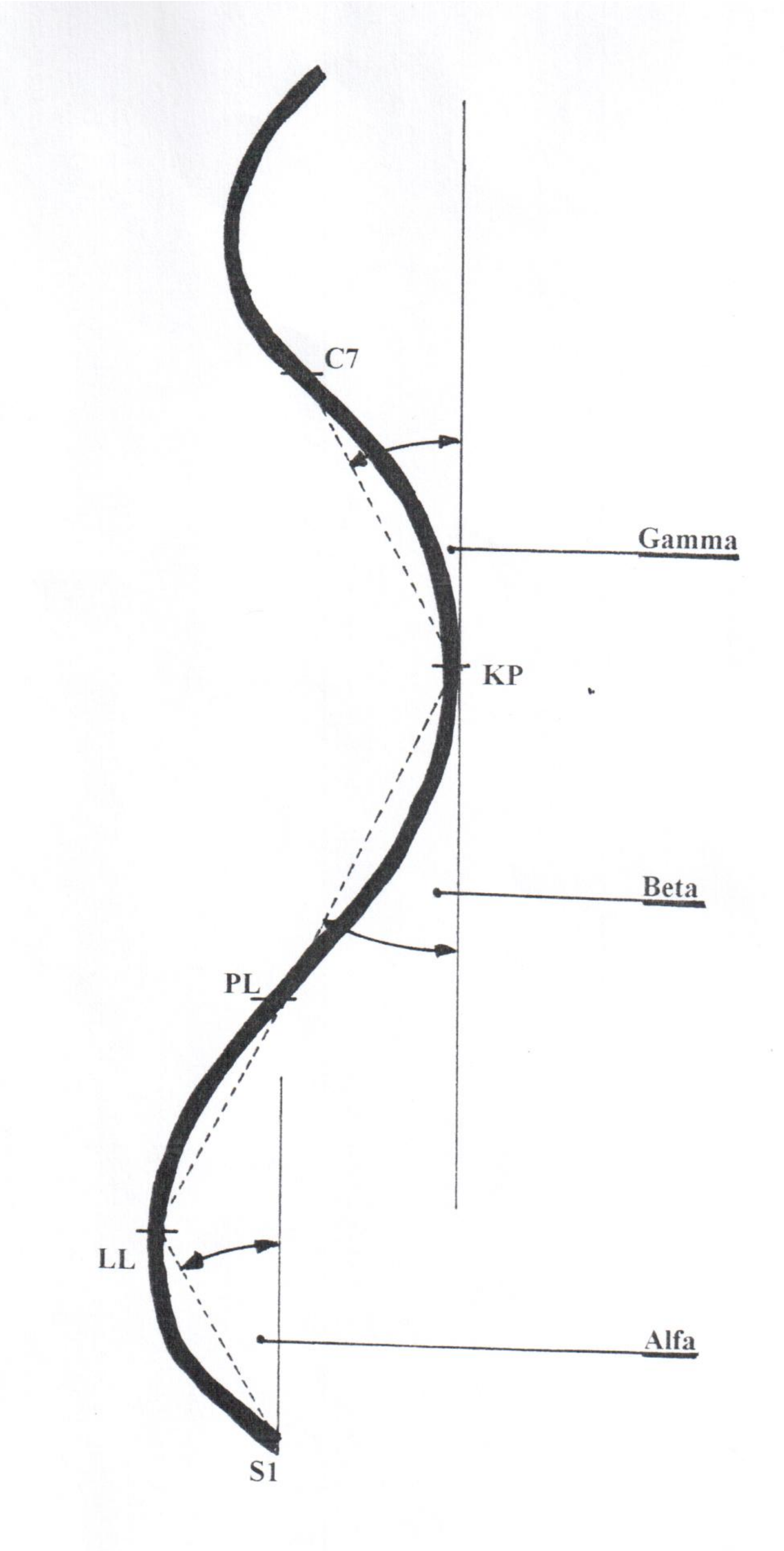
Transversal plane				
28	KSM	degrees	Angle of pelvis turn	The angle between the line passing through Ml point and being at the same time perpendicular to the axis of the camera and the line passing through Ml and MP points. Pelvis to the
29	KSM -	degrees		The angle between the line passing through Mp point and being at the same time perpendicular to the axis of the camera and the line passing through Ml and MP points. The pelvis turned to the left.
Anthropometric parametres				
30	W.C.	cm	Body height (W.C.) and weight (M.C.) were measured on a medical scale with an accuracy of 1 g and 1 mm.	
31	M.C.	kg		
	Additional parametres			
32	Environment – urban / rural			
33	Age			
34	Sex – M/F			

Source: own research



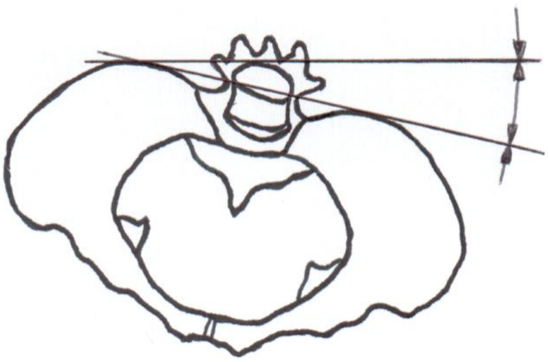
Source: own research

Fig. 1. Linear features of the spine un the sagittal plane



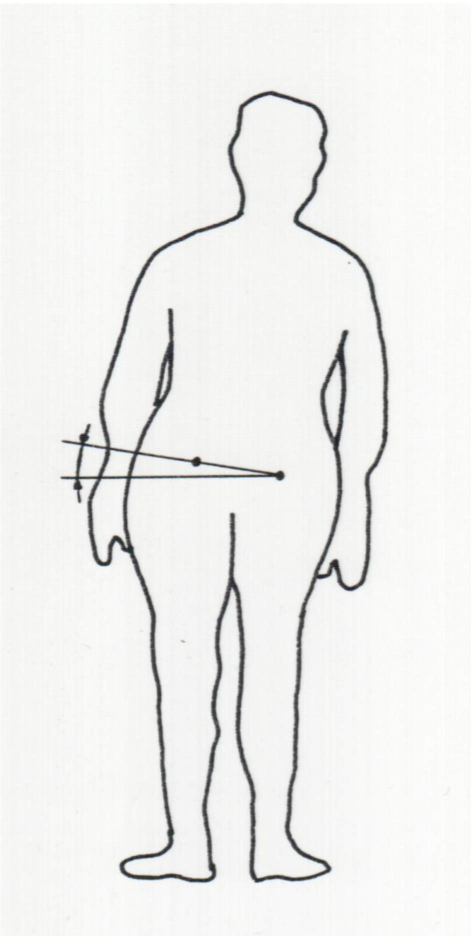
Source: own research

Fig. 2. Angular features of the spine in the sagittal plane



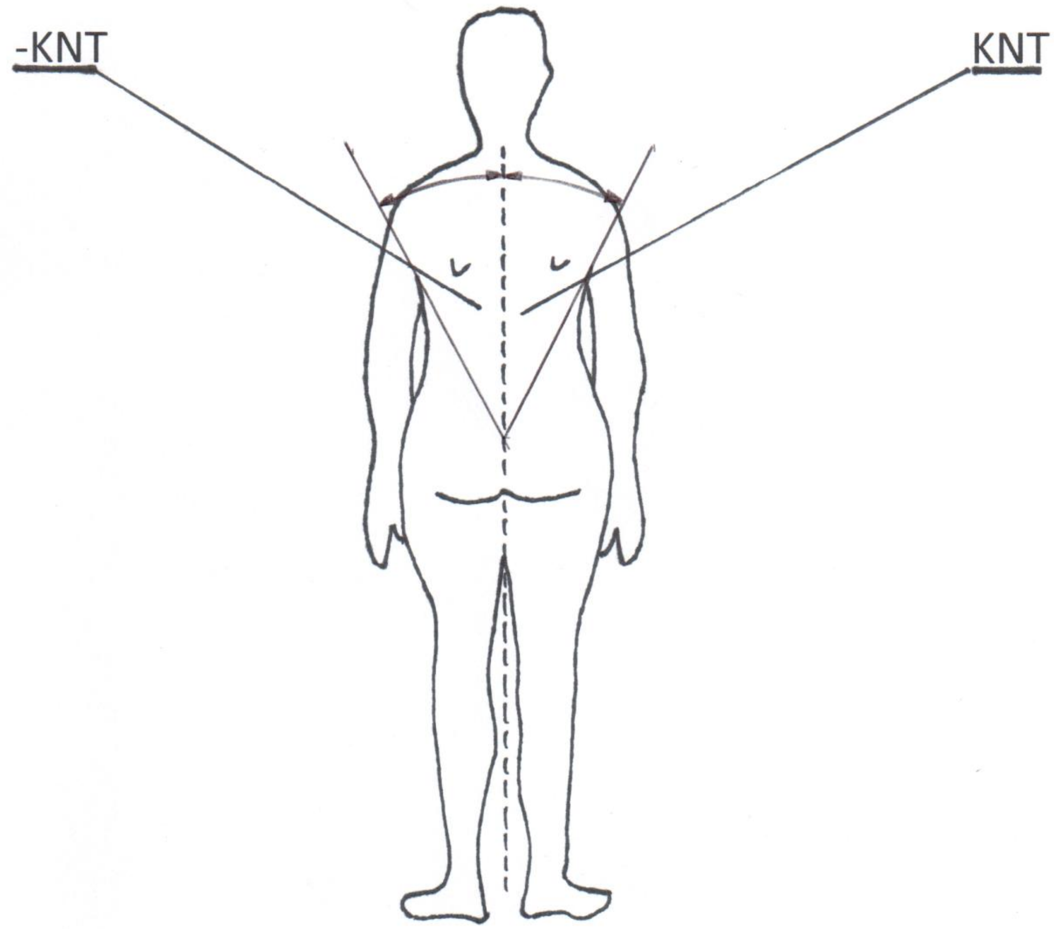
Source: own research

Fig. 3. Angle of pelvis turn in the transversal plane (KSM)



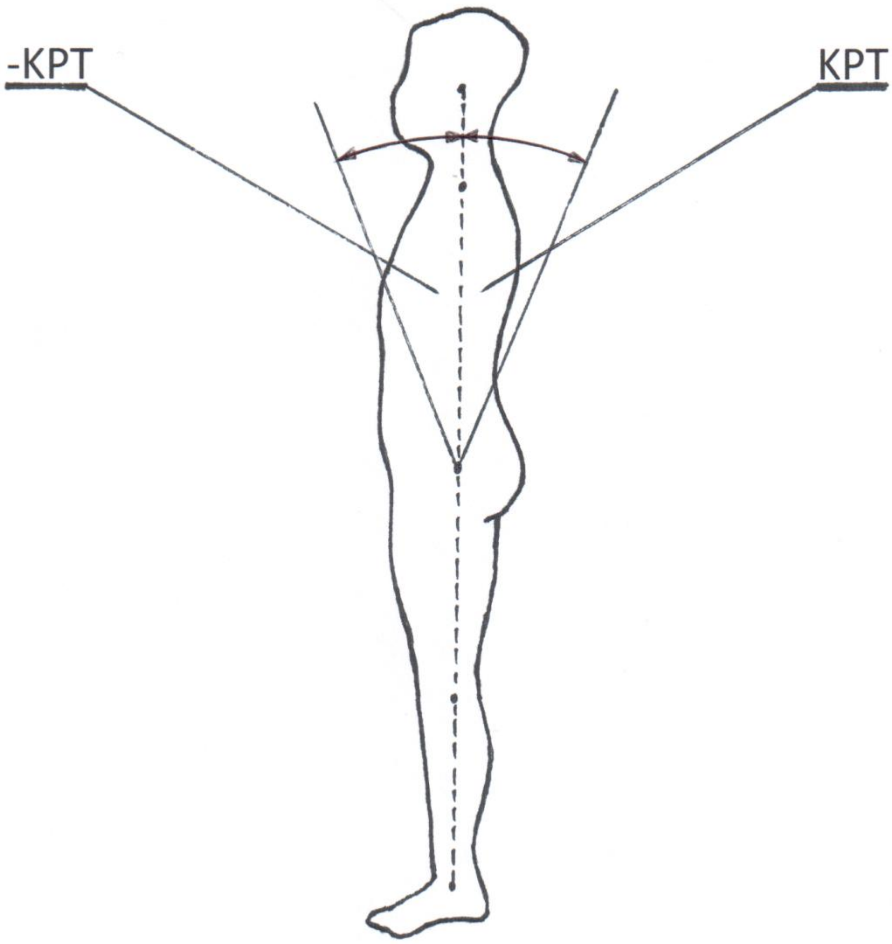
Source: own research

Fig. 4. Angle of pelvis tilt in the frontal plane (KNM)



Source: own research

Fig. 5. Angle of the torso flexion to the left (-KNT) or to the right (KNT) in the frontal plane



Source: own research

Fig. 6. Angle of the torso flexion (-KPT) or extension (KPT) in the sagittal plane

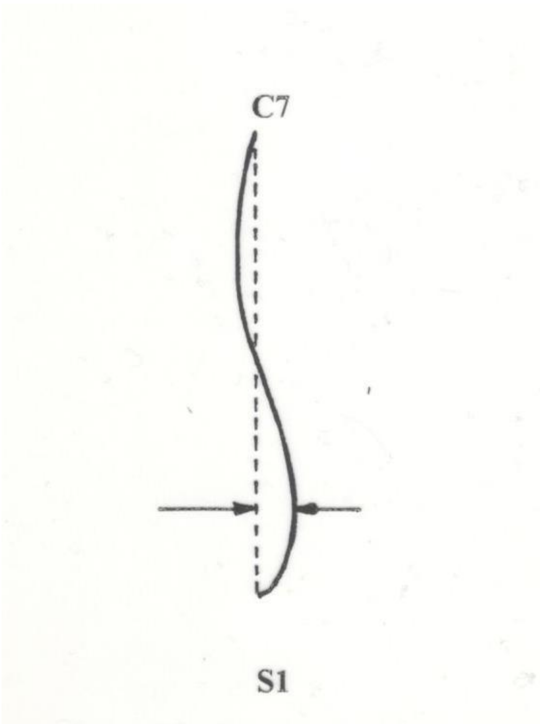


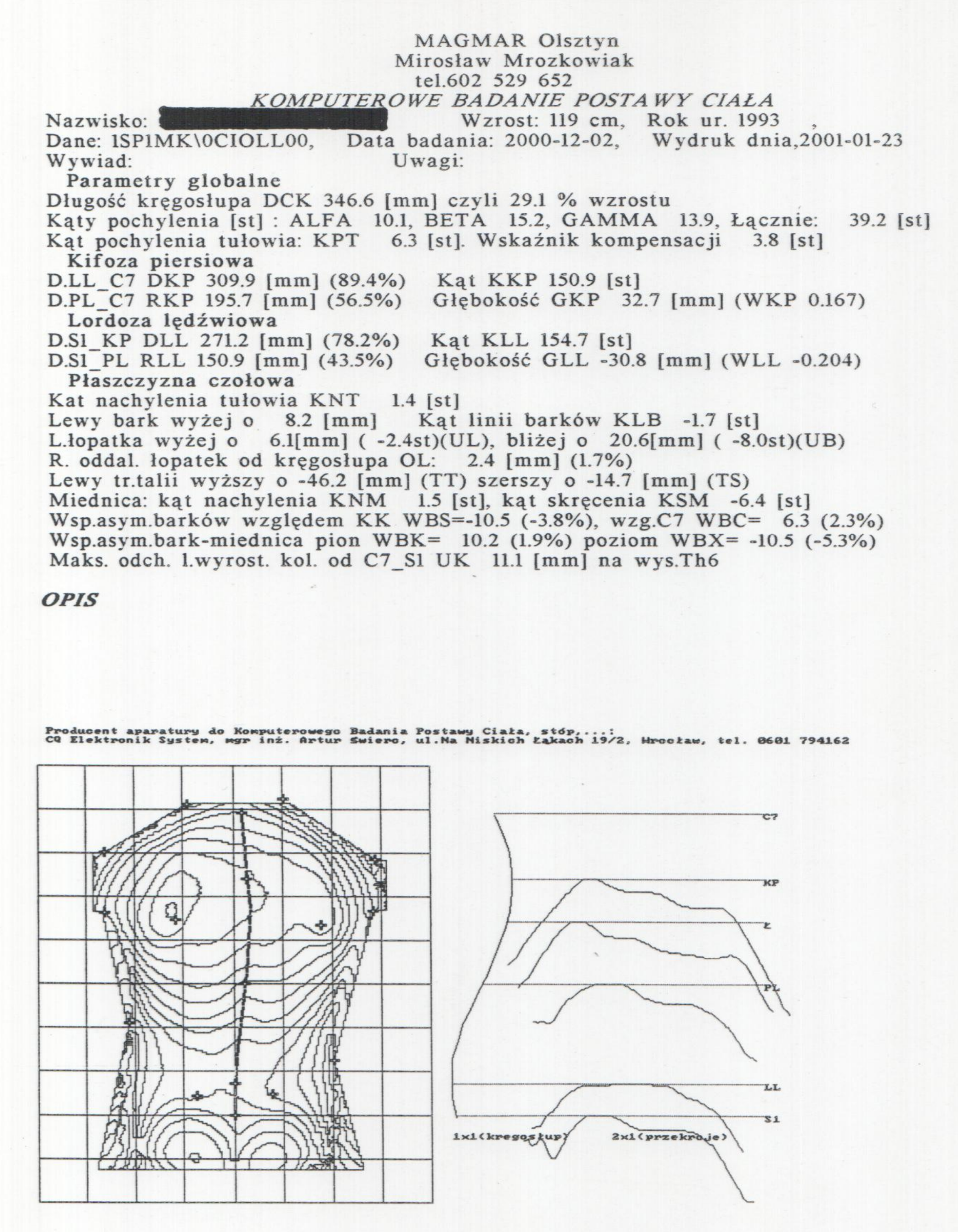
Fig. 7. The greatest deviation of the spinous process of the vertebra from the vertical to the right (UK), or to the left (UK-). Distance measured in the horizontal axis.

To minimize the risk of errors in measuring selected postural characteristics, the following test procedure was developed [9]:

1. Habitual posture of the subject against the background of a white slightly illuminated sheet: casual, unforced posture, with feet slightly apart, knee and hip joints in extension, arms hanging along the torso and eyes directed straight ahead, with the back to the camera at 2.5 meters from it, with the toes of the feet at a line perpendicular to the axis of the camera.
2. Marking on the skin of the subject's back the following points: the top of the spinous process of the last cervical vertebra (C7), the spinous process that is the peak of thoracic kyphosis (KP), the spinous process that is the peak of lumbar lordosis (LL), the place where thoracic kyphosis transitions to lumbar lordosis (PL), the lower angles of the shoulder blades (Ll and Lp), the posterior upper iliac spine (Ml and Mp), and the S1 vertebra. A white necklace was placed on the subject's neck for unambiguous marking of points B1 and B3. Long hair was tied up to expose point C7.
3. After inputting the necessary data about the respondent (name, year of birth, weight and body height, remarks about the condition of the knees and heels, chest, past injuries, surgeries, musculoskeletal diseases, gait, etc.) a digital image of the back in each of the 4 positions from the middle phase of exhalation is registered in the computer memory.

4. The processing of the recorded images is carried out without the participation of the subject.

5. After recording the mathematical characteristics of the images in the computer memory, the printing of the value of the features, which spatially describe the posture, followed, Fig. 8.



MAGMAR Olsztyn
Mirosław Mrozkowiak
tel.602 529 652

KOMPUTEROWE BADANIE POSTAWY CIAŁA

Nazwisko: [redacted] Wzrost: 119 cm, Rok ur. 1993 ,
Dane: 1SP1MK\0CIOLL00, Data badania: 2000-12-02, Wydruk dnia,2001-01-23
Wywiad: Uwagi:
Parametry globalne
Długość kręgosłupa DCK 346.6 [mm] czyli 29.1 % wzrostu
Kąty pochylenia [st] : ALFA 10.1, BETA 15.2, GAMMA 13.9, Łącznie: 39.2 [st]
Kąt pochylenia tułowia: KPT 6.3 [st]. Wskaźnik kompensacji 3.8 [st]
Kifoza piersiowa
D.LL_C7 DKP 309.9 [mm] (89.4%) Kąt KKP 150.9 [st]
D.PL_C7 RKP 195.7 [mm] (56.5%) Głębokość GKP 32.7 [mm] (WKP 0.167)
Lordoza lędźwiowa
D.S1_KP DLL 271.2 [mm] (78.2%) Kąt KLL 154.7 [st]
D.S1_PL RLL 150.9 [mm] (43.5%) Głębokość GLL -30.8 [mm] (WLL -0.204)
Płaszczyzna czołowa
Kat nachylenia tułowia KNT 1.4 [st]
Lewy bark wyżej o 8.2 [mm] Kąt linii barków KLB -1.7 [st]
L.łopatka wyżej o 6.1[mm] (-2.4st)(UL), bliżej o 20.6[mm] (-8.0st)(UB)
R. oddal. łopatek od kręgosłupa OL: 2.4 [mm] (1.7%)
Lewy tr.talii wyższy o -46.2 [mm] (TT) szerszy o -14.7 [mm] (TS)
Miednica: kąt nachylenia KNM 1.5 [st], kąt skręcenia KSM -6.4 [st]
Wsp.asym.barków względem KK WBS=-10.5 (-3.8%), wzg.C7 WBC= 6.3 (2.3%)
Wsp.asym.bark-miednica pion WBK= 10.2 (1.9%) poziom WBX= -10.5 (-5.3%)
Maks. odch. l.wyrost. kol. od C7_S1 UK 11.1 [mm] na wys.Th6

OPIS

Producent aparatury do Komputerowego Badania Postawy Ciała, stóp,...:
CQ Elektronik System, mgr inż. Artur Świero, ul.Na Niskich Łąkach 19/2, Wrocław, tel. 0601 794162

Figure 1. An example of a record sheet of measurements of the posture features of the spine-pelvis syndrome

MAGMAR Olsztyn

Mirosław Mrozkowiak

Phone number: 602 529 652

COMPUTERIZED EXAMINATION OF THE BODY POSTURE

Name:	Height: 119 cm,	Year of birth: 1993
Data: 1SP1MK\0CIOLL00,	Date of examination: 2000-12-02,	Printout: 2001-01-23
Medical intelligence:	Comments:	

Global parametres

Length of the spine: DCK 346.6 [mm] meaning 29.1% of height

Tilt angles [deg.]: ALFA 10.1, BETA 15.2, GAMMA 13.9 In total: 39,2 [deg.]

Torso tilt angle: KPT 6.3 [deg.] Compensation rate: 3.8 [deg.]

Thoracic kyphosis

D.LL_C7 DKP 309.9 [mm] (89.4%) KKP angle 150.9 [deg.]

D.PL_C7 RKP 195.7 [mm] (56.5%) GKP depth 32.7 [mm] (WKP 0.167)

Lumbar lordosis

D.S1_KP DLL 271.2 [mm] (78.2%) KLL angle 154.7 [deg.]

D.S1_PL RLL 150.9 [mm] (43.5%) GLL depth -30.8 [mm] (WLL -0.204)

Frontal plane

Torso tilt angle KNT 1.4 [deg.]

Left shoulder higher about 8.2 [mm] Angle of shoulder blades line KLB -1.7 [deg.]

Left shoulder blade higher about 6.1 [mm] (-2.4 deg.) (UL), closer about 20.6 [mm] (-8.0 deg.) (UB)

The difference of the distance of shoulder blades from the spine OL: 2.4 [mm] (1.7%)

Left waist triangle higher about -46.2 [mm] (TT), wider about -14.7 [mm] (TS)

The pelvis: tilt angle KNM 1.5 [deg.], turn angle KSM -6.4 [deg.]

Shoulder's asymmetry rate regarding KK WBS = -10.5 (-3.8%), regarding C7 WBC = 6.3 (2.3%)

Shoulder- pelvis asymmetry rate vertical WBK = 10.2 (1.9%) horizontal WBX = -10.5 (-5.3%)

Maximum deviation of 1. spinous process from C7_S1 UK 11.1 [mm] at Th6 level

DESCRIPTION

The manufacturer of the measuring device of Computerized Examination Of the Body Posture, feet,…:
CQ Electronic System, M.E. Artur Świerc, Na Niskich Lakach street, 19/2, Wroclaw, phone numer: 0601 794162

Figure 8: Example of a worksheet for measuring postural characteristics of the spine-pelvis complex.

Empirical data were quantitative and qualitative characteristics (gender, place of residence, etc.). Values of positional statistics (arithmetic mean, quartiles), dispersion parameter (standard deviation) and symmetry indices (asymmetry coefficient, clustering coefficient) were calculated, which gave a complete view of the distribution of the studied features considering age groups and gender. For the selected parameters, the significance of changes in average values in subsequent years within each sex was analyzed (Student's t-test was used). The conclusions can be drawn from the obtained results about the quality and dynamics of changes in the studied characteristics. In addition, within age groups, comparative analyses of average values between genders were performed (Student's t-test).

3. Results obtained

Angle of the trunk extension and flexion in the sagittal plane

Two influential parameters were selected for multiple regression analysis with selection of a subset of the optimal set of variables: trunk extension angle (KPT) and flexion (KPT-). The set of variable features included features of the spine-pelvis complex: 1 - 29, tab. 3. The regression shows that the effect was as follows: the Alpha angle - lumbar-pelvic angle has a significant positive effect on trunk flexion angle (KPT-), and negative trunk extension angle (KPT), on Beta angle - thoracolumbar angle the trunk extension angle (KPT) has a significant positive influence , and negative the trunk flexion angle (KPT-), on Gamma angle - upper thoracic angle the trunk flexion angle (KPT-) has a significant positive influence, and negative the trunk extension angle (KPT), on Delta angle - sum of angular values (Alpha+Beta+Gamma) the trunk flexion angle (KPT-) and the trunk extension angle (KPT) has a significant positive influence, on DCK - total spine length the trunk extension angle (KPT) has a significant positive influence, and negative the trunk flexion angle (KPT-), on DCK % - percentage of total spine length Wc the trunk extension angle (KPT) has a significant positive influence, and negative the trunk flexion angle (KPT-), on DKP - thoracic kyphosis length the trunk extension angle (KPT) has a significant positive influence, and negative the trunk flexion angle (KPT-), on DKP % - percentage of the length of thoracic kyphosis DCK the trunk extension angle (KNT) has a significant positive influence, and negative the trunk flexion angle (KPT-), on KKP - thoracic kyphosis angle the trunk extension angle (KPT) has a significant negative influence, on RKP - the height of thoracic kyphosis the trunk extension angle (KPT) has a significant positive influence, on RKP % - percentage of the length of thoracic kyphosis DCK the trunk extension angle (KPT) has a significant negative influence, on GKP - depth of thoracic kyphosis the trunk extension angle has a significant positive influence (KPT), and negative the trunk flexion angle (KPT-), on DLL - length of lumbar lordosis the trunk extension angle (KPT) has a significant positive influence and negative the trunk flexion angle (KPT-), on DLL % - percentage of the length of lumbar lordosis DCK the trunk extension angle has a significant positive influence (KPT), and negative the trunk flexion angle (KPT-), on KLL - lumbar lordosis angle the trunk flexion angle (KPT-) has a significant positive influence, and negative the trunk extension angle (KPT), on RLL- the height of lumbar lordosis the trunk extension angle (KPT) has a significant positive influence and negative the trunk flexion angle (KPT-), on RLL % - percentage of the height of lumbar lordosis DCK the trunk extension angle (KPT) has a significant positive influence, on GLL- it is the depth of lumbar lordosis, where the trunk extension angle has a significant positive influence (KPT), and negative influence is the trunk flexion angle (KPT-), tab. 4, 6.

Tab. 4. Multiple regression analysis with selection of a subset of optimal explanatory variables like city, age, gender, height and weight, flexion, and extension angle of the of the trunk and features 1 - 20. N = 16608

Name of parametres of variables in the model										R2%	I. r.
Variables		Influences									
no	Name	Xo	City	Age	Sex	W.C.	M.C.	KPT	KPT-		
1	Alfa	7,95		-0,01	-0,29	0,03		-0,11	0,53	52,87	***
2	Beta	6,94	0,19	-0,01		0,02		0,78	-0,6	49,37	***
3	Gamma	9,71		-0,01	0,13	0,02		-0,28	0,55	44,44	***
4	Delta	24,49	0,29	-0,03		0,08		0,39	0,48	13,15	***
5	DCK	211,95	-4,53	0,06		1,12	0,16	0,96	-0,84	27,36	***
6	DCK%	37,73	-0,41	-0,01		-0,07	0,01	0,1	-0,09	44,58	***
9	DKP	176,04	-4,41			0,91	0,21	2,95	-4,28	31,22	***
10	DKP%	82,51	-0,5	0,0	0,3		0,01	0,6	-1,05	3,14	***
11	KKP	165,29		0,02		-0,07	0,01	-0,56		24,84	***
12	RKP	120,63	-4,1			0,58	0,35	0,4		29,53	***
13	RKP%	55,89	-0,71				0,06	-0,1		19,33	***
14	GKP	8,99	-0,6	-0,0		0,08		2,12	-1,38	56,05	***
15	DLL	174,64	-2,64		-1,03	0,68		3,94	-3,9	25,46	***
16	DLL%	79,77		0,01		-0,04	-0,03	0,92	-0,98	38,17	***
17	KLL	164,42	-0,2	0,02		-0,06		-0,51	0,14	45,77	***
18	RLL	92,99		0,04	0,84	0,53	-0,15	0,82	-0,45	14,18	***
19	RLL%	44,11	0,8				-0,06	0,09		19,7	***
20	GLL -	1,71	0,35	-0,02		0,13	-0,02	1,95	-1,3	54,03	***

Source: own research

Tab. 5. Multiple regression analysis with selection of a subset of optimal explanatory variables like city, age, gender, height and weight, and angle of the of the trunk in the frontal plane to the left and right. N = 16608

Name of parametres of variables in the model										R2 %	I. r.
Variables		Influences									
No	Name	Xo	Miasto	Wiek	Płeć	W.C.	M.C.	KNM	KNM-		
1	Alfa	6,88	0,4	-0,01	-1,0	0,02	0,03	-0,12	0,14	2,34	***
2	Beta	14,76		-0,0		-0,01	-0,04	0,14		4,57	***
3	Gamma	6,4		-0,01	0,44	0,06				9,32	***
4	Delta	28,98	0,38	-0,03	-0,45	0,06			0,22	4,52	***
5	DCK	215,99	-5,05	0,06		1,15		0,91	1,04	25,48	***
6	DCK%	38,77	-0,45	-0,01		-0,07	0,0	0,07	0,07	42,64	***
9	DKP	208,82	-6,09		3,11	0,79		0,86		16,38	***
10	DKP%	89,87	-0,82	0,01	0,92	-0,03	-0,03		-0,15	2,25	***
11	KKP	159,3		0,02	-0,56	-0,05	0,04	-0,22		5,36	***
12	RKP	127,23	-4,84		1,75	0,6	0,3	0,59		19,2	***
13	RKP%	56,44	-0,8	0,0	0,51		0,06			3,24	***
14	GKP	29,92	-1,23		0,52	-0,03	-0,08	0,34		5,7	***
15	DLL	210,55	-3,78			0,45	-0,15	0,9		10,4	***
16	DLL%	87,88	-0,24	0,02		-0,11	-0,07			7,36	***
17	KLL	159,7	-0,44	0,02	0,92	-0,01			-0,23	1,49	***
18	RLL	99,29	0,88	-0,03	-1,74	0,45	-0,16	0,43	0,55	7,27	***
19	RLL%	43,52	0,89	-0,0	-0,51		-0,06			3,43	***
20	GLL -	23,69		-0,01	0,39		-0,1	0,33		3,62	***

Source: own research

Tab. 6. Multiple regression of parameters of the variable with selection of the optimal subset N = 16608

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
7																													
8																													
21																													
22																													

Source: own research

The legend:
Features listed vertically affect those ranked horizontally.
Red – significant positive influence
Yellow – significant negative influence
White – irrelevant influence

Torso flexion angle to the left and to the right in the frontal plane
Two influential parameters were selected for multiple regression analysis with selection of a subset of the optimal set of variables like trunk flexion angle to the right (KNT) and left (KNT-). The set of variable features included the parameters of the spine-pelvis complex: 1 - 29, tab. 3. From the regression, it is clear that the effect on the variable features was as follows: the Alpha angle - lumbosacral angle is significantly positively influenced by the right flexion angle (KNT), and negatively influenced by the torso flexion angle to the left (KNT-), on Beta angle - angle of inclination of the thoracolumbar segment the angle of flexion to the left (KNT-) has a significant positive effect, on Delta angle - sum of angular values (Alpha+Beta+Gamma) the angle of flexion to the right (KNT) has a significant positive effect, on DCK - total length of the spine the angle of flexion to the left (KNT-) and to the right (KNT) have a significant positive effect, on DCK % - percentage of the total length of the spine Wc the angle flexion to the left (KNT-) and to the right (KNT) have a significant positive effect, on DKP – the length of thoracic kyphosis left flexion angle (KNT-) has a significant positive influence, on DKP % - percentage of the length of thoracic kyphosis DCK the right flexion angle (KNT) has a significant negative influence, on KKP - angle of thoracic kyphosis the left flexion angle (KNT-) has a significant negative influence, on RKP – the height of thoracic kyphosis the left flexion angle (KNT-) has a significant positive influence, on GKP - depth of thoracic kyphosis the angle of flexion to the left (KNT-) has a significant positive influence, on DLL – the length of lumbar lordosis the angle of flexion to the left (KNT) has a significant positive influence, on KLL - angle of lumbar lordosis the angle of flexion to the right (KNT) has a significant negative influence, on RLL – the height of lumbar lordosis the left flexion angle (KNT-) and right flexion angle (KNT) have a significant positive influence, on GLL- - the depth of lumbar lordosis the left flexion angle (KNT-) has a significant positive influence, Tab. 5, 6.

4. Discussion

Due to editorial limitations and the very large number of the obtained test results, the author deliberately limited himself to the angles of trunk flexion and extension in the sagittal and frontal planes. The presented statistical analysis shows the mutual influence of the values of the selected features. The study showed no independent trait, however, the degree of influence varied. This shows that the different postural traits are interrelated and that changing one of them influences the change of another. It is important for the person responsible for choosing the proper exercise to be aware of the fact that by decreasing one of the angles they positively or negatively influence other postural features.

A study of posture carried out using the photogrammetric method in a group of 480 students in grades I-III of an elementary school showed that the parameters characterizing posture are parameters that influence each other, and that the most dependent feature of all is the angle of torso flexion, and the least dependent parameter is the length of thoracic kyphosis [10]. Wilczynski [11] presented, based on a study in a population of 153 girls, 18 cases of asymmetry at age of 14, 16 cases at age of 15 and 38 cases among 16-year-old girls. Conducting an analysis of the correlation coefficients between the features of body structure and posture and the time of simple reaction to a visual stimulus, he found a relationship in direct proportion to the angle of flexion and extension of the trunk in the sagittal plane in 14-year-old girls. Other studies [12, 13, 14] have shown that asymmetries occurring in the trunk have a significant impact on the distribution of body weight across the weight-bearing surfaces of the musculoskeletal system. Persistent load asymmetries can cause overload and deformation changes, which can consequently result in lower limbs and spinal pain. According to some publications [15, 16], the asymmetries that occur in the spine find their determinants in the pathomechanical changes that lead to formation and development of scoliosis. Each change in shape causes a chain of changes in structures and organs located near the spine, as well as away from it. The foundation of these changes can vary. These may be anatomical and pathological changes. Deviation of the axis of the spine causes displacement of individual body segments. This is accompanied by changes in the soft spinal elements, causing their contraction on the concavity side of the curvature, and stretching on the convex side.

The causes of errors and subsequent postural defects are multiple. These range from genetic conditions, static-dynamic imbalances, various diseases, and epigenetic factors. The literature on the influence of these factors is rich, however, it has not been studied how selected features of body posture affect others. The discussed dependencies have not only a scientific or cognitive value, but above all they carry practical guidelines for those conducting corrective and compensatory exercises [17]. One is puzzled by the lack of a significant effect of the values of the two angles of the trunk analyzed on the angle of pelvic tilt to the left and right in the frontal plane, as well as torsion to the left and right in the transversal plane. It should be thought that the values of the angles were too small for a statistical relationship to be found, since the qualification of individuals for the research program excluded obvious defects and postural errors.

5. Conclusions

1. The effect of the trunk flexion and extension angles in the sagittal plane as well as left and right flexion in the frontal plane on the spinal features is multidirectional and varied.
2. Spinal traits are significantly and positively influenced, in particular, by the value of the trunk extension angle in the sagittal plane and the value of the left flexion angle in the frontal plane, and negatively by the value of the flexion angle in the sagittal plane.
3. The value of the angles of the trunk extension and flexion in the sagittal plane and left and right flexion in the frontal plane particularly significantly and positively affect the total length of the spine and the percentage of its growth, the Delta angle, and the height of the lumbar lordosis. The angle of inclination of the lumbosacral section of the spine, the total length of the spine and its percentage of the body height as well as the height of the lumbar lordosis are the features most dependent on the angles describing the verticality of the axial organ. The significant negative effect on the value of the spine features is significantly smaller. The most negatively dependent features are angle of inclination of the lumbosacral spine, length and angle of thoracic kyphosis, and angle of lumbar lordosis.
4. None of the examined angles affect the characteristics of the pelvis

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