GENDER- AND AGE-RELATED FEATURES OF POSTURE DISORDERS IN THE SAGITTAL PLANE IN CHILDREN AND ADOLESCENTS INVESTIGATED BY COMPUTER OPTICAL TOPOGRAPHY*

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Objective. To study the features of sagittal posture formation and the structure of postural disorders in children and adolescents with due account for gender and age based on the computer optical topography (COMOT) data.
Material and Methods. Results of posture screening in children and adolescents using COMOT method were incorporated into the clinical database including more than 33,000 patients with an almost uniform distribution by age. The study was carried out in 13 age groups generated from this database and involved males and females aged 5–17 years.
Results. The age-related changes in the structure of sagittal postural disorders are significantly different between males and females and strictly correspond to changes in mean heights of the lumbar lordosis and thoracic kyphosis with age, and in the index of their balance. Postural features in children of the age of 5 have minimum gender differences with a prevalence of kyphosed postures, and later differences accrue with the age with a trend toward kyphosis in boys and lordosis in girls, achieving the maximum difference by the age of 17.
Conclusion. The study revealed objective quantitative features of the posture formation in children and adolescents, as well as demonstrated unique capabilities of optical topography for population studies of the posture status.
Key Words: computer optical topography, age and gender related posture features in the sagittal plane.

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Introduction

The introduction of optical topography methods in the early 1970s has revealed new possibilities for mass screening in order to objectively assess the body shape. Development of computerized methods of topography screening in the mid-1990s allowed one to obtain statistical data with quantitative assessment of the posture characteristics [1, 5–7]. The results of screening survey of age and gender related posture characteristics in children and adolescents using the computer optical topography (COMOT) technique, which was carried out in three pre-schools and two secondary schools in Novosibirsk in 2001, were published for the first time [4]. Total of twelve age groups were formed among patients aged 6–17 years (100 males and 100 females in each group). The data were analyzed by plotting the mean values and deviations of most topographical parameters for each age and gender groups. In the group of children aged 6 there was the minimal deviation between males and females for most topographic parameters. However, starting from the age of 7, females have a tendency towards the development of posture with increased lumbar lordosis and decreased thoracic kyphosis, while males tend to have increased thoracic kyphosis. The discovery of this fact that is well-known among the orthopedists proved the correctness of the topographical data. However, other features of the posture formation were not identified due to the small sample size.

Posture disorders and spine deformation in three dimensions, including the sagittal plane [2], were categorized according to the COMOT data [3] in 2011. This classification and accumulated statistical data allowed more accurate and detailed investigation of posture formation in the sagittal plane.

The objective of this study was to investigate the age and gender related features of posture development in the sagittal plane and the structure of posture disorders in children and adolescents using the COMOT data.

Material and Methods

In the present study, the Clinical Database of Screening Survey METOS (MEdical TOpographic Systems) (CDSSM) that has been developed specifically for scientific research, was used. The CDSSM included the clinical survey data obtained in children from Abakan, Novosibirsk, Omsk, Perm, Tolyatti and Tyumen cities using a second-generation

Optical Topograph for Spine Deformities (TODP) system (with a fixed optical system). The database included more than 33,000 patients (~5,500 per city) with almost equal distribution by age and gender (age ranging from 4.5 to 17.5). The total number of males and females was 16,640 and 16,947, with mean age of 11.11 ± 3.26 and 11.22 ± 3.26 years, respectively. During the compilation of the CDSSM every single image from the source bases was verified; some of them were excluded and the incorrectly processed ones were reprocessed. A total of 13 age groups (age ranging from 5 to 17) with each group including patients of the same age (integer ±6 months) were formed.

Postural state in the sagittal plane was analyzed and classified based on quantitative criteria that differentiate the severity of deviations from the harmonious state of posture into: normal (harmonic poster) minor deviations, mild deviations, and severe deviations. All possible relationships largest lumbar lordosis and thoracic kyphosis considered are considered [2]. Classification has 21 types of postures: Normal-harmonic posture (N); 8 types of posture with minor deviations from harmonic posture (Sudnormal): Subnormal with violation of the of the trunk Balance in sagittal plane (S-B), Subnormal with violation of the physiological curves Geometry (apex position or curves length ratio) (S-G), Subnormal with Decrease of Kyphosis and Lordosis (S-DKL), Subnormal with Increase of Kyphosis and Lordosis (S-IKL), Subnormal with Decrease of Kyphosis (S-DK), Subnormal with Increase of Lordosis (S-IK), Subnormal with Decrease of Lordosis (S-DL) Subnormal with Increase of Kyphosis (S-IK); 7 types of posture with mild deviations from harmonic posture (Postural Disorders): flat back, flattened lordosis and kyphosis (PD-FB), flat concave back, flattened kyphosis and increased lordosis (PD-FCB), concave back, increased lordosis and normal kyphosis (DP-CB), round concave back, balanced increase in lordosis and kyphosis (DP-RCB), round flat back, flattened lordosis and normal kyphosis (DP-RFB), hunched back, increased and extended kyphosis and flattened lordosis (DP-HuB), round back, increased kyphosis with normal lordosis (DP-RB); 5 types of posture with severe deviations from harmonic posture (Spinal Deformities): flat back syndrome, lack of physiological curvatures (SD-FBS), hyperkyphosis and hyperlordosis, balanced distinct increase of both lordosis and kyphosis (SD-HyKL), hyperlordosis, distinct increase in lordosis (SD-HyL), hyperkyphosis of 1st degree, distinct increase in kyphosis (SD-HyK1), hyperkyphosis of 2nd degree, a significant increase of kyphosis (SD-HyK2). TODP built-in software (WTOPO 3.911) along with the Microsoft Excel program was used to process the statistical data and form the age groups with allowance for the gender and posture disorders. Student's t-test was used to determine significant differences between the mean values of topographic parameters.

Results and Discussion

Tables 1 and 2 show the data obtained for age-related the structure of postural disorders and spinal deformities for males and females, respectively. The third row in both tables represents the total number of patients in each age group. In the first part of tables, the prevalence of each posture disorder is shown; the second part includes the distribution of postures into groups by lordosis and kyphosis balance: BKL group, balanced kyphosis and lordosis, that includes N, S-B, S-G, S-DKL, S-IKL, PD-FB, PD-RCB, SD-FBS, SD-HyKL; PK group, predominance of kyphosis, that includes S-DL, S-IK, PD-RFB, PD-HuB, DP-RB, SD-HyK1, SD-HyK2; PL group, predominance of lordosis, that includes S-DK, S-IL, DP-FCB, DP-CB, SD-HL [2]. In the last part of tables, posture disorders are combined in four groups by the deformity severity: Normal- harmonic posture (N), Sudnormal posture with minor deviations from harmonic posture (S), posture with mild deviations from harmonic posture (PD), and posture with severe deviations from harmonic posture (SD).

Fig. 1 shows the dynamics of the age structure of posture disorders in the sagittal plane plotted according to the data in Tables 1, 2. The prevalence of all 21 types of posture disorders was shown for each age group. The first columns for each set correspond to the prevalence in the group of 5-year-old patients (the sum across all types of posture is 100 %). The graph indicates that there is a significant difference in posture disorders related to the gender and age.

Fig. 2 shows the comparison of the oldest and youngest groups for both genders. Compared to the other age groups, at the age of 5 both males and females will have similar pattern of the structure of disorders, while at the age of 17, patterns differ most significantly. For the group of 5-year-old, three most common disorders were as follows: round-flat back (DP-RFB, 27.1 % males and 20.08 % females), Sudnormal posture with Decrease of Lordosis (S-DL, 15.46 % males and 15.01 % females), Sudnormal posture with Increase of kyphosis (SP-IK, 8.4 % males and 10.72 % females), notably, all of these disorders were of kyphotic nature. In the group of 17-year-olds, males have the same kyphotic nature of posture disorders and the top four of them are round-flat back (DP-RFB, 17.5 %), round back (DP-RB, 14.03 %), Sudnormal posture with Decrease of Lordosis (S-DL, 11.33 %) and Sudnormal posture with Increase of Kyphosis e (S-IK, 11.07 %). In the same age group, females exhibited lordosis posture defects with the top four of them being flat-concave back (DP-FCB, 20.27 %), Sudnormal posture with Decrease of p Kyphosis (S-DK, 8.82 %), concave back (DP-CB, 8.72 %), and Sudnormal posture with Increase of Lordosis (S-IL, 7.46 %). The flat back syndrome (SD-SBS) was the most frequent disorder among the distinct disorders in the age group of 5-year-olds for both genders (0.76 % males and 1.75 % females); in the group of 17-year-olds, the 1st degree hyperkyphosis (SD-HyK1, 7.46 %) and hyperlordosis (SD-HyL, 3.26 %) prevailed for males and females, respectively.

Fig. 3 shows the graphs of the age-related dynamics of posture disorders based on the balance of kyphosis and lordosis that were plotted using second part of Tables 1, 2. Graphs demonstrate both a

significant difference in the average prevalence of these variants within groups and their gender-related age dynamics. Males typically had posture with predominance of kyphosis (55.55 %), and then the posture with balanced kyphosis and lordosis (29.67 %), while the least frequent one was posture with predominance of lordosis (17.79 %). Meanwhile, females demonstrated a reversed pattern: the most frequent one was posture with predominance of lordosis (36.79 %), then, the posture with balanced kyphosis and lordosis (35.13 %) and the least prevalent one was posture with predominance of kyphosis (28.08 %). However, in the group of females aged 5, the distribution of posture types for females differed significantly from the average distribution and was similar to the distribution for males.

The age-related dynamics of posture deviations for males was less complicated than that for females: the prevalence of balanced and lordosed postures was gradually increasing up to the median age interval and then gradually decreased to the level being lower than it used to be in the beginning. The prevalence of kyphosed posture was found to have a completely opposite tendency: it was gradually decreasing till the median age interval and then gradually increased to the level higher than it used to be in the beginning. No distinct correlation between the balanced posture for females and age was revealed; however the kyphosed and lordosed postures had opposite trends: the prevalence of kyphosed posture was gradually decreasing and that of lordosed posture was growing up to age of 11. After that, the kyphosed and lordosed postures had inversed trends of the occurrence rate up to the age of 14. The inversion trend changed back again afterwards. The dynamics of prevalence of the posture disorder types (Fig. 3) was found to be

Table 1

Age-related dynamics of the structure of posture disorders in the sagittal plane for male patients

Parameters	Age, years													
	5	6	7	8	9	10	11	12	13	14	15	16	17	5–17
Total number, n	536	972	1110	1623	1536	1591	1540	1542	1592	1492	1301	1028	777	16640
1. Distribution of posture disorder by types, %														
N	6.11	8.33	7.57	8.07	8.46	8.05	7.47	7.46	7.1	7.84	4.69	3.4	4.38	6.84
S-B	7.63	7.3	7.39	6.35	7.36	8.3	7.92	6.55	8.61	6.64	5.92	5.06	4.5	6.89
S-G	1.53	1.95	1.53	2.34	2.54	2.77	2.4	2.72	2.7	2.14	2.38	2.63	2.45	2.31
S-DKL	2.48	3.81	4.86	3.02	3.06	3.02	2.79	3.24	2.95	2.75	2.61	2.63	3.22	3.11
S-IKL	1.34	1.65	3.69	4.31	4.23	4.53	5.78	6.61	5.03	4.42	5	3.89	2.7	4.09
S-DK	2.29	3.6	4.23	4.93	4.69	4.34	4.09	3.76	3.83	2.61	2.69	2.04	1.67	3.44
S-IL	2.67	2.06	3.51	3.94	4.43	3.71	3.51	3.63	3.39	3.35	2.23	1.46	0.64	2.96
S-DL	15.46	12.55	13.51	11.95	14.06	11.75	12.08	12.78	12.37	11.26	11.68	10.6	11.33	12.41
S-IK	8.4	10.08	10.36	9.43	10.55	13.51	12.53	12.78	11.68	13.81	13.22	13.13	11.07	11.58
PD-FB	6.68	5.45	5.41	4.68	4.1	3.02	3.05	2.33	2.58	3.49	3.84	3.31	3.47	3.95
PD-FCB	4.58	6.58	6.4	6.65	6.05	6.03	7.01	5.38	5.4	4.09	3.23	3.6	2.32	5.18
PD-CB	2.29	1.95	2.97	3.33	3.45	3.33	3.18	2.46	2.14	2.41	1.61	2.33	0.77	2.48
PD-RCB	0.19	0.31	1.17	1.17	2.02	1.19	2.14	3.7	2.58	2.48	2.23	2.24	1.67	1.78
PD-RFB	27.1	22.53	14.14	15.47	10.22	10.37	10.45	9.53	10.8	10.52	14.37	16.34	17.5	14.57
PD-HuB	7.06	5.66	5.14	5.36	4.95	4.53	4.35	4.47	4.33	4.89	6.15	7.68	7.85	5.57
PD-RB	2.29	3.19	4.68	5.73	6.45	7.67	8.38	8.43	10.18	12.6	11.84	11.58	14.03	8.23
SD-FBS	0.76	0.93	0.99	1.05	0.72	0.57	0.32	0.39	0.44	0.54	0.23	0.58	0.51	0.62
SD-HyKL	0	0	0.09	0	0.07	0.06	0	0.26	0.06	0.2	0.15	0	0.13	0.08
SD-HyL	0.57	0.41	1.44	1.05	0.98	1.51	1.04	0.97	0.44	0.27	0.15	0.1	0.39	0.72
SD-HyK1	0.57	1.65	0.9	1.05	1.43	1.7	1.36	2.46	3.2	3.22	5.23	6.03	7.46	2.79
SD-HyK2	0	0	0	0.12	0.2	0.06	0.13	0.06	0.19	0.47	0.54	1.36	1.93	0.39
Lordosis and kyphosis balance, %														
BKL	26.72	29.73	32.7	30.99	32.55	31.49	31.88	33.27	32.04	30.5	27.06	23.74	23.04	29.67
PK	60.88	55.66	48.74	49.11	47.85	49.59	49.29	50.52	52.76	56.77	63.03	66.73	71.17	55.55
PL	12.4	14.61	18.56	19.9	19.6	18.92	18.83	16.21	15.2	12.73	9.92	9.53	5.79	14.79
Severity of posture disorders, %														
N	6.11	8.33	7.57	8.07	8.46	8.05	7.47	7.46	7.1	7.84	4.69	3.4	4.38	6.84
S	41.79	43	49.1	46.27	50.91	51.92	51.1	52.08	50.57	46.98	45.73	41.44	37.58	46.81
PD	50.19	45.68	39.91	42.39	37.24	36.14	38.57	36.32	38	40.48	43.27	47.08	47.62	41.76
SD	1.9	3	3.4	3.3	3.4	3.9	2.9	4.2	4.3	4.7	6.3	8.1	10.4	4.59

similar in all six cities according to the CDSSM database, thus attesting to the fact that there was a common trend in the posture formation process. Kyphosed posture for males (DP-RFB, DP-HyB) and females (DP-RFB, S-DL, S-IK, DP-HyB), and lordosed posture for males (S-DK, S-IL, DP-FCB, DP-CB) and females (DP-FCB, DP-CB, S-IL) were found to represent the age- and gender-related dynamics of posture disorders.

Fig. 4 shows age-related dynamics of the severity of disorders plotted using the last part of Tables 1, 2. These graphs indicate that males were characterized by an increased deformity occurrence rate: N was decreasing from 6.11 to 4.38 %; S prevalence was increasing from 41.79 to 52.08 % (group of 12-year-old), then decreasing to 37.58 %; DP was characterized by a decrease from 50.19 to 36.14 % (group of 10-year-olds), then increasing back to 47.62 %; for SD there was a slow increase from 1.9 % with a slowdown up to age 11, and then increase with acceleration up to 10.4 % at the age of 14. The S graph for females somewhat resembles the distribution of the kyphosed posture (Fig. 3b), while the graphs for DP and SD resemble the dynamics of the lordosed posture but with smaller amplitudes. This trend could be explained by the fact that S postures were mostly represented by kyphosed postures, while DP and SD were represented by lordosed postures. To explain the trend discovered for age-related posture disorder, the mean values and deviations of the following parameters were calculated: HIL – normalized integral height of the lordotic curve; HIK – normalized integral height of the kyphotic curve; IHI – index of balance of HIL and HIK; SA1 – anterior pelvis (sacrum) inclination angle; SA3 – anterior upper thoracic spine inclination angle at the C7 level; ST – anterior or posterior body inclination angle; SN – anterior or posterior body inclina-

Table 2

Age-related dynamics of the structure of posture disorders in the sagittal plane for female patients

Parameters	Age, years													
	5	6	7	8	9	10	11	12	13	14	15	16	17	5–17
Total number, n	538	1043	1048	1627	1590	1575	1510	1511	1528	1456	1388	1183	952	16947
1. Distribution of posture disorder by types, %														
N	7.99	8.63	6.20	7.38	8.24	9.21	6.23	7.68	8.64	7.97	6.56	6.59	6.09	7.49
S-B	7.41	10.07	7.06	7.07	6.35	6.73	7.09	5.89	7.26	7.97	7.64	5.41	5.04	7.00
S-G	3.12	2.88	2.77	2.77	2.52	2.92	3.38	2.25	2.81	4.46	4.18	4.73	4.52	3.33
S-DKL	3.90	3.84	5.53	5.22	4.21	4.83	4.50	4.10	3.80	3.43	4.76	4.40	3.78	4.33
S-IKL	2.73	2.59	2.77	4.86	4.97	4.63	4.90	4.96	5.30	4.53	6.34	5.83	4.94	4.57
S-DK	4.87	7.00	5.53	6.95	6.98	6.35	8.01	7.74	6.87	5.36	6.70	7.02	8.82	6.79
S-IL	2.73	4.12	5.44	5.41	5.91	6.03	5.76	5.43	5.10	5.77	6.27	6.51	7.46	5.53
S-DL	15.01	8.72	8.97	7.62	7.74	7.43	7.81	6.68	7.33	8.65	5.98	7.19	4.41	7.97
S-IK	10.72	8.82	8.59	5.90	5.97	6.16	5.36	7.28	7.13	8.72	6.70	7.10	5.57	7.23
PD-FB	2.92	4.89	5.92	7.01	5.22	5.27	4.44	5.23	5.50	3.71	3.67	2.70	3.05	4.58
PD-FCB	5.07	11.51	16.03	16.96	18.55	19.75	22.45	22.17	16.49	15.04	15.56	16.57	20.27	16.65
PD-CB	2.73	3.84	4.68	5.29	5.66	5.59	6.09	5.63	4.32	5.56	6.84	8.11	8.72	5.62
PD-RCB	0.19	1.63	0.95	1.91	1.51	2.16	1.92	2.05	4.32	3.30	3.89	4.40	3.68	2.45
PD-RFB	20.08	12.66	8.78	6.82	7.04	5.14	4.24	5.36	4.78	5.49	4.25	3.80	3.05	7.04
PD-HuB	4.87	2.59	2.86	1.54	1.64	0.89	0.99	0.93	1.70	1.30	1.44	1.01	1.47	1.79
PD-RB	2.92	2.11	3.05	2.77	3.21	2.60	3.44	2.91	3.99	4.05	3.82	3.47	3.57	3.22
SD-FBS	1.75	1.73	1.43	1.29	1.76	1.14	0.73	1.59	1.05	1.37	0.79	0.85	0.84	1.26
SD-HyKL	0.00	0.10	0.00	0.00	0.00	0.00	0.07	0.20	0.13	0.07	0.43	0.17	0.42	0.12
SD-HyL	0.39	1.92	2.67	2.21	2.08	2.67	1.72	1.46	2.42	2.20	2.88	2.79	3.26	2.20
SD-HyK1	0.39	0.38	0.76	0.98	0.44	0.44	0.73	0.46	1.05	0.82	1.15	1.18	0.84	0.74
SD-HyK2	0.19	0.00	0.00	0.06	0.00	0.06	0.13	0.00	0.00	0.21	0.14	0.17	0.21	0.09
Lordosis and kyphosis balance, %														
BKL	30.02	36.34	32.63	37.49	34.78	36.89	33.25	33.95	38.81	36.81	38.26	35.08	32.35	35.13
PK	54.19	35.28	33.02	25.69	26.04	22.73	22.72	23.63	25.98	29.26	23.49	23.92	19.12	28.08
PL	15.79	28.38	34.35	36.82	39.18	40.38	44.04	42.42	35.21	33.93	38.26	41.00	48.53	36.79
Severity of posture disorders, %														
N	7.99	8.63	6.20	7.38	8.24	9.21	6.23	7.68	8.64	7.97	6.56	6.59	6.09	7.49
S	50.49	48.03	46.66	45.79	44.65	45.08	46.82	44.34	45.62	48.90	48.56	48.18	44.54	46.74
PD	38.79	39.21	42.27	42.29	42.83	41.40	43.58	44.28	41.10	38.46	39.48	40.07	43.80	41.35
SD	2.70	4.10	4.90	4.50	4.30	4.30	3.40	3.70	4.60	4.70	5.40	5.20	5.60	4.41

tion angle at the C7 level relative to the apex of lumbar lordosis (tilt angle of the "C7 – lordosis apex" segment); SK – anterior or posterior inclination angle of the highest apex of the kyphosis relative to sacrum (inclination angle of the "kyphosis apex – apical point of gluteal cleft" segment); DAL – deviation of the lordotic apex from normal level ("-" – caudal, "+" – cranial); DAK – deviation of the kyphotic apex from the normal level ("-" – caudal, "+" – cranial); IDLK – ratio of thoracic kyphosis length to lumbar lordosis index ("-" – extended lordosis, "+" – extended kyphosis); PTI-S – integral index of the body dorsal surface deformity in the sagittal plane; PTI-OS – integral index of body orientation in the sagittal plane; PTI-DS – integral index of body deformities in the sagittal plane [2]. For parameters that have no average value close to the zero point (e.g., V-HIK), variability was calculated using the variation coefficient; the mean square deviation

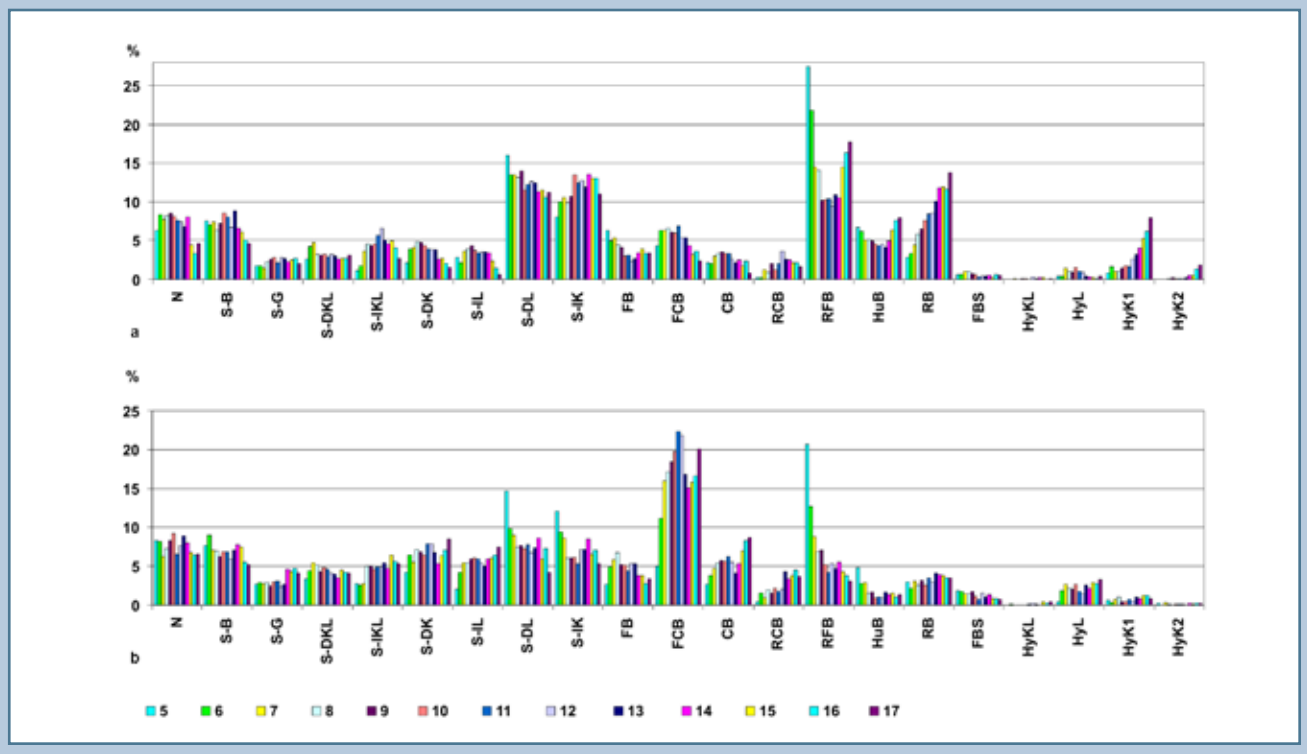

Fig. 1
The dynamics of posture disorders in the sagittal plane as function of age for patients aged 5 to 17: **a** – males; **b** – females

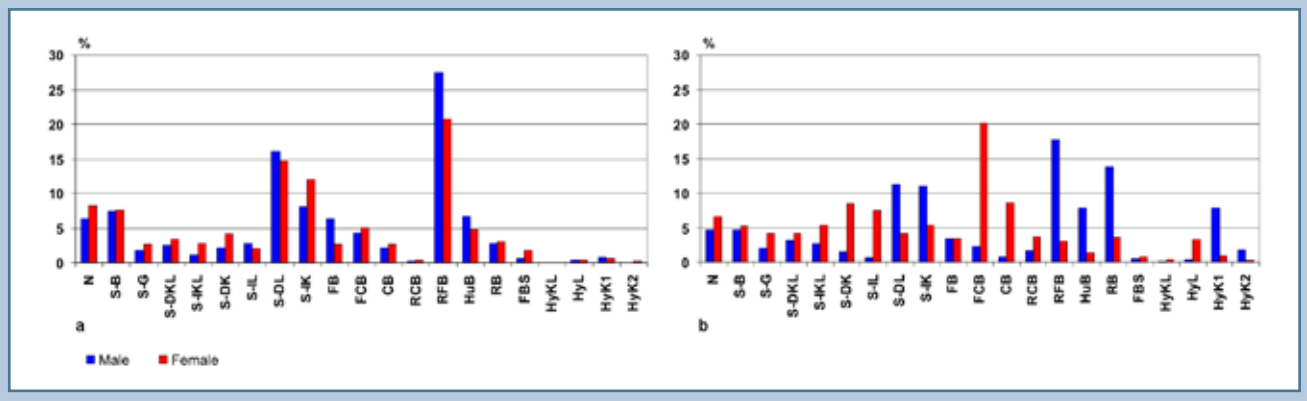

Fig. 2
The structure of posture disorders in the sagittal plane as function of age for both males and females: **a)** at the age of 5; **b)** at the age of 17

values were used to calculate the other parameters (e.g. S-IHI).

The data are shown in Tables 3, 4. These data were used to plot graphs of mean values (Fig. 5), variation coefficients, and mean square deviations (Fig. 6).

The variations in PTI indices were not analyzed as the law for their distribution differed significantly from the normal one. Statistical analysis of the data was performed for all other parameters comparing males and females; the following results were revealed. For groups of 5-year-olds, there were no differences in parameters HIK, SA3, ST, and IDLK (for SA3, there were differences in the group of 6-year-olds neither). The difference for other parameters was significant, with the p value of ⩾0.1 (SN, SK). For the remaining age groups, all analyzed parameters showed statistical significance of p ⩾ 0.02 (excluding ST, DAL, DAK, IDLR parameters, since after the age of 12 they were not significantly different). By the age of 17 (as compared to the group of 5-year-olds), the difference between males and females increased considerably for the following parameters: HIK, HIL, IHI, SA1, SN, and SK. This fact clearly indicates that there is a general trend in males and females to develop kyphosed and lordosed postures, respectively.

The age dependence of the angle of physiological curves for males (Fig. 5) was found to be less complicated than that for females. The deviation of the kyphosis height HIK from the value for harmonic posture was linearly increasing with age, approaching the threshold values for the normal posture in terms of kyphosis aggravation. Meanwhile, lordosis height HIL was slowly increasing from the threshold values of the normal posture for flattened lordosis in the beginning, with slowdown at the age of 8, reaching values of the harmonic posture at the age of 12, and then gradually decreasing with some acceleration after the age of 14 to the values below

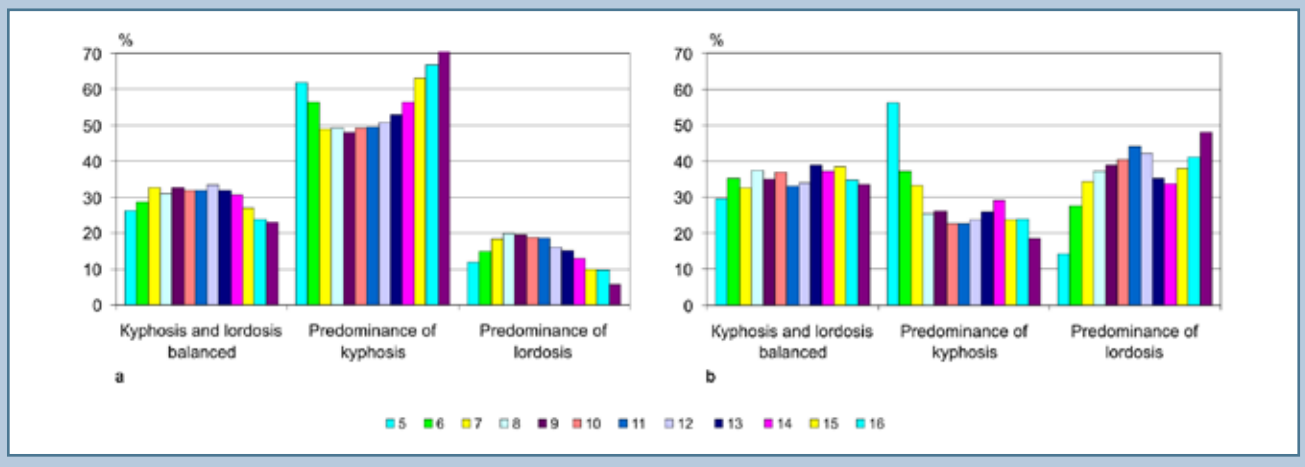

Fig. 3
Kyphosis and lordosis or balanced posture characters occurrence rate for patients aged 5 to 17: **a** – males; **b** – females

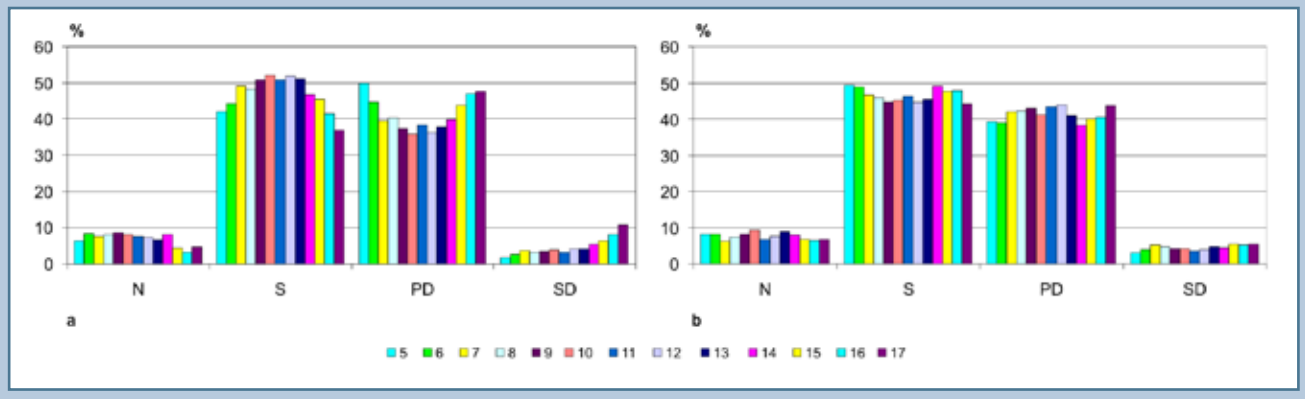

Fig. 4
Severity of posture disorder in the sagittal plane as function of age for patients aged 5 to 17: **a** – males; **b** – females

the normal level for flattened lordosis at the age of 17. The kyphosis height HIK for females was rapidly decreasing in the beginning (till the age of 6–7), then decreasing at a slower rate (till the age of 12), after that it was starting to increase (till the age of 14), and then decreased again (the HIK value stayed in the normal range all the time). The lordosis height HIL for females was increasing from values below the normal level slowly (till the age of 6–7), then faster (till the age of 11), and then slower again reaching the value level for harmonic posture at the age of 14 (and slightly exceeding it). Next, the value rapidly and linearly increased up to the age of 17, reaching the above normal values for lordosis aggravation.

These unusual graphs for HIK and HIL for females can be possibly explained by a plain psychological reason. When mammary glands are formed (at the age of 12), females tend to slouch, which slightly increases kyphosis. This period ends after the age of 14, and females straighten their shoulders and push chest forward, reducing kyphosis and increasing lordosis, thus forming the flat-concave back that is typical of women.

The variation coefficient (Fig. 6) for the kyphosis height, V-HIK, for males was practically constant and stayed at the level of 22 %. Females were characterized by higher values and had a gradual increase from 21 % at the age of 5 to 27 % at the age of 12, followed by a slight decrease to 26 %. The variation coefficient for the lordosis height, V-HIL, was found to be the same for both genders until the age of 14. It gradually decreased subsequently from 33 to 29 % and from 30 to 23 % at the age of 17 for males and females, respectively. The trend of the S-IHI graph (index of physiological curve balance) for both genders was similar and slightly decreased from 1.2 to 1.05. The graph for S-DAK (kyphotic apex offset) showed a significantly higher growth rate with age for females as compared to that for males. The graph S-IDKL (index

Table 3

Data on the age-dependent posture status in the sagittal plane for males

Parameters	Age, years													
	5	6	7	8	9	10	11	12	13	14	15	16	17	5-17
Total number, n	536	972	1110	1623	1536	1591	1540	1542	1592	1492	1301	1028	777	16640
1. Average values of topographic parameters														
HIK, cm	2.50	2.48	2.50	2.52	2.56	2.59	2.61	2.67	2.67	2.72	2.77	2.82	2.85	2.63
HIL, cm	1.56	1.65	1.79	1.79	1.87	1.89	1.90	1.91	1.87	1.85	1.78	1.74	1.69	1.79
IHI	1.51	1.30	1.08	1.13	1.03	1.04	1.04	1.11	1.16	1.26	1.45	1.57	1.69	1.26
SA1, deg.	-13.21	-14.02	-15.61	-15.81	-16.97	-17.53	-17.69	-18.12	-18.07	-17.69	-16.83	-16.08	-15.56	-16.40
SA3, deg.	-26.69	-26.13	-26.43	-26.95	-27.88	-28.71	-29.28	-30.29	-30.66	-31.07	-31.48	-32.02	-32.48	-26.69
ST, deg.	0.70	0.81	0.69	0.44	0.18	-0.26	-0.42	-0.76	-1.26	-1.23	-1.16	-0.81	-0.86	-0.30
SN, deg.	-0.63	-0.31	-0.17	-0.37	-0.68	-1.07	-1.23	-1.64	-2.20	-2.31	-2.49	-2.29	-2.52	-0.63
SK, deg.	2.02	1.94	1.55	1.35	0.97	0.54	0.39	0.11	-0.32	-0.14	0.17	0.66	0.79	0.77
DAL, deg.	-1.78	-1.54	-1.19	-0.96	-0.71	-0.39	-0.23	0.11	0.60	0.88	0.80	0.33	0.27	-0.29
DAK, deg.	-0.56	-0.49	-0.22	-0.30	-0.26	-0.20	0.00	-0.11	0.05	0.03	0.05	0.01	-0.09	-0.16
IDLK, deg.	1.29	0.82	0.56	0.34	0.26	0.05	-0.24	-0.16	-0.53	-0.53	-0.42	0.03	0.28	0.13
PTI-S	1.10	1.04	1.00	0.97	0.95	0.94	0.95	0.94	0.96	0.96	1.01	1.05	1.08	1.00
PTI-OS	1.39	1.27	1.21	1.15	1.11	1.10	1.10	1.11	1.14	1.12	1.15	1.15	1.17	1.17
PTI-DS	0.99	0.95	0.93	0.91	0.88	0.89	0.89	0.88	0.88	0.89	0.95	1.01	1.03	0.93
2. Variation coefficient (V) and the root-mean-square deviation of topographic parameters														
V-HIK, %	19.81	22.21	22.06	21.66	21.63	21.66	21.22	21.46	21.52	21.99	22.31	22.60	23.45	21.81
V-HIL, %	33.42	29.75	29.23	28.40	26.46	25.94	25.18	25.36	25.11	25.42	27.20	28.45	28.81	27.59
S-IHI	1.21	1.20	1.16	1.17	1.09	1.10	1.07	1.02	1.03	1.03	1.04	1.08	1.05	1.10
V-SA1, %	43.69	38.82	35.68	34.74	30.75	30.40	28.66	27.52	27.39	28.15	30.08	32.28	32.96	32.39
V-SA3, %	23.51	25.25	24.40	23.41	22.26	22.24	21.12	20.62	20.94	22.12	21.43	22.55	22.07	22.46
S-ST, deg.	3.30	3.01	2.99	2.74	2.74	2.67	2.71	2.68	2.55	2.48	2.48	2.44	2.46	2.71
S-SN, deg.	3.70	3.33	3.42	3.15	3.11	3.02	3.06	3.03	2.83	2.79	2.69	2.82	2.68	3.05
S-SK, deg.	3.50	3.32	3.24	3.10	3.07	3.07	3.05	3.00	2.98	2.92	3.00	2.88	2.99	3.09
S-DAL, deg.	3.09	3.17	3.10	3.15	3.07	3.18	3.21	3.13	3.17	3.33	3.57	3.85	3.90	3.30
S-DAK, deg.	2.55	2.61	2.65	2.65	2.72	2.81	2.88	2.87	2.92	2.91	3.03	3.25	3.29	2.86
S-IDLK, deg.	4.28	4.55	4.51	4.51	4.43	4.46	4.46	4.21	4.18	4.42	4.51	5.00	4.92	4.49
V-PTI-S, %	35.11	35.21	34.41	34.73	33.76	34.53	32.58	31.96	31.68	34.41	32.10	31.01	32.68	33.40
V-PTI-OS, %	53.23	55.67	55.43	54.88	52.71	52.58	52.49	51.20	50.97	52.88	48.54	46.00	47.70	51.87
V-PTI-DS, %	37.59	38.69	38.65	37.70	38.65	38.39	36.68	35.90	35.56	39.88	37.40	36.92	38.45	37.73

of the kyphosis to lordosis length ratio) shows a significantly higher variable rate for females than for males at the ages of 6–14. Other graphs show similar trends with the tendency for a decrease in VSA1, VSA3, S-ST, S-SN, S-SK, VPT-IS, VPT-IOS and for increase in S-DAL; meanwhile, 17-year-old males demonstrate a higher variation rate of the shift in the lordotic apex (and for the lordosis height V-HIL as well).

Thus, we can speculate that females, as compared to males, demonstrate a greater variability in height and position of the kyphotic apex, in the location of "kyphosis-lordosis" border (S-IDLK) and close variability in lordosis length and index of physiological curves balance (S-INI). 17-year-old males demonstrate a higher variability in the height and position of the lordotic apex. Parameters for body position and orientation in the sagittal plane for both genders have a similar variability in size (being higher at young and lower at older age); the same result was also suggested by a decrease in the integral index variation coefficient for body orientation V-PTI-OS with age.

Going back to the age dependence of posture disorders that is shown in Figs. 3 and 4, one should pay attention to the shape of the graphs for HIK, HIL and especially IHI (Fig. 5), which were calculated as the difference between the kyphosis and lordosis heights divided by their half-sum [2]. It can be found by comparing graphs for the kyphosed posture for males (Fig. 3a) and females (Fig. 3b) and the graph for IHI (Fig. 5) that they have completely similar trends. This shows that the trends of age-related posture disorders for males and females arises from the dependence of HIK, HIL and IHI parameters on age. There is nothing strange in this fact, since these three parameters are the main criteria for classifying posture disorders by types [2].

Table 5 provides quantitative assessment of the similarity of diagrams in Figs. 3 and 4 and the graphs for HIK, HIL

Table 4

Data on the age-dependent posture status in the sagittal plane for females

Parameters	Age, years													
	5	6	7	8	9	10	11	12	13	14	15	16	17	5-17
Total number, n	538	1043	1048	1627	1590	1575	1510	1511	1528	1456	1388	1183	952	16947
1. Average values of topographic parameters														
HIK, cm	2.47	2.34	2.30	2.27	2.26	2.25	2.24	2.23	2.35	2.37	2.39	2.37	2.32	2.32
HIL, cm	1.69	1.88	1.94	1.98	1.99	2.03	2.05	2.03	2.04	2.03	2.10	2.13	2.18	2.01
IHI	1.22	0.72	0.56	0.44	0.40	0.32	0.27	0.28	0.44	0.50	0.40	0.35	0.19	0.47
SA1, deg.	-15.07	-17.11	-17.77	-18.64	-19.07	-19.93	-20.35	-20.57	-20.63	-20.44	-21.28	-21.54	-22.21	-19.59
SA3, deg.	-27.40	-25.83	-25.37	-25.65	-26.02	-26.38	-26.61	-26.97	-28.29	-28.88	-29.61	-30.04	-29.73	-27.45
ST, deg.	0.69	0.76	0.63	0.29	0.01	-0.45	-0.76	-1.10	-0.92	-0.77	-0.59	-0.50	-0.54	-0.25
SN, deg.	-0.27	0.42	0.50	0.31	0.07	-0.26	-0.52	-0.85	-0.87	-0.77	-0.42	-0.21	-0.02	-0.22
SK, deg.	1.64	1.10	0.77	0.28	-0.06	-0.64	-1.01	-1.34	-0.98	-0.77	-0.75	-0.79	-1.05	-0.28
DAL, deg.	-1.33	-0.63	-0.19	-0.14	0.01	0.39	0.62	0.97	0.65	0.60	0.69	1.06	1.13	0.29
DAK, deg.	-0.18	0.11	0.35	0.38	0.32	0.45	0.34	0.24	-0.21	-0.32	-0.11	0.33	0.37	-0.18
IDLK, deg.	1.14	0.13	-0.54	-0.60	-0.45	-0.74	-0.74	-0.75	0.05	0.42	0.36	0.07	-0.10	-0.13
PTI-S	1.02	0.99	1.00	0.99	0.97	0.96	0.98	0.99	0.99	0.98	0.99	1.02	1.05	0.99
PTI-OS	1.22	1.19	1.16	1.11	1.06	1.07	1.08	1.11	1.11	1.09	1.07	1.09	1.12	1.11
PTI-DS	0.93	0.92	0.94	0.95	0.95	0.93	0.94	0.95	0.94	0.93	0.95	0.97	1.01	0.95
2. Variation coefficient (V) and root-mean-square deviation of topographic parameters														
V-HIK, %	20.95	23.04	24.46	25.65	25.88	25.40	26.68	27.38	26.38	24.98	25.61	25.29	26.18	25.22
V-HIL, %	29.84	28.03	27.64	26.32	25.82	24.95	22.98	23.62	24.40	25.06	24.03	23.62	23.19	25.35
S-IHI	1.17	1.15	1.18	1.12	1.15	1.07	1.08	1.10	1.06	1.07	1.04	1.04	1.05	1.10
V-SA1, %	36.73	31.76	32.29	28.99	27.59	26.21	24.26	24.86	24.83	25.72	25.29	25.70	25.80	27.36
V-SA3, %	22.25	23.43	24.11	24.32	25.06	23.07	24.10	24.91	23.13	23.20	22.83	21.26	21.97	23.31
S-ST, deg.	3.00	3.07	2.98	2.80	2.62	2.62	2.54	2.47	2.56	2.52	2.42	2.45	2.41	2.65
S-SN, deg.	3.32	3.42	3.31	3.07	3.00	2.92	2.82	2.75	2.83	2.97	2.85	2.83	2.75	2.99
S-SK, deg.	3.30	3.36	3.43	3.27	3.04	3.05	3.07	2.98	3.07	2.89	2.79	2.91	2.92	3.08
S-DAL, deg.	2.89	3.10	3.19	3.16	3.30	3.27	3.35	3.40	3.51	3.54	3.35	3.48	3.50	3.31
S-DAK, deg.	2.74	2.90	3.04	3.24	3.32	3.43	3.67	3.81	4.07	4.07	4.24	4.43	4.68	3.66
S-IDLK, deg.	4.25	4.88	4.82	4.86	4.93	4.79	4.92	4.93	5.09	4.98	4.94	4.94	5.08	4.88
V-PTI-S, %	35.26	35.66	35.36	33.52	35.15	35.60	35.19	35.30	35.94	35.05	33.53	34.63	34.16	34.95
V-PTI-OS, %	56.77	59.18	60.76	55.44	54.77	54.15	51.75	51.26	51.78	52.39	51.10	51.07	51.34	53.98
V-PTI-DS, %	39.39	40.94	38.74	38.42	40.41	41.53	41.65	41.89	43.47	42.11	40.14	41.02	40.19	40.76

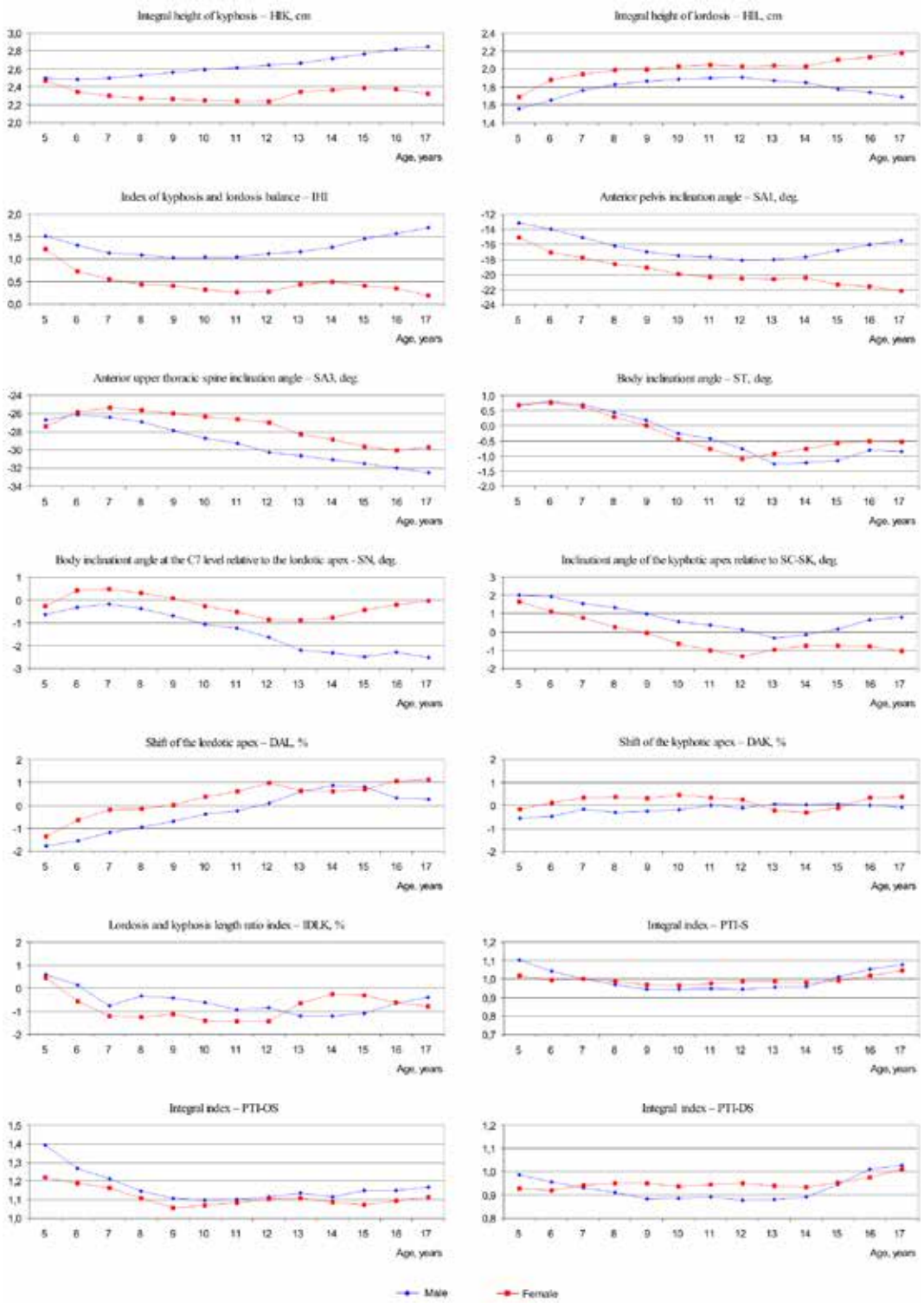

Fig. 5
Topographic parameters describing the posture status in the sagittal plane as function of age

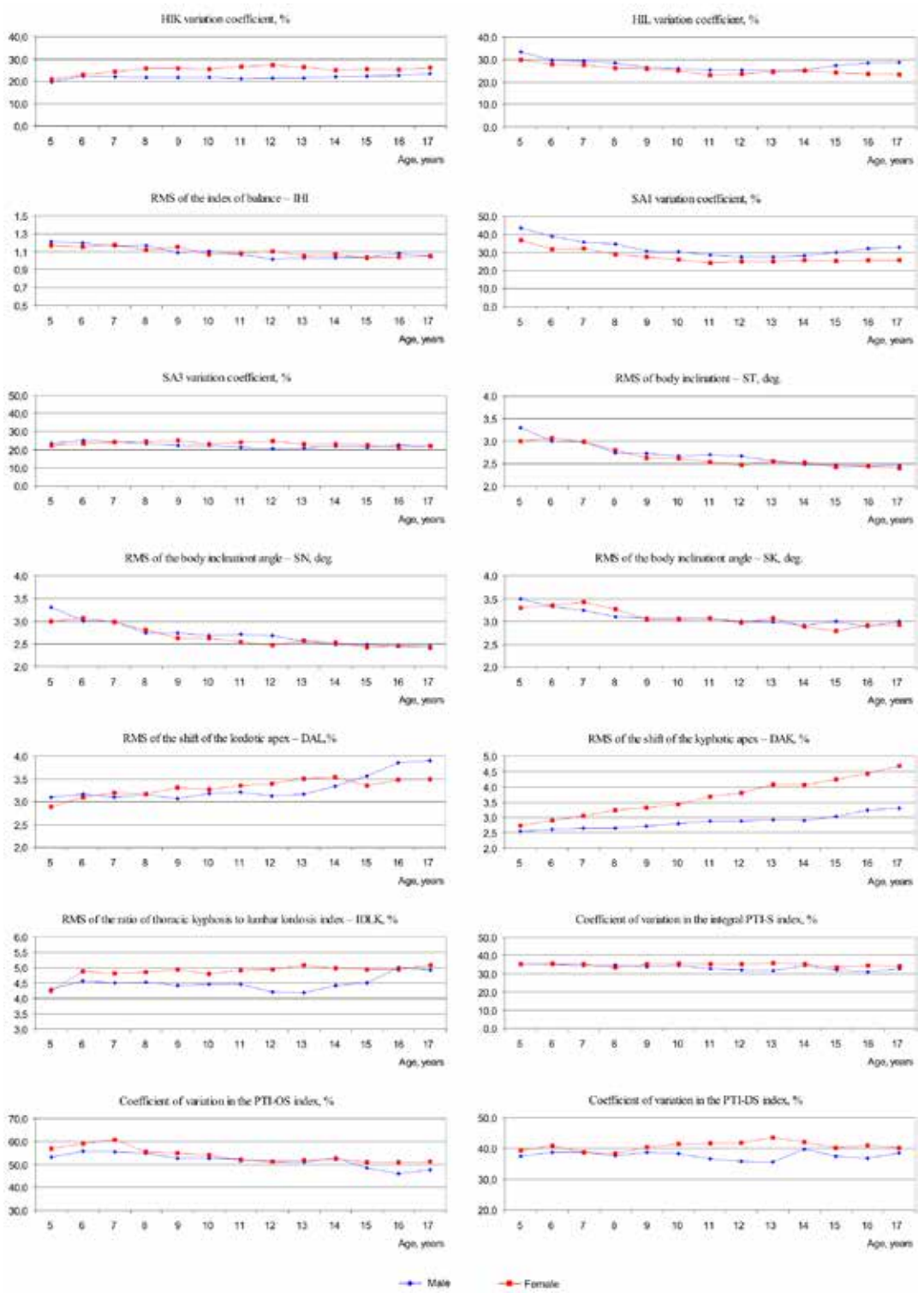

Fig. 6
Variation coefficient and the root-mean-square deviation (RMS) of the topographic parameters describing the posture status in the sagittal plane as function of age

Table 5

Correlation between the dynamics of posture disorder in the sagittal plane and parameters of kyphosis, lordosis and their balance for males (M) and females (F)

Parameter	Correlation coefficient					
	HIK		HIL		IHI	
	M	F	M	F	M	F
1.						
BKL	-0.6225	-0.1130	0.6601	0.3900	-0.9550	-0.3540
PK	0.7161	0.6430	-0.6153	-0.9400	0.9830	0.9890
PL	-0.7516	-0.6770	0.5499	0.9170	-0.9550	-0.9820
2.						
N	-0.7630	-0.0110	0.4135	-0.8560	-0.4000	0.3010
S	-0.3620	0.8290	0.8288	-0.9140	-0.4900	0.7130
PD	0.1770	-0.8130	-0.9161	0.8670	0.3920	-0.6320
SD	0.9030	0.0280	-0.1208	0.6990	0.7430	-0.5540

and IHI (Fig. 5) obtained by calculating the correlation coefficients for the corresponding diagrams and graphs. The graph for IHI for males strictly determines the inverse (with respect to the graphs) trend of the balanced and lordosed postures (the correlation coefficient in both cases is -0.955) and the direct trend for the kyphosed posture graph (the correlation coefficient is 0.983). The same graph for females strictly defines the inverse trend for lordosed posture (the correlation coefficient is -0.982), the direct trend for the kyphosed posture (the correlation coefficient is 0.989) and is slightly associated with the inversed trend for the balanced posture graph (the correlation coefficient is -0.354). Using the data in Table 5, one can define the dependence between the severity of kyphosis and lordosis and the number of patients in each group according to the posture type. Thus, for males, in order to increase the N group it is more important to decrease kyphosis (the correlation coefficient is -0.763) than to increase lordosis (the correlation coefficient is 0.4135). The situation is opposite for females: a decrease in lordosis is very important (correlation coefficient is 0.856), while there is almost no correlation with the kyphosis severity (the correlation coefficient is -0.011). This type of analysis can be performed in a similar way for other groups of posture disorders.

Conclusions

Features of the posture formation in the sagittal plane were studied in children and adolescents aged 5 to 17 years using the representative data sample (more than 33,000 patients from six different regions) that was obtained using a second-generation TODP system during topographical screening survey. Following conclusions can be drawn from the study results.

1. The age-dependent variations in posture disorders in the sagittal planes differ significantly for males and females and are mostly determined by variation in the mean value of lumbar lordosis and thoracic kyphosis heights and indices of their balance.

2. At the age of 5, the structures of postural disorders for males and females do not differ qualitatively from each other and are characterized by the prevalence of kyphosed posture. The mean kyphosis heights for both genders are equal to one another and are rather close to the normal value, while the mean value of lordosis height is below the normal level with higher level of flattening of lordosis for males.

3. At the age of 17, the structures of posture disorders for males and females have the greatest difference and are characterized by kyphosed posture for males and lordosed posture character for females.

4. In all age groups, females demonstrate a higher variability in the kyphotic apex and "kyphosis-lordosis" border positions, and the close variability of lordosis length and index of balance for physiological curves compared to that for males. For males of the older age groups, the variability of the lordosis length and the position of its apex become higher than that for females.

5. Parameters for the body position and orientation in the sagittal plane for both genders have a similar variability size: higher at younger and lower at older ages.

6. The best posture status was observed for both genders at ages of 8–14 according to the integral indices (PTI-S, PTI-OS, PTI-DS); males generally had a better posture than females. At the age below 8, both genders had deviations in body orientation (PTI-OS index) and after the age of 14, the deviations were associated with the deformation of physiological curves (PTI-DS index). Meanwhile, the deviations in males were pronounced stronger compared to those in females (for both younger and older ages).

This study conducted for such a large amount of statistical material using the COMOT method allowed us to reveal an objective quantitative pattern of the posture formation processes in the sagittal plane in children and adolescents. In our opinion, this pattern can be of interest both for the researchers and for practicing physicians.

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