

# Classification of Postural Disorders and Spinal Deformities in the Three Dimensions According to Computer Optical Topography

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**Abstract:** The appearance of surface topography has opened up new opportunities for population-based studies of postural disorders and spinal deformities. In Russia such study began in 1996 and nowadays a large amount of statistical data on the pediatric population has been accumulated. Analysis of the postural disorder and spinal deformity varieties has allowed us to create a new classification of these disorders. Classification is based on three-dimensional estimation of the trunk and on the orthopedic division of structural scoliosis into 4 grades assumed in Russia.

**Keywords.** Classification, postural disorders, scoliosis, surface topography

## 1. Introduction

Until recently the assessment of posture was carried out only in two planes: frontal and sagittal. The horizontal plane remained unheeded by orthopedists. In Russia the invention of a new method of instrumental diagnostics - computer optical topography (COMOT) - provided a possibility to evaluate the postural disorders in 3 planes, to estimate violations of the trunk orientation and its shape deformation and asymmetry.

## 2. Method

COMOT was developed in 1994 at Novosibirsk Research Institute of Traumatology and Orthopaedics. It is based on a fringe projection method and phase spatial detection. Commercial available TODP system was developed on the basis of this method. Over the years more than 240 systems were produced, which are used in 67 cities of Russia for school screening, risk monitoring and control of the results of conservative and surgical treatment of scoliosis, both in public and commercial activities [1,2].

## 3. Results

The proposed classification is based on the notion of harmonic posture, the criteria of which are: the optimal static trunk in frontal and sagittal planes, the absence of trunk

"twisting" (rotation of shoulder girdle relative to the pelvis) in horizontal plane, the symmetry of the trunk relative to the median line, the absence of lateral curvature of the spine, the balance of physiological curves and their anatomically correct position.

The severity of deviations from the harmonious state of posture is evaluated on the basis of  $\sigma$ -normalized topographic parameters:  $P_{\sigma}=(P-P_n)/\sigma$ , where P - the value of the parameters,  $P_n$  - value of the norm and  $\sigma$  – standard deviation. The value of  $|P_{\sigma}|$  from 0 to 2/3 corresponds to harmonic posture (Normal, N); from 2/3 to 1 – to minor deviations (Subnormal, S); from 1 to 2 – to mild deviations (Postural disorders, PD); from 2 to 3 to expressed deviations and more than 3 – to severe deviations (Spinal deformities, SD). The overall assessment of the posture is done using the integral Posterior Trunk Index (PTI), calculated according to the root-mean-square of integral indexes for each plane: frontal - PTI-F, sagittal - PTI-S and the horizontal PTI-G. An integral index for a plane has lower level indexes. For example, a frontal plane index (PTI-F) includes following level indexes: PTI-OF and PTI-DF, which is calculated according to the root-mean-square of  $\sigma$ -normalized topographic parameters of the trunk orientation and deformation, respectively.

Classification of postural disorders in the frontal, sagittal and horizontal planes is shown in Table 1-3, respectively.

**Table 1.** Classification of postural disorders and spinal deformities in frontal plane.

Notation	Name of type and brief description	Health group	Main topographic criteria*
N	Normal - harmonic posture	I	PTI-F<2/3 & PTI-OF<2/3 & !SS0 & !PTS0 & !FS0
S	Subnormal - minor deviations without scoliosis	I	2/3<PTI-F<1.2 & 2/3<PTI-OF<1.2 & !SS0 & !PTS0 & !FS0
S-FS0	Functional Scoliosis - minor deviations	I	$ MD_{\sigma} >2/3$ & Lev<80% & !SS0 & !PTS0 & !FS1 & PTI-F<1.2
S-PTS0	Pelvis Tilt Scoliosis - minor deviations	I	$ MD_{\sigma} >2/3$ & $ FP_{\sigma} >2/3$ & MD*FP<0 & Lev<55% & !SS0 & !PTS1 & !FS1 & PTI-F<1.2
S-SS0	Structural Scoliosis - minor deviations	I	$IA\geq 4.5^{\circ}$ & $ LA \geq 5^{\circ}$ & $ R >1.35^{\circ}$ & $LA*R>0$ & !PTS1 & !SS1 & !FS1 & PTI-F $\leq$ 1.2
PD-FS1	Functional Scoliosis - mild deviations	II	$ MD_{\sigma} >1$ & Lev<80% & !PTS1 & !SS1
PD-PTS1	Pelvis Tilt Scoliosis - mild deviations	II	$ MD_{\sigma} >1$ & $ FP_{\sigma} >1$ & MD*FP<0 & Lev<65% & !SS1-2 & !PTS2
PD-SS1	Structural Scoliosis - mild deviations	II	$IA\geq 7^{\circ}$ & $ LA \geq 5^{\circ}$ & $ R >1.55^{\circ}$ & $LA*R>0$ & !PTS2 & !SS1-2
PD-OD	Other mild Disorders without scoliosis	II	PTI-F>1.2 & !SS1 & !PTS1 & !FS1
SD-PTS2	Pelvis Tilt Scoliosis – expressed deviations	III	$ MD_{\sigma} >2$ & $ FP_{\sigma} >2$ & MD*FP<0 & Lev<60% & !SS2
SD-SS1-2	Structural Scoliosis – expressed deviations	III	$ LA \geq 9^{\circ}$ & $ R >1.75^{\circ}$ & $IA\geq 9^{\circ}$ & $LA*R>0$ & !SS2
SD-SS2	Structural Scoliosis – expressed deviations	III	$ LA \geq 15^{\circ}$ & $ R >2^{\circ}$ & $IA\geq 11^{\circ}$ & $LA*R>0$ & !SS3
SD-SS3	Structural Scoliosis - severe deviations	IV	$ LA \geq 25^{\circ}$ & $ R >3^{\circ}$ & $LA*R>0$ & !SS4
SD-SS4	Structural Scoliosis - severe deviations	IV	$ LA \geq 50^{\circ}$ & $ R >3^{\circ}$ & $LA*R>0$

\* !SS0 (!FS0, !PTS0) - means the absence of conditions for the SS0 (FS0, PTS0) and more severe scoliosis.

In addition to integral indexes, in frontal plane this classification uses the following parameters: LA - the lateral asymmetry angle (topographic analogue of Cobb angle with a sign that sets the direction of scoliotic convexity of the arc, "-" for left-sided and "+" for right-sided arch); R - the rotation angle of scoliotic arch in apex with a corresponding sign, as for LA; IA – the integral scoliosis angle ( $IA = |(LA+3*R)/2|$ ); MD – the maximum lateral deviation of the spinous processes from C7 - Natal Cleft line with a corresponding sign; Lev - level of MD in percents, where 0% - level of Natal Cleft, and 100% - C7; FP – the pelvis tilt (tilt angle of the PSIS line in the frontal plane), with a sign "+" for left-sided and "-" for right-sided tilt.

**Table 2.** Classification of postural disorders and spinal deformities in sagittal plane.

Notation	Name of type and brief description	HG <sup>1</sup>	Main topographic criteria
N	Normal - harmonic posture (BKL <sup>2</sup> )	I	$PTI-S < 2/3$ & $PTI-DS < 2/3$ & $PTI-OS < 1$ & $0.2 < IHI < 1.0$ & $(HIL_{\sigma} + HIK_{\sigma})/2 < 2/3$
S-B	Subnormal with violation of the trunk Balance in sagittal plane (BKL)	I	$(PTI-S \geq 2/3    PTI-OS \geq 1) \& PTI-OS > PTI-DS \& 0.2 < IHI < 1.0$ & $(HIL_{\sigma} + HIK_{\sigma})/2 < 2/3$
S-G	Subnormal with violation of the physiological curves Geometry (apex position or curves length ratio) (BKL)	I	$(PTI-S \geq 2/3    PTI-DS \geq 1) \& PTI-DS \geq PTI-OS \& 0.2 < IHI < 1.0$ & $(HIL_{\sigma} + HIK_{\sigma})/2 < 2/3$
S-DKL	Subnormal with Decrease of Kyphosis and Lordosis (BKL)	I	$0 < IHI < 1.2 \& (-1 < HIL_{\sigma} \leq -2/3 \& -1 < HIK_{\sigma} \leq -2/3)    -1.1 < (HIL_{\sigma} + HIK_{\sigma})/2 \leq -0.6 \& HIK_{\sigma} \leq 0.15 \& HIL_{\sigma} \leq -0.15$
S-IKL	Subnormal with Increase of Kyphosis and Lordosis (BKL)	I	$0 < IHI < 1.2 \& (2/3 \leq HIL_{\sigma} < 1 \& 2/3 \leq HIK_{\sigma} < 1)    0.6 \leq (HIL_{\sigma} + HIK_{\sigma})/2 < 1.1 \& HIK_{\sigma} \geq 0.15 \& HIL_{\sigma} \geq 0.15$
S-DK	Subnormal with Decrease of Kyphosis (PL <sup>3</sup> )	I	$IHI \leq 0.2 \&  HIK_{\sigma}  < 1.1 \&  HIL_{\sigma}  < 1 \&  HIK_{\sigma}  \geq  HIL_{\sigma} $
S-IL	Subnormal with Increase of Lordosis (PL)	I	$IHI \leq 0.2 \&  HIK_{\sigma}  < 1 \&  HIL_{\sigma}  < 1 \&  HIL_{\sigma}  \geq  HIK_{\sigma} $
S-DL	Subnormal with Decrease of Lordosis (PK <sup>4</sup> )	I	$IHI \geq 1 \&  HIK_{\sigma}  < 1 \&  HIL_{\sigma}  < 1.1 \&  HIL_{\sigma}  \geq  HIK_{\sigma} $
S-IK	Subnormal with Increase of Kyphosis (PK)	I	$IHI \geq 1 \&  HIK_{\sigma}  < 1.1 \&  HIL_{\sigma}  < 1 \&  HIK_{\sigma}  \geq  HIL_{\sigma} $
PD-FB	Postural Disorders - Flat Back (BKL)	II	$-2 < HIL_{\sigma} \leq -1 \& -2 < HIK_{\sigma} \leq -1    -1 \leq IHI \leq 1.3 \& (HIL_{\sigma} + HIK_{\sigma})/2 \leq -1$
PD-FCB	Postural Disorders - Flat-Concave Back (PL)	II	$IHI \leq 0 \& (HIL_{\sigma} < 2 \& HIL_{\sigma} \geq 1 \& HIK_{\sigma} \leq -2/3)    -1 < HIL_{\sigma} < 1 \& HIK_{\sigma} \leq -1$
PD-CB	Postural Disorders - Concave Back (PL)	II	$IHI \leq 0.2 \& 1 \leq HIL_{\sigma} < 2 \& 0 \leq HIK_{\sigma} < 1.05$
PD-RCB	Postural Disorders - Round-Concave Back, (BKL)	II	$0.2 < IHI < 1.0 \& (1 \leq HIL_{\sigma} < 2 \& 1 \leq HIK_{\sigma} < 2)    1 \leq (HIL_{\sigma} + HIK_{\sigma})/2 < 2$
PD-RFB	Postural Disorders – Round-Flat Back (PK)	II	$IHI \geq 1 \& HIL_{\sigma} \pm \leq -1 \& 0 < HIK_{\sigma} < 1$
PD-HuB	Postural Disorders - Hunched Back (PK)	II	$IHI \geq 1 \& (HIL_{\sigma} + 1 < IDLK/10) \& (1 \leq HIK_{\sigma} < 2)$
PD-RB	Postural Disorders – Round Back (PK)	II	$IHI \geq 1 \& HIL_{\sigma} + 1 \geq IDLK/10 \& 1 \leq HIK_{\sigma} < 2$
SD-FBS	Spinal Deform.-Flat Back Syndrome (BKL)	III	$HIL_{\sigma} \leq -2 \& HIK_{\sigma} \leq -2    (HIL_{\sigma} + HIK_{\sigma})/2 \leq -1.75$
SD-HyKL	Spinal Deformities - HyperKyphosis and hyperLordosis (BKL)	III	$HIL_{\sigma} \geq 2 \& HIK_{\sigma} \geq 2    0.2 < IHI < 1 \& (HIL_{\sigma} + HIK_{\sigma})/2 \geq 2 \& HIL_{\sigma} \geq 5/3 \& HIK_{\sigma} \geq 5/3$
SD-HyL	Spinal Deformities – HyperLordosis (PL)	III	$IHI \leq 0.2 \& HIL_{\sigma} \pm \geq 2.0 \& HIK_{\sigma} \pm < 5/3$
SD-HyK1	Spinal Deformities - HyperKyphosis I (PK)	III	$IHI \geq 1 \& 2 \leq HIK_{\sigma} < 3 \& HIL_{\sigma} < 2$
SD-HyK2	Spinal Deformities - HyperKyphosis II (PK)	IV	$IHI \geq 1 \& HIK_{\sigma} \geq 3 \& HIL_{\sigma} < 2$

HG<sup>1</sup> – Health group; BKL<sup>2</sup> – balanced kyphosis and lordosis; PL<sup>3</sup> – predominance of lordosis; PK<sup>4</sup> – predominance of kyphosis.

In addition to integral indexes, this classification in sagittal plane uses the following parameters:  $HIK_{\sigma}$  and  $HIL_{\sigma}$  -  $\sigma$ -normalized parameter HIK and HIL (integral height of thoracic kyphosis and lumbar lordosis normalized to trunk length); IDLK - index ratio of the length of kyphosis and lordosis in percents as compared with normal value (for example, the value of IDLK = -4.5, means that the boundary of kyphosis and lordosis on a scale of C7 - Natal Cleft shifted in the direction of increasing lordosis by 4.5%). IHI - index of balance of thoracic kyphosis and lumbar lordosis, which is calculated by the following formula:

$$IHI=10*(HIK-HIL)/(HIK+HIL+HIN),$$

where 10 is normalizing factor, HIN - half the sum of the normal values for HIK and HIL (IHI value from 0.2 to 1.0 corresponds to the balanced kyphosis and lordosis, IHI <0.2 - predominance of lordosis and IHI >1.0 - the predominance of kyphosis).

**Table 3.** Classification of postural disorders and spinal deformities in horizontal plane.

Notation	Named of type and brief description	Health group	Main topographic criteria
N	Normal - harmonic posture without trunk twist	I	$ GT_{\sigma}  < 2/3$
S	Subnormal - minor trunk twist	I	$2/3 \leq  GT_{\sigma}  < 1$
PD-TT	Postural Disorders - mild Trunk Twist - mutual rotation of pelvis and shoulder girdle	II	$1 \leq  GT_{\sigma}  < 2$ & $ GH-Gcor  < 2* GP-Gcor $ & $ GP-Gcor  < 2* GH-Gcor $
PD-RP	Postural Disorders - mild trunk twist with Rotation predominance of Pelvis	II	$1 \leq  GT_{\sigma}  < 2$ & $ GP-Gcor  \geq 2* GH-Gcor $
PD-RS	Postural Disorders - mild trunk twist with Rotation predominance of Shoulder girdle	II	$1 \leq  GT_{\sigma}  < 2$ & $ GH-Gcor  \geq 2* GP-Gcor $
SD-HTT	Spinal Deformities - Hyper Trunk Twist - mutual rotation of pelvis and shoulder girdle	III	$ GT_{\sigma}  \geq 2$ & $ GH-Gcor  < 2* GH-Gcor $ & $ GP-Gcor  < 2* GH-Gcor $
SD-HRP	Spinal Deformities - Hyper trunk twist with Rotation predominance of Pelvis	III	$ GT_{\sigma}  \geq 2$ & $ GP-Gcor  \geq 2* GH-Gcor $
SD-HRS	Spinal deformities - hyper trunk twist with Rotation predominance of Shoulder girdle	III	$ GT_{\sigma}  \geq 2$ & $ GH-Gcor  \geq 2* GP-Gcor $

In horizontal plane this classification uses the following parameters:  $GT_{\sigma}$  –  $\sigma$ -normalized parameter GT (twist angle of the shoulder girdle relative to the pelvis; GH - the shoulder girdle rotation angle; GP - the pelvis rotation (angle of PSIS line); Gcor - correction angle of the trunk rotation, which corresponds to the angle of trunk rotation in horizontal plane caused by incorrect patient position. Subtraction of Gcor is necessary to compare the magnitude of rotation of the pelvis and shoulder girdle in the absolute coordinate system. All these parameters have a plus sign, if the rotation is directed clockwise.

#### 4. Discussion

For the first time the 3D classification of postural disorders and spinal deformities with quantitative assessment of the state of posture in sagittal, frontal and horizontal planes basing on the computer optical topography data was proposed. In each plane 5 states of posture are distinguished in accordance with the degree of postural defect manifestation: normal (harmonic or excellent posture), subnormal (minor deviations),

postural disorders (mild deviations) and 2 states of spinal deformities (expressed and severe deviations).

Also, incorrect posture is differentiated by the type of violations. In the frontal plane there are 4 varieties: without scoliosis (postural disorders without lateral deviation of the spine); the functional scoliosis; compensatory scoliosis (pelvic tilt scoliosis) and structural scoliosis. Functional scoliosis is a scoliosis without manifestations of arch apex rotation and without laterally agreed tilt of the pelvis. Compensatory scoliosis is a scoliosis without manifestations of the arch apex rotation and with laterally agreed tilt of the pelvis. Structural scoliosis is a scoliosis with laterally agreed arc apex rotation.

In sagittal plane, posture is divided into 3 variants according to the ratio of kyphosis and lordosis values: balanced kyphosis and lordosis, predominance of lordosis and predominance of kyphosis. In horizontal plane 3 variants of trunk twisting are distinguished depending on the predominant rotation of the pelvis or shoulder girdle or their mutual rotation: rotated pelvis, rotated shoulder girdle and twisted trunk.

The proposed classification has been integrated into software of TODP system and is widely used in medical practice in Russia including the interpretation of the results of screening of schoolchildren. It allows obtaining formal conclusion on the state of posture and spinal deformities for each patient, which greatly simplifies the task of the doctor-interpreter. Based on the screening results, a child is assigned to one of four health groups of posture states according to the maximum severity of postural disorders and spinal deformities in any of three planes, as shown in Tables 1-3. Health groups have been approved by the order of the Russian Ministry of Health to improve the organization of medical care for children.

Application of this classification for screening allows forming individual recommendations for each patient, and receiving detailed statistic reports for class, school, district and the whole city.

## **Conclusion**

The proposed classification is based on long term experience (since 1994) of application of computer optical topography for screening in Russia. It proved to be useful for interpretation of results of mass screening not only for scoliosis but also for 3D posture disorders of the child population. We consider that the proposed classification is useful for specialists of other countries dealing with postural disorders and spinal deformities.

## **References**

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