CHANGES IN SPINOPELVIC RELATIONSHIPS IN CHILDREN WITH SPONDYLOLISTHESIS AFTER SURGICAL TREATMENT AND THEIR CORRELATION WITH THE ASSESSMENT OF QUALITY OF LIFE

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Objective. To assess sagittal balance parameters in children with spondylolisthesis before and after surgical treatment and to analyze their correlation with quality of life.

Material and Methods. A retrospective analysis of postural radiographs of 98 children and adolescents was performed. The patients were divided into 2 groups: Group 1 included 43 patients under 17 years of age (mean age 12.0 ± 2.6 years) without spinal pathology, and Group 2 — 55 patients under 17 years of age (mean age 13.3 ± 2.5 years) with spondylolisthesis before and after surgical treatment. In patients of Group 1, the main spinopelvic parameters (PT, PI, SS, LL, PI-LL, TK) were calculated and studied. In patients of Group 2, parameters characterizing local lumbosacral kyphosis (SA, Dub-LSA, LSJA) were calculated and studied in addition to the main ones. The obtained results were compared with the conditional norm for children. The intensity of pain syndrome and quality of life were assessed using questionnaires and scales (Ped`s QL, ODI, VAS) before surgical treatment, at the time of discharge from the hospital, and after 3 months since surgery. Statistical data analysis was carried out using the statistical programming language and the R environment (version 3.6.1) in RStudio IDE (version 1.2.1335) with representation in the M ± SD format for normally distributed random variables and Me [Q1; Q3] for variables with abnormal distribution. Categorical indicators were presented as an absolute number and a percentage ratio. The null hypothesis in statistical tests was rejected at a significance level of $p < 0.05$

Results. A decrease in the intensity of pain syndrome and an improvement in the quality of life were observed after surgical treatment in all cases. Statistical analysis of the relationship between parameters characterizing local lumbosacral kyphosis (Dub-LSA, SA, LSJA) and the results of using questionnaires and scales (Ped`s QL, ODI, VAS) showed a statistically significant positive correlation ($r = 0.57$; $p = 0.004$) of the LSJA score and pain intensity assessed before surgery, as well as a statistically significant negative correlation ($r = -0.47$; $p = 0.004$) of the LSJA score before surgery and the results of the PED`s QL questionnaire after surgery. In a comparison group analysis, it was found that after surgical treatment, there was a tendency towards normalization of sagittal parameters, though their complete recovery to normal values was not achieved. Local lumbosacral kyphosis was completely eliminated in all cases.

Conclusion. Correction of the angle of lumbosacral kyphosis during surgical treatment of children with spondylolisthesis directly correlates with indicators characterizing the quality of life, which makes its elimination the main purpose of the operation. The degree of correction of the sagittal balance parameters (PT, SS, LL) has no significant impact on the quality of life, and their correction to the target calculated values is not required at an initially high PI value. In cases of decompensation of the sagittal and coronal balances of the trunk with low grades of spondylolisthesis, combined with impaired gait and anterior inclination of the torso (lumbar-femoral rigidity syndrome), the instrumental restoration of segmental lordosis at the level of L5—S1 and decompression of neural structures lead to correction of sagittal balance and normalization of gait.

Key Words: children, adolescents, severe spondylolisthesis, sagittal imbalance, lumbosacral kyphosis, lumbar-femoral rigidity syndrome.
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Severe spondylolisthesis in children in most cases is characterized by high PI values that may be a causative factor of this disease and lead to the development of sagittal imbalance [1, 2]. Severe spondylolisthesis is also characterized by the presence of lumbosacral kyphosis, which correlates with the quality of life of patients [3]. The restoration of sagittal parameters or their maximum approximation to normal values is one of the aims of surgical treatment of spondylolisthesis. Nowadays, literature sources contain an extremely small number of studies devoted to sagittal parameters in children, which is due to ethical standards [4–11].

Sagittal balance abnormalities can develop in children with grade I–II slippage (also known as low-grade spondylolisthesis) in conjunction with neurological diseases, pain syndrome, lumbofemoral rigidity syndrome [12]. In this group of patients an upright position of the trunk is restored after decompression of neural structures and does not require

maximum reduction of the displaced vertebra [13].

The question of optimal degree of recovery and target indicators of sagittal parameters in children with spondylolisthesis remains open.

The objective is to assess sagittal balance parameters in children with spondylolisthesis before and after surgical treatment and to analyze their correlation with quality of life.

Material and Methods

A retrospective study included 98 children and adolescents. All patients were divided into two groups.

Group 1 included 43 patients under 17 years old (mean age 12.0 ± 2.6 years) without spinal pathology. We included patients who applied on an outpatient basis, complaining of back pain and/or postural disorders. Postural radiographs were performed to exclude pathology of the musculoskeletal system. The inclusion criteria in the group were the absence of spinal deformities (scoliotic, kyphotic, post-traumatic, and spondylolisthesis) and other orthopedic pathology.

Group 2 included 55 patients under 17 years old (mean age 13.3 ± 2.5 years) with L5 spondylolisthesis admitted for surgical treatment. All patients had type I spondylolisthesis (acquired) according to the classification of Marchetti and Bartolozzi [14] with varying degrees of severity of dysplastic changes. The inclusion criterion in this group was the presence of the L5 spondylolisthesis in the absence of other orthopedic pathology.

All patients in Group 2 underwent surgical treatment: monosegmental fixation of L5–S1, fixation of L4–L5–S1 and fusion of L5–S1 by cage with autograft according to the PLIF technique. An anterior fusion of L5–S1 was performed in 32 patients with a cage with autograft through the anterior extraperitoneal approach.

All the examined patients underwent postural radiography. The study was carried out in accordance with a Spinal Deformity Study Group (SDSG) standard to minimize changes in the spinal sagittal contour and prevent compensatory shifts in posture [15]. A patient is in a standing position; knee and hip joints are in a neutral, comfortable position for a patient; arms are bent at the shoulder and elbow joints with the fingers located in the collarbone area; if there is a shortening of the lower limb of more than 2 cm, an X-ray shall be performed with compensation for pelvic alignment.

According to postural radiography in the lateral projection, patients in Group 1 underwent radiometric calculations of the following parameters: pelvic tilt (PT), pelvic incidence (PI), sacral slope (SS), lumbar lordosis (LL), the difference between the values of the pelvic incidence index and lumbar lordosis (PI-LL), thoracic kyphosis (TK).

For Group 2 patients, in addition to the main ones, the parameters characterizing lumbosacral kyphosis were also calculated. The slip angle (SA), Dubousset lumbosacral angle (Dub-LSA), lumbosacral joint angle (LSJA) were estimated in these individuals. The analysis of radiometric parameters was done using SurgiMap and Radiant software.

In Group 2 patients, the quality of life and intensity of the pain syndrome were evaluated before surgical treatment, at the time of discharge from the hospital, and 3 months after surgery, using the following scales and questionnaires: Quality of Life Scale (Ped's QL 4.0 Generic Core Scales), ODI (Oswestry Disability Index), and VAS (Visual Analogue Scale).

Statistical data analysis was performed using the statistical programming language and the R environment (version 3.6.1) in the IDE RStudio (version 1.2.1335). The distribution of continuous and discrete quantitative variables in the sample is shown as the arithmetic mean and standard deviation (M ± SD) for normally distributed random variables, the median and quartiles (Me [Q1; Q3]) for quantities distribution of which differs from normal. Categorical indicators are given as an absolute number and a percentage ratio.

The correspondence of the sample to the normal distribution was defined using the Shapiro – Wilk test. The Mann – Whitney U Test was applied to test statistical hypotheses on the difference in the distribution of quantitative variables in independent samples; for dependent samples, the Wilcoxon signed-rank test was used for pairwise comparisons. The Spearman's rank correlation coefficient was used to estimate the correlation between the quantitative values. To evaluate the magnitude of postoperative changes and differences between the indicators in normal and pathological conditions (the magnitude of the effect), the Cliff's Delta was calculated with a 95 % confidence interval obtained using bootstrap technology. The null hypothesis in statistical tests was rejected at a significance level of $p < 0.05$.

Considering the absence of statistically significant gender differences in sagittal parameters according to the literature sources [8], no gender diversity was performed in the statistical analysis.

Results

For all patients in Group 1, the mean values for each parameter were defined and described, which were assumed to be a conditional age norm and compared with similar parameters in adults. We gave a detailed account of the study results in our previous paper [11].

Using the Meyerding classification, the patients in Group 2 were distributed according to the degree of vertebral slippage as follows: grade I: 4 patients; grade II: 22 patients; grade III: 18 patients; grade IV: 9 patients; and grade V (spondyloptosis): 2 patients. According to the classification of spondylolisthesis in the SDSG [15], patients were distributed as follows: type 1: 3 patients; type 2: 8 patients; type 3: 14 patients; type 4: 4 patients; type 5: 21 patients; and type 6: 5 patients.

The sagittal parameters of the spine were estimated before and after surgical treatment in Group 2 patients. The mean values of the spinopelvic parameters were compared with similar ones in healthy children from Group 1 (Fig. 1). Statistically significant differences were obtained as the result of comparison (Table 1).

The Cliff's Delta was calculated with a 95 % confidence interval to evaluate the number of postoperative alterations and differences between the indicators in normal findings and spondylolisthesis (the magnitude of the effect; Table 2).

After surgical treatment, SS, LL, and TK parameters significantly rose in Group 2 patients, which decreased with severe degrees of spondylolisthesis. These outcomes can be regarded as a compensatory mechanism for maintaining the upright position.

Fig. 1 demonstrates that the main spinopelvic parameters (PT, LL, and TK) in children with spondylolisthesis have not been fully restored after surgical treatment. Nevertheless, there is a trend in their approximation to normal values. In turn, the SS parameter is restored above the target values.

Nonetheless, all patients in Group 2 had a regression of radicular and local pain syndromes in the lumbar spine after surgical treatment, that leads to an improvement in quality of life (Table 3). Patients with gait disorders and the anterior inclination of the trunk noted a complete recovery of gait for up to three months, as well as the restoration of upright posture.

Comparison of the parameters of local lumbosacral kyphosis (Dub-LSA, SA, LSJA) showed a statistically significant increase in the Dub-LSA parameter (before surgery: 86.0° ± 11.1°; after surgery: 113.0° ± 7.7°), as well as a reduction in SA (before surgery: 11.0° ± 6.0°; after surgery: 2.0° ± 1.7°), LSJA (before surgery: 9.0° ± 4.0°; after surgery: 2.0° ± 1.4°).

The analysis data of sagittal parameters characterizing local lumbosacral kyphosis in patients of Group 2 before and after surgery are given in Fig. 2.

The changes in Dub-LSA, SA, and LSJA parameters obtained after the procedure suggest a decrease in local kyphosis after the L5 vertebra reduction.

We have performed a statistical analysis of the correlation between parameters characterizing local lumbosacral kyphosis (Dub-LSA, SA, LSJA) and the results of questionnaires and scales (Ped's QL, ODI, VAS) before and after surgery.

As a result, we received a statistically significant positive correlation ($r = 0.57$; $p = 0.004$) between the LSJA parameter and the results of evaluating the intensity of the pain syndrome according to the VAS before surgery. The higher the value of the LSJA parameter before surgery, the higher the results of evaluating the intensity of the pain syndrome according to VAS at the preoperative stage (Fig. 3).

There was also a statistically significant negative correlation ($r = -0.47$; $p = 0.004$) between the LSJA parameter before surgery and the results of the PED's QL questionnaire after surgery. The higher the LSJA parameter before surgery, the lower the result according to the PED's QL questionnaire after surgery (Fig. 4).

The data obtained as a result of the analysis indicate that local lumbosacral kyphosis in children with spondylolisthesis correlates with quality of life and pain syndrome intensity.

Discussion

Today, there is no single accepted standard for sagittal balance in children. There is a number of published papers in the Russian literature dedicated to this issue. Nevertheless, in all the publications, the studied group has one or another pathology, and the data collected are compared with the mean values for children proposed by foreign authors. For example, O.G. Prudnikova and A.M. Aranovich [16] computed and analysed sagittal parameters in children with achondroplasia, and used data from Mac-Thiong et al. [8] as a comparison group for healthy children aged 7.3 ± 1.8 years old. In the papers by P.I. Bortulev et al. [17, 18], the analysis of spinopelvic relationships in children with hip subluxation in Legg-Calv -Perthes disease and with dysplastic hip subluxation was done. The data received were compared with the mean values for children proposed by Hesarikia et al. [19].

Many studies [4–11] have shown that children and adolescents suffering from severe degrees of spondylolisthesis have a significantly higher PI indicator than healthy children. Since PI is a constant that defines the indicators PT, SS, and LL [20], which in turn represent pelvic position, there is a theory that a high PI has a direct impact on spondylolisthesis progression.

Given that the PI value is essential for calculating all other indicators of sagittal balance, standard formulas for calculating target values of sagittal parameters as a tool for planning and evaluating surgical outcomes for severe degrees of spondylolisthesis are not always appropriate. In our study, for example, the parameters of sagittal balance in children and adolescents with spondylolisthesis were assessed before and after surgery. As a result, within three months, all patients with sagittal imbalances showed a recovery of upright posture and normal gait. In turn, the sagittal parameters of this group of patients could not be restored to their estimated values: PT was restored by an average of 4.0°, LL by 16.0°, and TK by 10.3°. The SS parameter was excessively increased, on average by 10.3°, in contrast to local lumbosacral kyphosis, which was completely eliminated in all cases: Dub-LSA (before surgery: 86.0° ± 11.1°; after surgery: 113.0° ± 7.7°); SA (before surgery: 11.0° ± 6.0°; after surgery: 2.0° ± 1.7°); LSJA (before surgery: 9.0° ± 4.0°; after surgery: 2.0° ± 1.4°).

Tanguay et al. [3] analyzed the surgical outcomes of 96 children and adolescents with spondylolisthesis (mean age: 13.6 ± 3.6 years) and also found a clear correlation between the parameters of lumbosacral kyphosis and the patients quality of life.

In our study, 7 patients with low degrees of spondylolisthesis had severe pain syndrome with impaired gait and/or impaired upright posture. As a result of the evaluation of their neurological status, the syndrome of lumbar-femoral rigidity was detected. All patients of this group underwent two-staged surgery. The first stage of the procedure was revision and decompression of neural structures with transpedicular fixation and reduction of the L5 vertebra. The second stage was L5–S1 fusion through the anterior extraperitoneal approach. There was a regression of neurological symptoms and restoration of the sagittal profile of

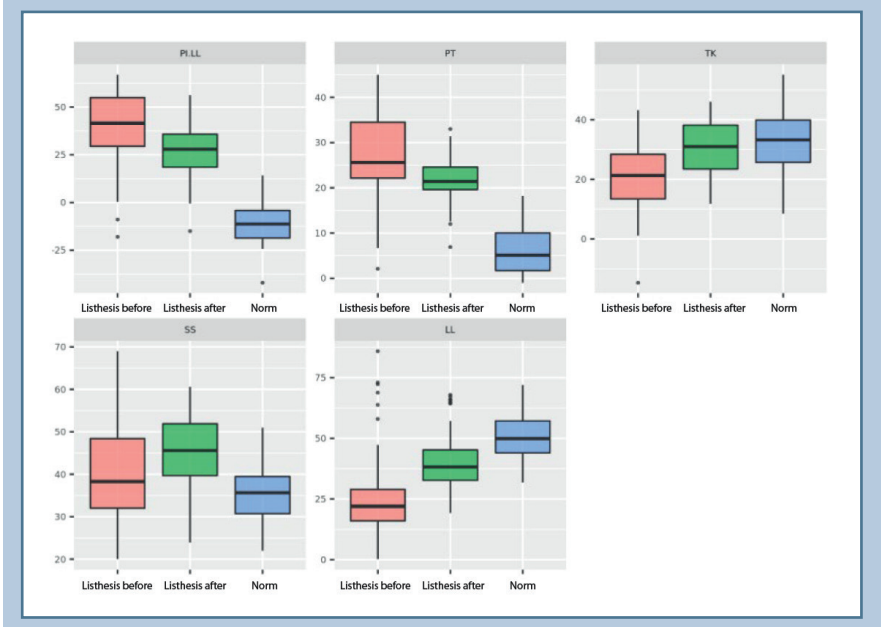

Fig. 1
Sagittal parameters (degrees) of patients with spondylolisthesis (Group 2) before and after surgery in comparison with the parameters of healthy children from Group 1

the spine within three months since surgery in all cases after decompression and stabilization treatment.

Nowadays, the mechanism of lumbofemoral rigidity is not fully investigated. However, there are papers [12, 13] describing a specific gait disorder and the inability to incline a trunk forward, a pronounced impairment in the lifting of straight legs in children and adolescents with spondylolisthesis. The authors attribute this to sensation of the cauda equina and mark the regression of the above symptoms after laminectomy of the L5 vertebra.

Conclusion

Correction of the lumbosacral kyphosis angle during surgical treatment of children with spondylolisthesis correlates directly with parameters of the quality of life. The correction degree of the sagittal balance parameters (PT, SS, and LL) has no significant effect on the quality of life.

In this regard, in the surgical treatment of spondylolisthesis in children,

Table 1
Sagittal parameters of patients with spondylolisthesis before and after surgery in comparison with the parameters of healthy children, degree

Parameter	Before surgery	After surgery	Norm	p value
Pelvic tilt	25.6 [22.15; 34.5]	21.4 [19.50; 24.50]	5.0 [2.0; 10.0]	0.002
Sacral slope	38.3 [32.05; 48.4]	45.6 [39.70; 51.90]	36.0 [31.0; 40.0]	0.001
Lumbar lordosis	22.0 [16.00; 28.90]	38.2 [32.70; 45.15]	50.0 [44.0; 57.5]	0.001
Thoracic kyphosis	21.3 [13.45; 28.40]	31.0 [23.50; 38.10]	33.5 [26.5; 40.5]	0.002

Me [Ql; Q3].

Table 2
The Cliff's Delta with 95 % confidence interval for parameters of healthy children and children with spondylolisthesis

Parameter	Before surgery and norm	After surgery and norm	Before and after surgery
Pelvic tilt	0.91 95 % CI [0.81; 0.98]	0.96 95 % CI [0.91; 0.99]	0.42 95 % CI [0.21; 0.62]
Sacral slope	0.27 95 % CI [0.04; 0.48]	0.65 95 % CI [0.49; 0.80]	-0.34 95 % CI [-0.53; -0.12]
Lumbar lordosis	-0.77 95 % CI [-0.91; -0.60]	-0.51 95 % CI [-0.70; -0.31]	-0.62 95 % CI [-0.80; -0.44]
Thoracic kyphosis	-0.62 95 % CI [-0.77; -0.44]	-0.21 95 % CI [-0.43; -0.01]	-0.48 95 % CI [-0.66; -0.27]

Table 3
Assessment of quality of life and pain syndrome in patients with spondylolisthesis

Questionnaire	Before surgery	At discharge	p value	3 months after surgery	p value
Ped`s QL, баллы	64.4 ± 11.4	–	–	82.6 ± 13.1	<0.001
ODI, %	38.8 ± 16.3	28.5 ± 12.6	<0.001	11.9 ± 9.3	<0.001
VAS, points	5.9 ± 3.1	3.9 ± 2.1	<0.001	2.3 ± 1.2	<0.001

M ± SD.

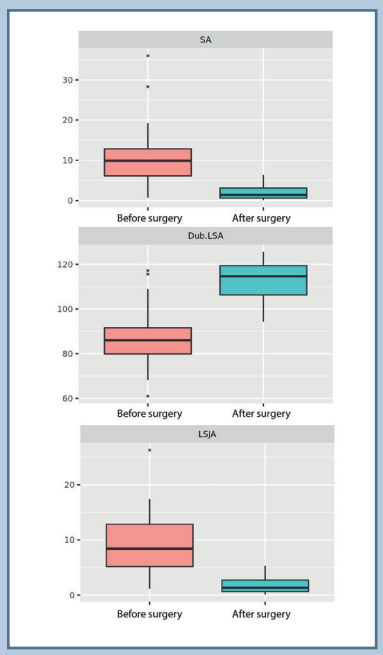

Fig. 2
Changes in Dub-LSA, SA, LSJA parameters (degrees) characterizing local lumbosacral kyphosis in patients with spondylolisthesis before and after surgical treatment

first of all, it is required to eliminate lumbosacral kyphosis, while correction of sagittal parameters (PT, SS, LL) to the target calculated values is not needed at the initial high value of PI.

In children with mild degrees of spondylolisthesis, decompensation of the sagittal and anterior balance of the trunk may develop and be combined with gait abnormalities and anterior inclination of the trunk (lumbofemoral rigidity syndrome). In such circumstances, instrumental restoration of segmental lordosis at the L5–S1 level and decompression of neural structures lead to correction of sagittal balance and normalization of gait.

The study had no sponsors.
The authors declare that they have no conflict of interest.
The study was approved by the local ethical committees of institutions.
All authors contributed significantly to the research and preparation of the article, read and approved the final version before publication.

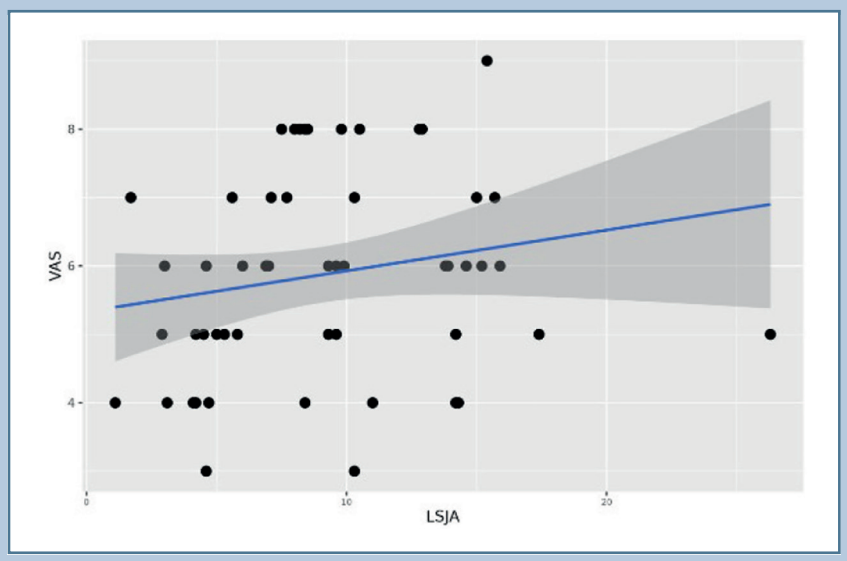

Fig. 3
Correlation between the LSJA parameter and the results of assessing the intensity of the pain syndrome according to VAS before surgical treatment

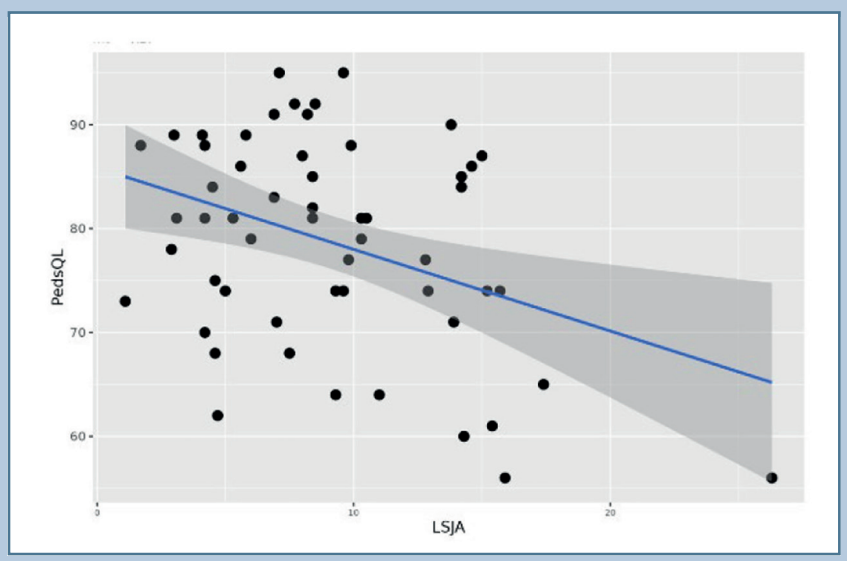

Fig. 4
Correlation of the LSJA parameter before surgery and the results of the PED's QL questionnaire after surgical treatment

References

1. **Labelle H, Roussouly P, Berthonnaud E, Dimnet J, O'Brien M.** The importance of spino-pelvic balance in L5–S1 developmental spondylolisthesis a review of pertinent radiologic measurements. Spine. 2005;30(6 Suppl):S27–S34. DOI: 10.1097/01.brs.0000155560.92580.90.
2. **Labelle H, Roussouly P, Berthonnaud E, Transfeldt E, O'Brien M, Chopin D, Hresko T, Dimnet J.** Spondylolisthesis, pelvic incidence, and spino-pelvic balance a correlation study. Spine. 2004;29:2049–2054. DOI: 10.1097/01.brs.0000138279.53439.cc.
3. **Tanguay F, Labelle H, Wang Z, Joncas J, de Guise JA, Mac-Thiong JM.** Clinical significance of lumbosacral kyphosis in adolescent spondylolisthesis. Spine. 2012;37:304–308. DOI: 10.1097/BRS.0b013e31821cc558.
4. **Cil A, Yazici M, Uzumcugil A, Kandemir U, Alanay A, Alanay Y, Acaroglu RE, Surat A.** The evolution of sagittal segmental alignment of the spine during childhood. Spine. 2005;30:93–100. DOI: 10.1097/01.brs.0000149074.21550.32.
5. **Gutman G, Labelle H, Barchi S, Roussouly P, Berthonnaud E, Mac-Thiong JM.** Normal sagittal parameters of global spinal balance in children and adolescents: a prospective study of 646 asymptomatic subjects. Eur Spine J. 2016;25:3650–3657. DOI: 10.1007/s00586-016-4665-3.
6. **Zhou XY, Zhao J, Li B, Wang ZB, Zhang ZC, Hu W, Cheng YJ, Li M, Wei XZ.** Assessment of sagittal spinopelvic balance in a population of normal chinese children. Spine. 2020;45:E787–E791. DOI: 10.1097/BRS.0000000000003428.
7. **Ghandhari H, Hesarikia H, Ameri E, Noori A.** Assessment of normal sagittal alignment of the spine and pelvis in children and adolescents. Biomed Res Int. 2013;2013:842624. DOI: 10.1155/2013/842624.
8. **Mac-Thiong JM, Berthonnaud E, Dimar JR 2nd, Betz RR, Labelle H.** Sagittal alignment of the spine and pelvis during growth. Spine. 2004;29:1642–1647. DOI: 10.1097/01.brs.0000132312.78469.7b.
9. **Lee CS, Noh H, Lee DH, Hwang CJ, Kim H, Cho SK.** Analysis of sagittal spinal alignment in 181 asymptomatic children. J Spinal Disord Tech. 2012;25:E259–E263. DOI: 10.1097/BSD.0b013e318261f346.
10. **Mac-Thiong JM, Labelle H, Berthonnaud E, Betz RR, Roussouly P.** Sagittal spinopelvic balance in normal children and adolescents. Eur Spine J. 2007;16:227–234. DOI: 10.1007/s00586-005-0013-8.
11. **Kuleshov AA, Vetrile MS, Zakharin VR, Ovsyankin AV, Kuzminova ES, Lisyansky IN, Makarov SN, Strunina UV.** Comparative characteristics of sagittal balance in normal children and with spondylolisthesis. N.N. Priorov Journal of Traumatology and Orthopedics. 2021;29(1):25–33. DOI: 10.17816/vto105177.
12. **Sevastikoglou JA, Spangfort E, Aaro S.** Operative treatment of spondylolisthesis in children and adolescents with tight hamstrings syndrome. Clin Orthop Relat Res. 1980;(147):192–199.
13. **Kayser R, Mahlfeld K, Heyde CE, Grasshoff H, Mellerowicz H.** Tight hamstring syndrome and extra- or intraspinal diseases in childhood: a multicenter study. Eur Spine J. 2006;15:403–408. DOI: 10.1007/s00586-005-0886-6.
14. **Marchetti PG, Bartolozzi P.** Spondylolisthesis: classification and etiopathogenesis. Progress in spinal pathology: Spondylolisthesis II. Bologna, Italy: Italian Scoliosis Research Group, 1986.
15. **Labelle H, Mac-Thiong JM, Roussouly P.** Spino-pelvic sagittal balance of spondylolisthesis: a review and classification. Eur Spine J. 2011;20(Suppl 5):641–664. DOI: 10.1007/s00586-011-1932-1.
16. **Prudnikova OG, Aranovich AM.** Clinical and radiological aspects of the sagittal balance of the spine in children with achondroplasia. Pediatric Traumatology, Orthopaedics and reconstructive Surgery. 2018;6(4):6–12. DOI: 10.17816/PTORS646-12.
17. **Bortulev PI, Vissarionov SV, Barsukov DB, Pozdnikin IY, Baskov VE, Baskaeva TV, Poznovich MS.** Evaluation of radiological parameters of the spino-pelvic complex in children with hip subluxation in legg-calve-perthes disease. Traumatology and Orthopedics of Russia. 2021;27(3):19–28. DOI: 10.21823/2311-2905-2021-27-3-19-28.
18. **Bortulev PI, Vissarionov SV, Baskov VE, Ovechkina AV, Barsukov DB, Pozdnikin IY**. Clinical and roentgenological criteria of spine-pelvis ratios in children with dysplastic femur subluxation. Traumatology and Orthopedics of Russia. 2018;24(3):74–82. DOI: 10.21823/2311-2905-2018-24-3-74-82.
19. **Hesarikia H, Rahimnia A, Emami Meybodi MK.** Differences between male and female sagittal spinopelvic parameters and alignment in asymptomatic pediatric and young adults. Minerva Ortop Traumatol. 2018;69:44–48. DOI: 10.23736/S0394-3410.18.03867-5.
20. **Legaye J, Duval-Beaupere G, Hecquet J, Marty C.** Pelvic incidence: a fundamental pelvic parameter for three-dimensional regulation of spinal sagittal curves. Eur Spine J. 1998;7:99–103. DOI: 10.1007/s005860050038.

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