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Analysis of sagittal curvature and its influencing factors in adolescent idiopathic scoliosis

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Abstract

This study aimed to explore the characteristics of changes in the sagittal arrangement of the spine between adolescent patients with idiopathic scoliosis (AIS) and normal adolescents, the risk factors for AIS and the factors affecting the progress of AIS.

X-ray images of the full length of the spine in standing position were taken in AIS patients and normal adolescents. Radiographic measurements made at intermediate follow-up included the following:C_1 and C_2 cervical lordosis and C_2 - C_7 curvature of cervical lordosis, C_2-C_7sagittal horizontal distance (C_2-C_7SagittalVerticalAxis, C_2-C_7SVA), TS-CL, after thoracic lobe (Thoracic Kyphosis, TK), thoracic lumbar segment Angle (thoracolumbar kyphosis, [TLK]), lumbar lordosis Angle (Lumbar Lordosis, LL), sacral slope Angle (Sacrum Slope, SS), pelvic tilt Angle (Pelvic Tilt, PT), pelvic incidence (PI), L_5 Incidence (Lumbar5 Slope (L_5S), L5 incidence (Lumbar5 Incidence (L_5I), sagittal horizontal distance ($_C$SVA), lower depression Angle of the 2nd cervical spine. The difference of sagittal plane parameters between AIS group and normal adolescent group was compared. To evaluate the progress of AIS, correlation analysis was conducted between diagonal 2 and other parameters. The main risk factors of AIS were determined by binary Logistic analysis.

The $_C$SVA of AIS patients was higher than that of healthy adolescents (AIS: 27.64 ± 19.56) mm. Healthy adolescents: (17.74 ± 12.8) mm), L5S (AIS: 19.93°= 7.07° and healthy adolescents: 15.38°= 7.78°, $P = .024 < .05$), C_2 downward sag Angle (AIS: 15.12°= 2.7°; Healthy adolescents: 12.97°= 4.56°); AIS patients had lower TS-CL (AIS: 22.48 ± 6.09 and healthy adolescents: 28.26°= 10.32°), PT (AIS: 10.42°= 4.53° and healthy adolescents: 15.80°=7.68°), (AIS: 41.87°=9.72° and healthy adolescents: 48.75°= 8.22°). The main risk factor for idiopathic scoliosis in adolescents was L_5 (OR = 1.239, 95%CI = 1.049–1.463, $P = .012 < .05$).

L_5S is a major risk factor for idiopathic scoliosis in adolescents. The larger PI is, the higher the risk of scoliosis progression is. In AIS patients, lumbar lordosis is increased, cervical lordosis is reduced, and even cervical kyphosis occurs.

Abbreviations: AIS = adolescent idiopathic scoliosis, L_5 = lumbar 5, L_5I = lumbar5 incidence, L_5S = lumbar5 slope, LL = lumbar lordosis, PI = pelvic incidence, PT = pelvic tilt, S_1 = sacrum 1, SS = sacrum slope, SVA = sagittal vertical axis, TLK = thoracolumbar kyphosis.

Keywords: adolescent idiopathic scoliosis, digital measurement, sagittal parameters

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1. Introduction

Adolescent idiopathic scoliosis (AIS) is the most common spinal deformity in adolescents.[1] It is a three-dimensional deformity of the coronal, sagittal, and horizontal surfaces of the spine. Patients with thoracic scoliosis have a higher incidence of neck pain, back pain and low back pain due to the presence of coronal plane deformity and reduced thoracic kyphosis [2] and abnormal spine biomechanics [3,4]. The loss of physiological curvature leads to pathological changes in the spine and accelerated disc degeneration, affecting the health-related quality of life of patients.[5] The incidence of sagittal imbalance in AIS patients is higher than that in healthy adolescents.[6] Sagittal imbalance in patients with spinal deformity is closely related to quality of life. When this balance is broken, spinal function is restricted, and corresponding symptoms will occur.[7] Glassman et al[8] and Mac-Thiong [9] found that when Sagittal Vertical Axis (/SVA /) > was 5 cm, it was in a state of spinal imbalance, and the patients' health-related quality of life score was reduced in this state. Themistocles et al. [10] reported that postoperative recovery of cervical lordosis in patients with spinal deformity was associated with health-related quality of life. And the pelvis plays an important role in the regulation of sagittal compensatory balance.

Currently, there are few reports on the change characteristics of the sagittal plane of AIS. For this reason, we studied the imaging data of AIS patients and normal adolescents, analyzed the change characteristics of the sagittal curvature of AIS, and analyzed the reasons for the change and its clinical significance.

2. Materials and methods

2.1. Subjects

Collection 60 teenagers who visited the Imaging department of Inner Mongolia International Mongolian Hospital from April 2014 to November 2018 were taken orthographic and lateral X-ray images [11] of the whole spine. Thirty (13 males and 17 females) were AIS patients with an Angle of 40°< Cobbs <80°was defined as cervical kyphosis. The control group was comprised of 30 normal adolescents, including 15 males and 15 females, aged 12 to 18 years, with an average of 15.2 years.

The protocol was approved by the medical ethics committee (YKD202001032) and all included patients expressed informed consent and participated in the study.

2.2. Hardware and software parameters

AIS patients and healthy adolescent volunteers took full-length frontal and lateral X-ray images of the standing spine (proximal over the anterior and posterior arch of the first cervical vertebra and distal to the femoral head 10 cm below). C_2-C_7 $\leq 0°$ was defined as cervical curvature straightening or lordosis, while C_2-C_7 $>0°$ was defined as cervical kyphotic. The measure processing of the (Joint Photographic Experts Group) data started using the "Mimics" (Materialise, Belgium). The linear and angular measurements were performed by 1 single examiner on the 2D pictures in Mimics. The measurement parameters are as follows:

1. Cervical sagittal alignment parameters: a. C_1-C_2 Cobb angle (C_1-C_2) was measured as the angle between the caudal endplate of cervical vertebra 1 and cervical vertebra 2. b. C_2-C_7 Cobb angle (C_2-C_7) was measured as the angle between the caudal endplate of cervical vertebra 2 and cervical vertebra 7. c. C_2-C_7 Sagittal Vertical Axis (C_2-C_7 SVA) was defined as the horizontal distance between the vertical line through the center of C_2 and posterior upper margin of C_7. When cSVA was greater than 4 cm, the health-related quality of life of the patients would be affected.[11,12] d. TS-CL: T_1 Slope minus CL (Fig. 1).
2. Thoracic kyphosis and Lumbar lordosis parameters: a. Thoracic Kyphosis (TK) was measured as the angle between the superior endplate of T_4 and the caudal endplate of T_{12}. b. Thoracolumbar kyphosis (TLK) was measured as the angle between the superior endplate of T_{11} and the caudal endplate of L_1. c. Lumbar Lordosis (LL) was measured as the angle between the upper edges of lumbar 1 (L_1) and sacrum 1 (S1) (Fig. 2).
3. Sagittal lumbosacral parameters: a. Sacrum Slope (SS) was measured as the angle between the superior endplate of S_1 and the horizontal line. b. Pelvic tilt (PT) was measured as the angle between the line connecting. c. Pelvic Incidence (PI) was measured as the angle between a line perpendicular to the superior endplate of sacrum 1 (S_1) at its midpoint and a line connecting this point to the center of the femoral heads. If the femoral heads did not overlap in the radiograph, the midpoint of the line connecting the center of the femoral head was taken as a reference point. d. Lumbar 5 Slope (L_5S) was measured as the angle between the superior endplate of L_5 and the horizontal line. e. Lumbar 5 Incidence (L_5I) was measured as the angle between a line perpendicular to the superior endplate of lumbar 5 (L_5) at its midpoint and a line connecting this point to the center of the femoral heads. If the femoral heads did not overlap in the radiograph, the midpoint of the line connecting the center of the femoral head was taken as a reference point (Fig. 3).
4. Global sagittal alignment parameters: a. Sagittal Vertical Axis (SVA) was defined as the horizontal distance between the vertical line through the center of C_7 and posterior upper margin of S_1. If the plumb line is located in front of the posterior upper margin of S1, then SVA is positive, otherwise it is negative. If SVA >5 cm, it is defined as unbalanced (Fig. 2).

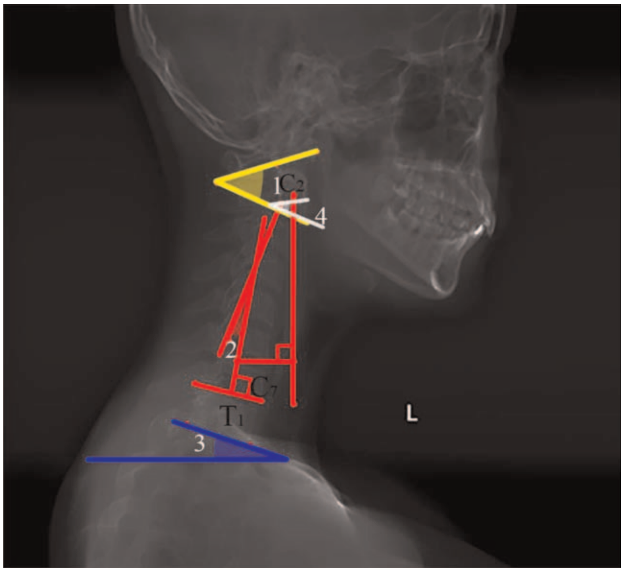

Figure 1. Sagittal parameters of cervical spine and depression of the lower margin of the second cervical spine (1: C_1-C_2; 2: C_2-C_7;3: T_1S;4: Depression of the lower margin of the second cervical spine).

Figure 2. Thoracic and lumbar spine sagittal plane parameters and sagittal plane horizontal distance (SVA).

b. Thoracic1 Slope (T_1S) was measured as the angle between the superior endplate of T_1 and the horizontal line (Fig. 1).

5. The growth of AIS and healthy adolescent volunteers was evaluated. Depression of the lower margin of C_2 (angle 2): the connection between the highest point at the bottom margin and the lowest point at the posterior margin of C_2 vertebral body and the lowest point at the bottom margin of C_2 vertebral body (Fig. 1).

2.3. Statistical analysis

The above parameters of each group of data were measured twice by the same person, and the mean value of the 2 results was used to represent the final value. SPSS25.0 software was used for statistical analysis. Descriptive statistical analysis was performed on AIS and healthy adolescent volunteers, and independent sample *t-test* was used to evaluate the differences between the 2 groups. Pearson correlation analysis was used for correlation analysis of diagonal 2 and other parameters to evaluate the progress of AIS. $P<.05$ was considered statistically significant.

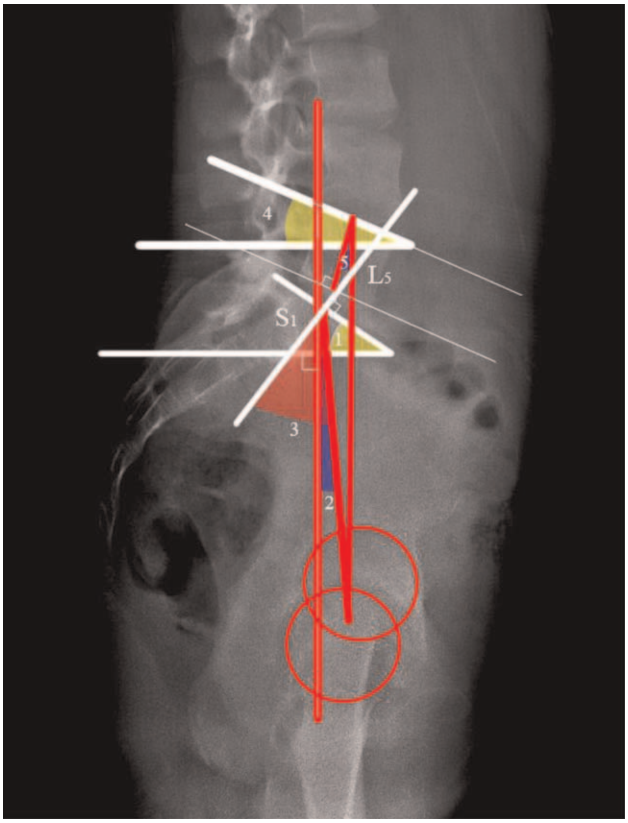

Figure 3. Sagittal lumbosacral parameters (1: SS; 2: PT;3: PI;4: L_5S; 5: L_5I).

3. Results

Compared with healthy adolescents, there were significant differences in T_1S, TS-CL, cSVA, C_2 downward depression Angle, SVA, L_5S, LL, PI and PT in AIS patients ($P<.05$). The following parameters were higher in AIS patients than in healthy adolescents: cSVA: AIS (27.64 ± 19.56) mm; Healthy adolescents: (17.74 ± 12.8) mm, $P=.024<.05$), L5S (AIS: 19.93°± 7.07° and healthy adolescents: 15.38°± 7.78°, $P=.024<.05$),C_2 downward recessed Angle AIS: 15.12°± 2.7°. Healthy adolescents: 12.97°± 4.56°, $P=.03<.05$), the following parameters were small: TS-CL (AIS: 22.48 ± 6.09 and healthy adolescents: 28.26° ± 10.32°, $P=.011<.05$), PT (AIS: 10.42°± 4.53° and healthy adolescents: 15.80°± 7.68°, $P=.002<.05$),PI (AIS: 41.87°± 9.72° and healthy adolescents: SVA (AIS:(3.53 ± 21.31) mm and healthy adolescents:(64.80 ± 72.51) mm, $P=.014<.05$). (Table 1).

Comparison of relevant parameters between AIS patients and healthy adolescents, there were significant differences between AIS patients and healthy adolescents in T_1S, TS-CL, cSVA, C_2 downward depression Angle, SVA, L_5S, LL, PI and PT ($P<.05$). The following parameters were higher in AIS patients than in healthy adolescents: cSVA: AIS (27.64 ± 19.56) mm; Healthy adolescents: (17.74 ± 12.8) mm, $P=.024<.05$), L_5S (AIS: 19.93° ± 7.07° and healthy adolescents: 15.38°± 7.78°, $P=.024<.05$), C_2 downward recessed Angle AIS: 15.12°± 2.7°. Healthy adolescents: 12.97°± 4.56°, $P=.03<.05$), the following param-

Table 1

Comparison of sagittal parameters between AIS patients and normal adolescents.

	Type	Cases	Min	Max	Average	Standard deviation	P	t
C_1C_2	Normal	30	−34.55	−20.45	−26.23	4.00	.955	0.057
	AIS	30	−33.63	30.35	−26.35	10.99		
C_2C_7	Normal	30	−21.78	−3.28	−8.97	6.54	.054	1.966
	AIS	30	−17.72	−4.78	−11.82	4.48		
T_1S	Normal	30	8.64	27.86	19.29	6.61	.000***	6.157
	AIS	30	4.23	16.84	10.67	3.9		
TS-CL	Normal	30	11.92	47.05	28.26	10.32	.011*	2.643
	AIS	30	9.58	30.01	22.48	6.09		
cSVA	Normal	30	3.12	41.30	17.74	12.8	.024*	−2.318
	AIS	30	12.30	76.54	27.64	19.56		
The downward sag Angle of C_2	Normal	30	3.60	22.36	12.97	4.56	.03*	−2.224
	AIS	30	10.85	20.82	15.12	2.7		
TK	Normal	30	8.24	34.89	21.12	10.53	.037*	−2.137
	AIS	30	12.43	47.02	27.26	11.69		
TLK	Normal	30	2.27	10.76	6.51	2.08	.406	−0.838
-								
	AIS	30	1.38	19.87	7.16	3.75		
SVA	Normal	30	−166.78	30.93	64.80	72.51	.000***	−4.44
	AIS	30	−38.26	25.14	3.53	21.31		
L_5I	Normal	27	2.52	26.18	8.06	5.57	.107	1.64
	AIS	30	0.10	17.77	5.90	4.37		
L_5S	Normal	27	2.48	33.63	15.38	7.77	.024*	−2.319
	AIS	30	3.47	36.53	19.93	7.07		
LL	Normal	25	17.42	65.30	41.32	12.47	.006**	−2.859
	AIS	30	34.01	65.40	49.51	8.73		
PI	Normal	30	38.35	76.31	48.75	8.22	.004**	2.96
	AIS	30	22.30	59.15	41.87	9.72		
SS	Normal	30	16.08	50.07	32.09	8.11	.281	−1.088
	AIS	30	18.95	47.42	34.37	8.10		
PT	Normal	30	1.41	35.36	15.80	7.68	.002**	3.305
	AIS	30	4.38	21.82	10.42	4.53		

L_5I = lumbar5 incidence, L_5S = lumbar5 slope, LL = Lumbar Lordosis, PI = pelvic incidence, PT = pelvic tilt, SS = sacrum slope, SVA = sagittal vertical axis, TLK = thoracolumbar kyphosis.
Note $^*P<.05$; $^{**}P<.01$; $^{***}P<.00$.

eters were small: TS-CL (AIS: 22.48±6.09 and healthy adolescents: 28.26°± 10.32°, $P=.011<.05$), PT (AIS: 10.42°± 4.53° and healthy adolescents: 15.80°± 7.68°, $P=0.002<.05$),PI (AIS: 41.87°± 9.72° and healthy adolescents: SVA (AIS:(3.53± 21.31) mm and healthy adolescents:(64.80±72.51) mm, $P=.014<.05$).(Table 1)

3.1. Correlations between progression of adolescent idiopathic scoliosis and other sagittal spinal parameters in AIS patients and normal controls

Correlation coefficient (r) is explained as follows: <.2 means weak correlation, 0.2 to 0.4 means weak correlation, 0.4 to 0.7 means moderate correlation, 0.7 to 0.9 means high correlation, and >0.9 means almost complete correlation. In the case group, the downward sag Angle of C_2 was moderately positively correlated with TS-CL and TLK. The downward sag Angle of C_2 is positively correlated with TK. The downward sag Angle of C_2 is negatively correlated with SVA. In the control group, the downward sag Angle of C_2 was negatively correlated with cSVA. The downward sag Angle of C_2 is negatively correlated with SVA. (Tables 2 and 3).

3.2. Binary logistic regression analysis

Binary logistic regression results showed that the main risk factors for idiopathic scoliosis in adolescents were L_5 (odds ratio) OR=1.239, 95% (confidence intervals) CI=1.049–1.463, $P=.012<.05$). (Table 4)

4. Discussion

Adolescent idiopathic scoliosis is a three-dimensional deformity that affects the physical and mental health of patients,[13,14] among which the changes and matching of cervical vertebra, thoracic vertebra, lumbar vertebra and pelvis in sagittal deformity correction have attracted the attention of physicians.[15,16] It is widely believed that sagittal spinal dislocation plays a crucial role in the mechanism of spinal disease. Hu et al [17] proposed that coronal deformity in AIS patients would lead to changes in sagittal parameters. Hwang et al[18] concluded that the thoracic kyphosis Angle of AIS patients with cervical kyphosis was significantly smaller than that of patients with cervical kyphosis.

Recently, more and more studies have been conducted on the changes of sagittal parameters of cervical spine.[19,20] In this study, it was observed that C_1-C_2 (-18.58°± 12.46° and −22.29° ± 13.60°, $P>.05$) and cSVA (1.40°± 0.94° and 1.52°± 1.12°, $P>.05$) decreased, and CL (7.56°± 4.97° and −2.72°± 10.92°, $P>.05$) increased. Chen et al [21] measured the changes in sagittal curvature of cervical spine in 43 cases of Lenke type 5 after posterior correction and found that postoperative improvement of TLK may contribute to the improvement of CSA. In addition,

Table 2

Correlation between C_2 downward depression Angle and other sagittal spine parameters.

	Type	Pearson correlation	Pearson significance (double-tailed)
C_1C_2	AIS	−0.028	0.883
	Normal	−0.056	0.77
C_2C_7	AIS	−0.368	0.045
	Normal	0.021	0.913
T_1S	AIS	0.241	0.199
	Normal	0.002	0.991
TS-CL	AIS	0.426*	0.019
	Normal	−0.012	0.95
cSVA	AIS	−0.325	0.08
	Normal	−0.544**	0.002
PT	AIS	−0.131	0.491
	Normal	−0.114	0.55
PI	AIS	0.274	0.143
	Normal	0.177	0.35
SS	AIS	0.198	0.295
	Normal	0.316	0.089
LL	AIS	0.023	0.902
	Normal	−0.004	0.984
TLK	AIS	0.455*	0.012
	Normal	0.302	0.105
TK	AIS	0.497**	0.005
	Normal	0.259	0.168
SVA	AIS	−0.472**	0.008
	Normal	−0.556**	0.001
L_5S	AIS	0.131	0.489
	Normal	0.185	0.357
L_5I	AIS	−0.109	0.567
	Normal	0.06	0.765

L_5I = lumbar5 incidence, L_5S = lumbar5 slope, LL = lumbar lordosis, PI = pelvic incidence, PT = pelvic tilt, SS = sacrum slope, SVA = sagittal vertical axis, TLK = thoracolumbar kyphosis.
* At the level of 0.05 (double-tailed); the correlation was significant.
** Significant correlation at 0.01 level (double tails).

Table 3

Correlation analysis between L_5S and other sagittal spine parameters in AIS and normal adolescents.

	Type	Pearson correlation	Pearson significance (double-tailed)
C_1C_2	AIS	−0.154	0.415
	Normal	0.324	0.099
CL	AIS	0.137	0.47
	Normal	0.414*	0.032
T_1S	AIS	−0.173	0.36
	Normal	−0.29	0.142
TS-CL	AIS	−0.212	0.261
	Normal	−0.432*	0.024
cSVA	AIS	0.089	0.642
	Normal	−0.276	0.163
PT	AIS	0.078	0.681
	Normal	−0.421*	0.029
PI	AIS	0.448*	0.013
	Normal	0.496**	0.009
SS	AIS	0.494**	0.005
	Normal	0.841**	0.000
LL	AIS	0.297	0.111
	Normal	0.622**	0.002
TLK	AIS	−0.14	0.46
	Normal	−0.312	0.113
TK	AIS	−0.068	0.72
	Normal	−0.312	0.113
SVA	AIS	−0.056	0.769
	Normal	−0.526**	0.005
L_5I	AIS	−0.144	0.448
	Normal	−0.568**	0.002

L_5I = lumbar5 incidence, L_5S = lumbar5 slope, LL = lumbar lordosis, PI = pelvic incidence, PT = pelvic tilt, SS = sacrum slope, SVA = sagittal vertical axis, TLK = thoracolumbar kyphosis.
* At the level of 0.05 (double-tailed); the correlation was significant.
** Significant correlation at 0.01 level (double tails).

there was a significant difference in cervical curvature between the sexes. Machino et al [22] found that the anterior convex Angle of cervical vertebra was larger in males than in females. The incidence of cervical sagittal abnormalities was higher in AIS patients, and Wang et al[19] found that all patients had improved CSA after surgery compared with those before surgery.

The results of this study showed that C_1-C_2 Angle decreased, cervical anterior convex Angle increased, and the sagittal position distance of cervical spine decreased, suggesting that the curvature of AIS cervical sagittal plane was mainly convex after abnormal. Thus, we concluded that the reduction of AIS thoracic kyphotic was to compensate for the shortening of the sagittal plane of the spinal balance and the reduction of the cervical anterior convex Angle and even the kyphotic Angle. However, the change of the cervical vertebrae sequence resulted in the increase of the visual Angle of elevation, and the body adjusted the upper cervical vertebrae sequence by reducing the C_1-C_2 Angle to maintain the anterior balance.

In our study, it was observed that SS in adolescent idiopathic scoliosis patients increased (34.37°± 8.10° and 32.09°± 8.11°, $P>.05$), PT (10.42°± 4.53° and 15.80°± 7.68°, $P<.05$), and PI (41.87°± 9.72° and 48.75°± 8.22°, $P<.05$). Pelvic incidence (PI) is an anatomical parameter (Yazay et al, 2017), which does not change in adulthood. The sacrum inclination and the pelvic inclination are postural parameters, and PI=PT+SS. The study results of Yuan et al (Yuan et al, 2019) showed that in patients with Lenke type 1 AIS, compared with non-selective fusion, selective fusion not only has an important value in maintaining lumbar mobility, but also retains the compensatory function of the posterior rotation of the pelvis from the standing position to the sitting position. In combination with previous studies, we suggest that PI maintains the sagittal balance of the spine by affecting the degree of Sacrum Slope (SS) and thus the degree of lumbar lordosis (LL).[23] The experimental results showed that the LL value of adolescent idiopathic scoliosis patients significantly increased LL (49.69°± 8.83° and 41.32°± 12.47°, $P<.05$). LL is very important for maintaining the upright posture of human body. Qiu et al [24] reported that LL value of healthy adolescents was close to (49.3°± 9.9°). Previous studies have reported a moderate or high correlation between LL and TK in AIS patients [25] and lumbar lordosis is mainly associated with thoracic sagittal plane balance and pelvic sagittal plane balance.[15,26] Labella et al. [27] proposed the concept of L_5I, which was positively correlated with the degree of lumbar spondylolisthesis. In the experiment, the L_5I value of AIS patients was reduced (5.90°± 4.37° and 8.06°± 5.57°, $P>.05$). The L_5S value of AIS patients was significantly increased (AIS: 19.93°± 7.07° and 15.38°± 7.78°, $P<.05$), indicating that the L_5 vertebral body was inclined forward and downward.

Binary Logistic regression analysis showed that the main risk factors for AIS were L_5S (OR=1.239, 95% CI=1.049–1.463, $P=.012<.05$), and L5S was significantly correlated with other

Table 4

Analysis of risk factors for adolescent idiopathic scoliosis.

	B	Standard error	Wald	*P*	OR	95% CI
L_5I	0.201	0.262	0.585	.444	1.222	0.731–2.043
L_5S	0.214	0.085	6.381	.012	1.239	1.049–1.463
LL	0.039	0.051	0.589	.443	1.04	0.941–1.149
PI	−0.115	0.1	1.326	.25	0.892	0.733–1.084
SS	0.005	0.104	0.002	.962	1.005	0.82–1.232
PT	−0.133	0.2	0.443	.506	0.875	0.591–1.296
Constant	0.372	2.605	0.02	.886	1.451	

CI = confidence intervals, L_5I = lumbar5 incidence, L_5S = lumbar5 slope, LL = lumbar lordosis; OR = odds ratio, PI = pelvic incidence, PT = pelvic tilt, SS = sacrum slope.

sagittal parameters, such as PI and SS.L_5S and PI (AIS: $r=0.448$, $P=.013<.05$, normal adolescents: $R=0.496$, $P=.009<.05$), L_5S and SS (AIS: $r=0.494$, $P=.005<.05$, normal adolescents: $r=0.841$, $P=.000<.05$). Zhang et al[28] found that PI is closely related to disc degeneration of L_5/S_1. We concluded that with an increase in L_5S, biomechanical factors would cause accelerated disc degeneration, leading to an increase in PI, an increase in sacral inclination, and a change in the spin-pelvis sagittal plane. In order to maintain the gravity balance of the spine, the lumbar lordosis Angle would be compensated.

As for the progression of idiopathic scoliosis in adolescents, Chen et al[29] found that the depression at the lower edge of the second cervical vertebra (Angle 2) was significantly correlated with wrist bone age ($r=0.86$), that is, the depression at the second cervical vertebra could predict bone age. In addition, in this study, there was a highly negative correlation between C_2 downward depression Angle and SVA ($R=-0.472$, $P=.008<.05$). Therefore, C_2 downward depression Angle was used as a parameter index to predict the growth peak of adolescents and the progression of adolescents with idiopathic scoliosis. In the case group, the downward sag Angle of C_2 was moderately positively correlated with TS-CL and TLK. The downward sag Angle of C_2 is positively correlated with TK.C_2 recesses downward. In the control group, C_2 downward depression Angle and the downward sag Angle of C_2 is negatively correlated with SVA. The correlation analysis showed that the depression of the lower margin of the 2nd cervical spine was moderately negatively correlated with cSVA ($r=-0.544$, $P=.002<.05$), and highly negatively correlated with SVA ($r=-0.556$, $P=.001<.05$) in normal adolescents. Since adolescent bones are at the peak of growth and development, the pelvic anatomical parameter PI increases with age and the degree of sacral inclination also increases, so the spin-pelvis sagittal plane balance plays a significant role in bone development.[30] But this article adolescent idiopathic scoliosis patients compared with normal adolescents showed no PI, SS and bone growth aspects, such as correlation, we suggest that patients with AIS spinal growth lost balance, spinal and pelvic sagittal balance, disappear for AIS progress adjustment, so we think that to maintain the spine - the pelvis in sagittal balance can prevent progress in AIS.

This paper has the following limitations: due to the small number of samples in the case group and the control group, the AIS patients were not followed up for investigation, and it was limited to the imaging measurement studies, resulting in errors in the measurement values of sagittal parameters. Moreover, due to the limitation of sample size, Lenke typing of AIS was not conducted, and differences between different types for experimental results were not discussed. Multicenter prospective studies with larger samples are still needed to further improve this system.

This study mainly analyzed the characteristics of spinal sagittal alignment changes between adolescent idiopathic scoliosis patients and normal adolescents and discussed the risk factors for AIS and related studies on the development of AIS. L_5S is a major risk factor for AIS, and is strongly correlated to the L_5S, PI, SS L_5S increases after the compensatory increase PI, SS, maintain the spine and pelvic sagittal balance, decompensation after lumbar lordosis Angle increases, such as 3 dimensional rotation of spine in thoracic vertebra protruding after decreases, and smooth back deformity, resulting in lumbar lordosis Angle increase jointly maintain sagittal balance, and upper cervical sequence C_1C_2 Angle decreases, and balance the forward-looking. The above studies are helpful to infer the causes of sagittal plane changes in patients with adolescent idiopathic scoliosis, delay the progress of AIS, and provide references for constructing the sagittal balance of AIS [12,31,32] in orthopedic surgery to improve patients' quality of life.

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