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ORIGINAL ARTICLE

Correlation analysis between postoperative hip pain and spino-pelvic/hip parameters in adult scoliosis patients after long-segment spinal fusion

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Abstract

Purpose To explore the correlations between postoperative hip pain and spino-pelvic/hip parameters in adult scoliosis patients after long-segment spinal fusion.

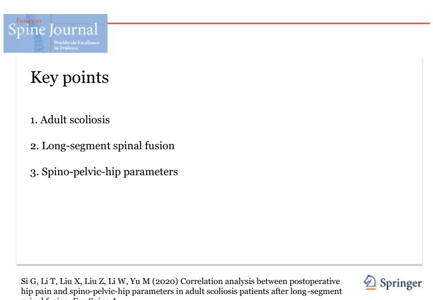
Methods We retrospectively identified adult scoliosis patients who underwent long-segment spinal fusions between December 2009 and August 2015. The patients were divided into a pain group (PG) and a control group (CG) based on whether hip pain was reported at the end of follow-up. There were 34 cases in the PG and 42 in the CG. The visual analogue scale was employed to assess the postoperative hip pain in PG patients. Two sets of parameters were recorded: one before and one after the surgery.

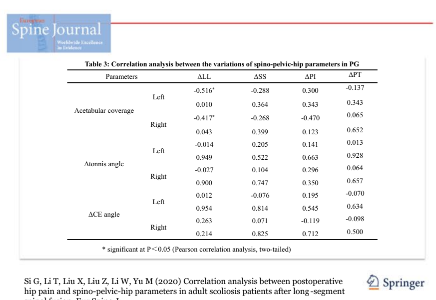
Results There were statistically significant differences in the variations in acetabular coverage and centre-edge (CE) angle between the two groups ($p < 0.05$), but there was no significant difference in the Tönnis angle, acetabular angle of Sharp, neck-shaft angle, lumbar lordosis (LL), sacral slope, pelvic incidence, pelvic tilt, coronal vertical axis, sagittal vertical axis or Cobb angle. The variation in acetabular coverage before and after operation in the PG was significantly correlated with that of LL ($p < 0.05$), while the changes in the CE angle and Tönnis angle were not significantly correlated with those in spino-pelvic parameters ($p > 0.05$).

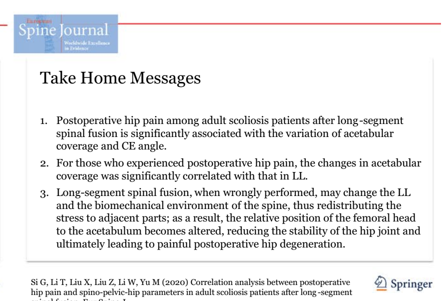
Conclusion Postoperative hip pain among adult scoliosis patients after long-segment spinal fusion is significantly associated with the variation in acetabular coverage and CE angle, and the change in acetabular coverage is correlated with that in LL for those who develop hip pain after the surgery.

Graphic abstract

These slides can be retrieved under Electronic Supplementary Material.







Gao Si and Tong Li have contributed equally to this work.

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Keywords Adult scoliosis · Long-segment spinal fusion · Hip joint · Spino-pelvic/hip parameters · Acetabular coverage

Introduction

Adult scoliosis is defined as a coronal deformity with a Cobb angle > 10° in a skeletally mature patient and can be subdivided into adult idiopathic scoliosis and adult degenerative scoliosis according to its causes. Based on epidemiological studies in approximately the past decade, the incidence of adult scoliosis is estimated at 17.0–29.4% [1, 2] and has reached as high as 60.0% among elderly people over 60 years old [3]. As the ageing of modern society accelerates, adult spinal deformity has become an increasingly serious public health problem [4, 5]. Adult scoliosis can lead to a variety of clinical symptoms, including low back pain, neurological dysfunction, loss of labour capacity, etc. These symptoms progressively worsen, and some patients may also develop sagittal and coronal spinal tilt. Patients with adult scoliosis usually also suffer from various dysfunctions in their daily lives, including lower limb gait changes and limb alignment abnormalities, which would harm weight-bearing joints such as the hips, knees and ankles and accelerate the progress of osteoarthrosis. Surgical treatment is an important way to alleviate the clinical symptoms of such patients. The purposes of this treatment method are to relieve pain, stabilize the spine and recover spinal balance. At present, the surgical protocols for adult scoliosis are mostly decompression only or decompression with short-/long-segment fixation [3]. Studies have shown that spinal fusion surgeries would lead to increased bio-stress on and thus accelerated degeneration of adjacent segments, which requires additional surgical intervention, despite their satisfactory correction of deformity and improvement of spinal balance [6]. However, few studies have examined the effects of long-segment spinal fixation and fusion to the sacrum or ilium on the motion trajectories of lower extremities, especially those on the hip joints, which are closely connected to the pelvis. This article aims to explore the correlations between postoperative hip pain and spino-pelvic/hip parameters in adult scoliosis patients after long-segment spinal fusion.

Materials and methods

The study recruited a consecutive series of 67 patients with adult scoliosis who underwent surgical treatment at our hospital from December 2009 to August 2015. The inclusion criteria included the following: (1) presence of adult scoliosis with a Cobb angle greater than 10°; (2) completion of a long-segment spinal fusion surgery (number of fusion segments greater than or equal to four, with the caudal anchorage to the sacrum or ilium); (3) no hip pain or acetabular dysplasia before surgery; (4) complete clinical data; and (5) follow-up period of more than 2 years. The exclusion criteria included (1) congenital diseases, spinal cord injury, skeletal muscle dysplasia or other factors affecting the diagnosis; (2) previous surgeries on the spine, pelvis, hip joint or other parts that might alter the spino-pelvis/hip parameters; and (3) combined with pelvic deformity, unequal length of lower limbs, lumbar spondylolisthesis or other conditions that might affect the abovementioned measurements. A total of 76 eligible subjects were enrolled in this study, including 22 males and 54 females. The average age was 58.7 ± 14.5 years (range 20–76 years). Clinical data, including age, gender, body mass index (BMI), operative time, hospitalization time, number of fusion segments, postoperative hip pain, spino-pelvic/hip parameters, were collected. All patients underwent regular follow-ups. In cases where postoperative hip pain was reported, VAS score (0–10 points) was used to evaluate the severity, and the pain areas were also recorded (including anterior superior iliac spine, iliac crest, posterior superior iliac spine, sacroiliac joint, femoral greater trochanter, pubic symphysis, the dorsal side of the ischial tuberosity, lower end of ischial tuberosity, inguinal region, hip joint, piriformis, etc.)

All patients received radiography both prior to their operation and at the last follow-up. Each patient's radiography data consisted of standing posteroanterior and lateral radiographs of the full spine. The patients stood in an upright position and gazed horizontally, with the extensions of knees and hip joints and the flexion of elbow joints (with the hands placed above the clavicle of the same side). The scope of radiography extended from the base of the skull to the proximal femur. The digital images were stored and extracted for measurement through the Picture Archiving and Communication Systems (PACS) (GE, USA). To reduce systematic bias, the measurement was first conducted independently by two researchers alone and then averaged. The following spino-pelvic parameters were measured (Fig. 1): (1) lumbar lordosis (LL), i.e. the angle between the upper end plate of the L1 and that of the S1 [7]; (2) sacral slope (SS), i.e. the angle between the end plate of the S1 and the horizontal line [8]; (3) pelvic incidence (PI), i.e. the angle between the line perpendicular to the S1 end plate at its midpoint and the line connecting this point to the femoral head axis [9]; (4) pelvic tilt (PT), i.e. the angle between a vertical line and the line from the centre of the femoral axis to the midpoint of the sacral end plate; (5) coronal vertical axis (CVA), i.e. the distance of the C7 plumb line from the centre sacral vertical line [10]; and (6) sagittal vertical axis (SVA), i.e. the

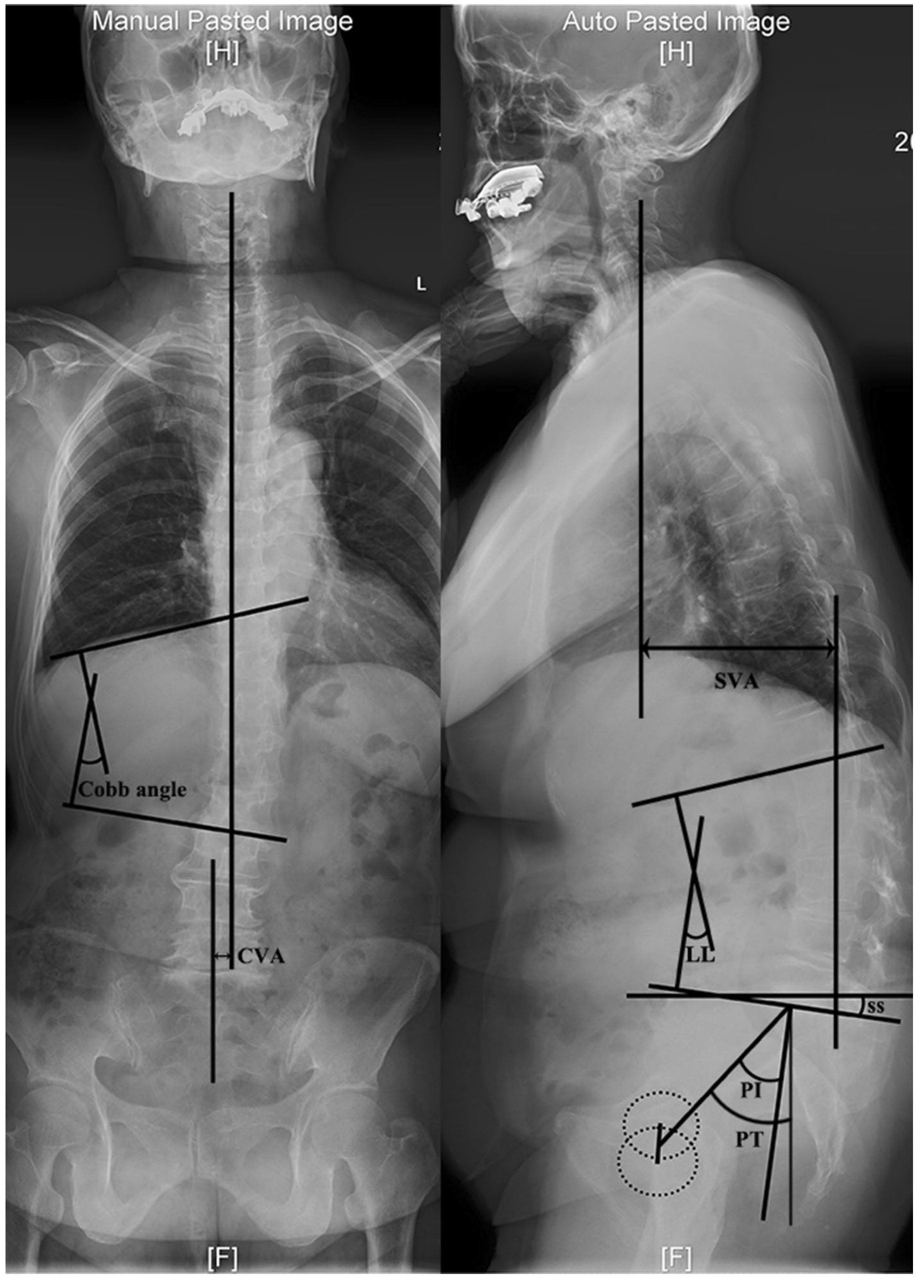

Fig. 1 Measurements of selected spinal parameters

distance from the posterior edge of the upper S1 end plate to the plumb line through the centre of the C7 [11].

The hip parameters being measured included the following (Fig. 2): (1) the centre-edge (CE) angle, i.e. the angle between a vertical line and the line connecting the femoral head centre with the lateral edge of the acetabulum [12]; (2) the acetabular angle of Sharp, i.e. the angle formed by a horizontal line connecting both triradiate cartilages and a line parallel to the acetabular roof [12]; (3) acetabular coverage, i.e. the transverse diameter of the partial femoral head covered by the acetabulum divided by that of the whole femoral head [12]; (4) the Tönnis angle, i.e. the angle between the horizontal line passing the inner edge of the acetabular arch and the line connecting the inner edge and the outer edge of the acetabular arch [13]; and (5) the femoral neck-shaft angle, i.e. the medial angle between the axis of the femoral shaft and that of the femoral neck on an anteroposterior radiograph of the hip joint [14]. All hip parameters were measured bilaterally.

SPSS 20.0 was used to analyse the data. Each parameter was compared before the operation, and at the last follow-up, and the variation was counted as Δ. All measurement data that conformed to the normal distribution were presented as $\bar{x} \pm s$, and t test and variance analysis were used for intergroup comparisons. For patients who reported hip pain at follow-up, the Pearson correlation coefficient was employed

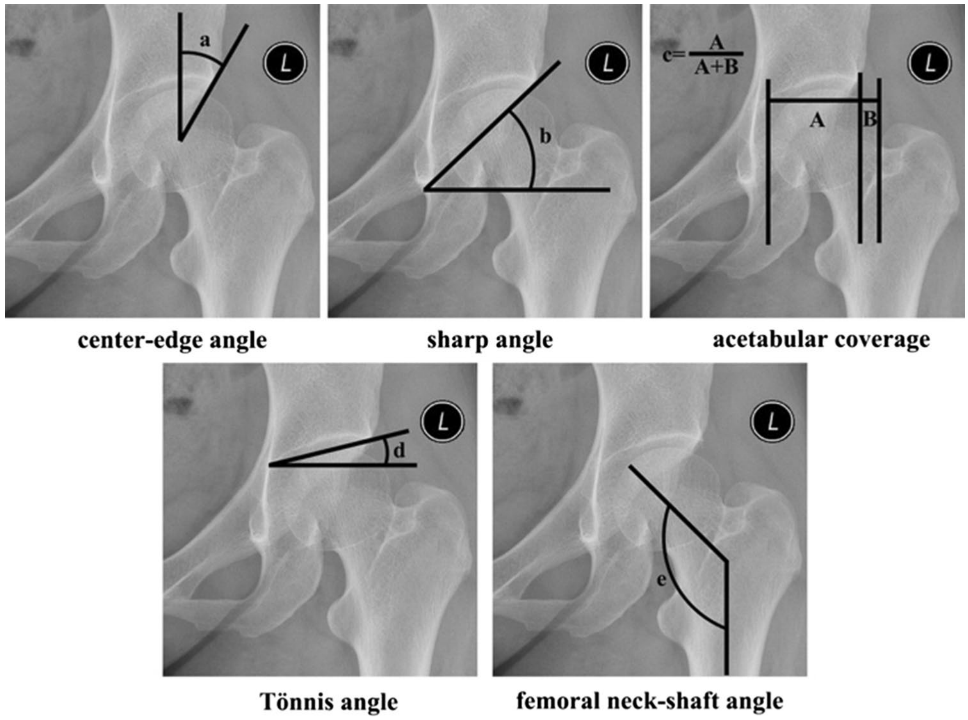

Fig. 2 Measurements of selected hip joint parameters. **a** Centre-edge angle (CE angle): the angle between a vertical line and the line connecting the femoral head centre with the lateral edge of the acetabulum. **b** Sharp angle (acetabular angle): the angle formed by a horizontal line connecting both triradiate cartilages and a line parallel to the acetabular roof. **c** Tönnis angle: the angle between the horizontal line passing the inner edge of the acetabular arch and the line connecting the inner edge and the outer edge of the acetabular arch. **d** Acetabular coverage: the transverse diameter of the partial femoral head covered by the acetabulum divided by the that of the whole femoral head. **e** Femoral neck-shaft angle: the medial angle between the axis of the femoral shaft and that of the femoral neck on an anteroposterior radiograph of the hip joint

to examine the relationships between acetabular coverage, Tönnis angle, CE angle, LL, SS, PI and PT. Statistical significance was set at $p < 0.05$.

Results

The number of segments in the spinal fusion ranged from four to 13 among the patients, and all fusions involved caudal anchorage to the sacrum or ilium. The average BMI was 26.0 ± 4.4 kg/m^2 (range 16.8–34.5 kg/m^2). Based on whether hip pain was reported in the last follow-up, the patients were divided into a pain group (PG) and a control group (CG). There were 42 subjects in the CG and 34 in the PG, among which ten experienced pain at the left hip, ten at the right hip and 14 at both hips. The distribution of postures that caused hip pain was as follows: for the left hip pain, four cases were caused by flexion, three by extension, ten by abduction, six by adduction and one by external rotation; for the right hip pain, four cases were caused by flexion, seven by extension, three by abduction, six by adduction, two by internal rotation and one by external rotation. The pain areas involved the sacroiliac joint in five cases, the ischial tuberosity region in 15 cases, the femoral greater trochanter in ten cases, the inguinal region in three cases and other areas in one case. The average Visual Analogue Scale (VAS) pain score in the PG was 3.9 ± 1.4 points (range 2–7 points). There were no statistically significant differences between the two groups in age, gender, number of fusion segments, BMI and the occurrence of S-2 alar iliac (S2AI) screw fixation (Table 1). All patients were followed up for at least 2 years, and the average follow-up time was 66.2 ± 22.8 months (range 24–110 months). For the PG, the average time of postoperative pain onset was 14.5 ± 5.8 months (range 5–27 months).

Table 1 Comparisons of demographic information between PG and CG ($\bar{x} \pm s$)

Demographics	PG	CG	*p*
Age (years)	61.7 ± 12.7	56.5 ± 16.6	0.191
Sex ratio (male/female)	8/26	9/33	0.287
Number of segments in the fusion	6.1 ± 2.4	6.5 ± 2.0	0.568
BMI	26.7 ± 4.0	25.6 ± 4.6	0.368
Number of S2AI cases*	8	10	0.698

*S2AI: second sacral alar iliac screw fixation

The patients received interventions to relieve the symptoms, such as health education, weight loss, joint activity training, muscle strength training and pain medication. They also underwent regular reexaminations, and no pain progression was observed during the study.

There were statistically significant differences in the variations in acetabular coverage and CE angle between the two groups ($p < 0.05$), but none in those of Tönnis angle, acetabular angle of Sharp, neck-shaft angle, LL, SS, PI, PT, CVA, SVA and Cobb angle (Table 2). The variation in acetabular coverage before and after operation in the PG was significantly correlated with that of LL angle ($p < 0.05$), while the changes in CE angle and Tönnis angle were not significantly correlated with those in spino-pelvic parameters ($p > 0.05$). In addition, the posteroanterior radiographs of the hip at the last follow-up for 18 patients in the PG showed hip joint degenerations, such as increased density at the upper edge of acetabulum, the formation of fine osteophytes at the concave edge of the femoral head and joint space narrowing.

Discussion

The pelvis is critical to maintaining the body posture, and it works synergistically with the spine to keep normal sagittal and coronal balances. The hip joint is the transmission shaft that links the pelvis and lower limbs. This site is also the initial force point during walking, which not only drives the lower limbs to move, but also stabilizes the self-balancing adjustment of the pelvis and spine. When lesions occur to the spine, especially when the LL is reduced or disappears (such as in ankylosing spondylitis), the LL can be altered to help maintain the normal spine posture through bending the knee and adjusting the PT or other compensatory mechanisms [15]. Spinal degenerative lesions can affect the hip joint through the compensatory mechanism of PT, thereby increasing the pressure on the hip joint and leading to femoro-acetabular impingement syndrome or osteoarthritis. With an increasingly ageing population, the incidence of degenerative spondyloarthropathy is growingly higher. In 1983, Offierski and MacNab first reported spine-hip syndrome, in which hip osteoarthritis could cause flexion deformity in the hip joint and the pelvis to lean forward. As a compensation, the lumbar spine becomes excessively lordotic to maintain the sagittal balance [16]. In addition, scoliosis may also compensate the spine to its optimal position by changing the direction of the pelvis. These changes lead to an increase in PT which may accelerate hip degeneration and cause hip discomfort. Long-segment spinal fusion is a common surgical method for scoliosis, but its impacts on hip joints have rarely been investigated. Our study aimed to explore the correlation between hip pain and the spino-pelvic/hip parameters after spinal fusion.

The hip joint consists of the acetabulum and the femoral head and is the largest and most stable joint in the human body. Both acetabular coverage and CE angle are indicators of the relative position between the femoral head and the acetabulum and of the stability of the femoral head within

Table 2 Comparisons of spino-pelvic/hip parameters between PG and CG

Parameters	PG			CG		
	Preoperative	Postoperative (last follow-up)	Variation	Preoperative	Postoperative (last follow-up)	Variation
LL (°)	20.2 ± 25.1	24.3 ± 28.8	2.6 ± 17.3	26.5 ± 21.2	30.4 ± 16.3	− 6.0 ± 16.0
SS (°)	22.1 ± 9.2	28.2 ± 7.0	− 1.4 ± 8.3	24.8 ± 12.7	27.6 ± 10.4	− 3.9 ± 9.1
PI (°)	47.4 ± 11.3	48.4 ± 14.2	1.2 ± 12.5	50.0 ± 12.4	51.3 ± 12.5	1.3 ± 6.6
PT (°)	25.3 ± 12.1	20.2 ± 11.2	5.1 ± 11.7	26.5 ± 12.6	23.7 ± 9.8	2.8 ± 11.2
CAV (mm)	16.7 ± 60.3	6.8 ± 34.4	2.5 ± 40.3	13.2 ± 28.4	8.7 ± 25.3	3.2 ± 28.2
SAV (mm)	79.2 ± 81.3	56.5 ± 31.7	− 19.2 ± 37.0	50.8 ± 48.4	52.6 ± 37.3	5.0 ± 51.4
Cobb angle (°)	53.1 ± 14.0	14.2 ± 8.6	21.2 ± 9.3	49.5 ± 14.0	13.3 ± 6.5	16.0 ± 12.1
Acetabular coverage (%)						
Left	83.2 ± 7.3	81.6 ± 6.0	0.67 ± 3.1	83.6 ± 6.1	84.3 ± 6.0	− 1.3 ± 2.8*
Right	83.4 ± 6.4	82.6 ± 6.4	0.75 ± 3.6	83.5 ± 6.1	83.8 ± 5.9	− 0.90 ± 2.8*
Tönnis angle (°)						
Left	6.1 ± 3.5	6.8 ± 6.7	− 2.4 ± 4.7	6.4 ± 6.2	6.5 ± 6.6	− 0.31 ± 3.8
Right	4.0 ± 4.6	5.2 ± 6.2	− 0.04 ± 3.9	7.2 ± 6.4	6.6 ± 7.0	0.30 ± 3.3
CE angle (°)						
Left	31.2 ± 9.3	33.1 ± 7.5	0.27 ± 3.3	33.6 ± 6.9	34.1 ± 7.7	− 1.7 ± 3.9*
Right	36.6 ± 7.4	36.1 ± 8.6	1.8 ± 3.0	34.3 ± 7.7	34.5 ± 7.2	− 0.1 ± 3.9*

*Different from PG with statistical significance ($p < 0.05$, t test) the acetabulum. The Tönnis angle reflects the degree of inclination of the acetabular bearing surface on the pelvic plain radiograph and indirectly reveals the relative positional change between the acetabulum and the femoral head. In this study, there were no significant differences in age, gender, number of fusion segments and BMI between the PG and the CG. However, the two groups showed a statistically significant difference in the variation in acetabular coverage and that of CE angle (Table 2). This result suggests that hip pain after long-segment spinal fusion may be due to changes in the relative position of the femoral head to the acetabulum, which would reduce acetabular coverage and accelerate hip degeneration. The correlation analysis of spino-pelvic/hip parameters in the PG showed that the change in acetabular coverage before and at the last follow-up was significantly correlated with the change in LL (Table 3), which further suggests that spinal fusion surgery, when wrongly performed, might change the lumbar lordosis and cause the pelvis to lean forward, thus changing the relative position of the femoral head to the acetabulum and reducing the posterior acetabular coverage (Fig. 3). As a result, the impacts between the femoral head cartilage and the bone surface would increase significantly during joint movements, accelerating joint degeneration. Long-segment spinal fusion without pelvic fixation can cause a significant increase in PI, which may lead to further pain of adjacent parts [17]. There was no significant difference in the variation in PI between the two groups in our study, which may indicate that the variation in PI has no correlation with postoperative hip pain. We also investigated whether the number of fusion segments would impact the likelihood of postoperative hip pain,

Table 3 Correlation analysis between the variations in spino-pelvic/hip parameters in PG

Parameters	ΔLL	ΔSS	ΔPI	ΔPT
Acetabular coverage				
Left	−0.516*	−0.288	0.300	−0.137
	0.010	0.364	0.343	0.343
Right	−0.417*	−0.268	−0.470	0.065
	0.043	0.399	0.123	0.652
ΔTönnis angle				
Left	−0.014	0.205	0.141	0.013
	0.949	0.522	0.663	0.928
Right	−0.027	0.104	0.296	0.064
	0.900	0.747	0.350	0.657
ΔCE angle				
Left	0.012	−0.076	0.195	−0.070
	0.954	0.814	0.545	0.634
Right	0.263	0.071	−0.119	−0.098
	0.214	0.825	0.712	0.500

*Significant at $p < 0.05$ (Pearson correlation analysis, two-tailed)

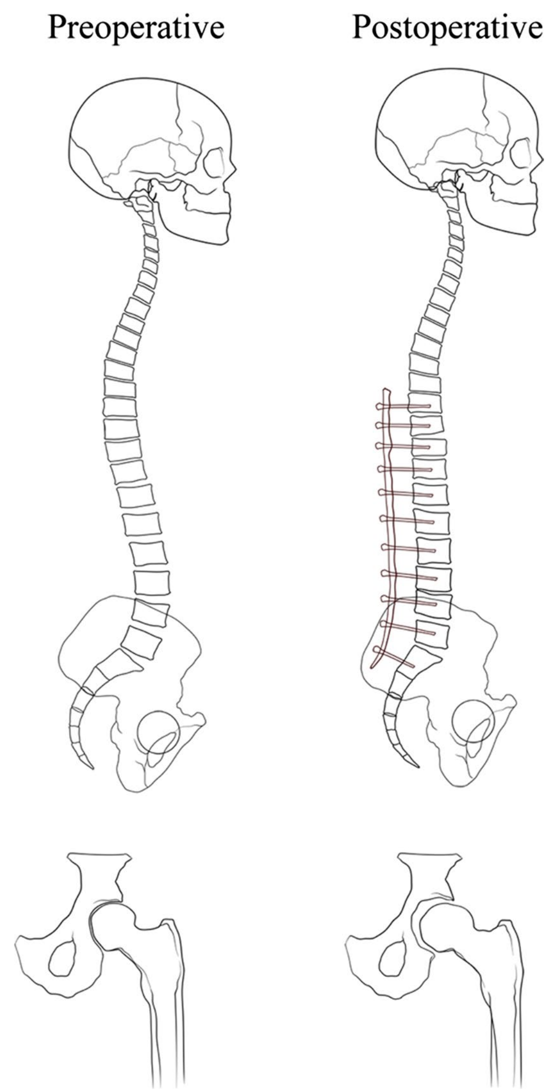

Fig. 3 Spine and hip joint morphology before and after surgery. Long-segment spinal fusion surgery, when wrongly performed, changes the lumbar lordosis and causes the pelvis to lean forward, thus changing the relative position of the femoral head to the acetabulum and reducing the posterior acetabular coverage

but the results showed no statistically significant difference, which is consistent with Merritt's conclusion [18]. In this study, there were eight patients in the PG and ten patients in the CG who received S2AI screw fixation, and none of them experienced screw loosening at the last follow-up. In this regard, there was no statistically significant difference between the two groups, which indicates that the S2AI screw fixation would not cause sacroiliac joint pain.

Existing studies have reported that long-segment spinal fusion will transfer forces to the adjacent segments and joints and exert tremendous pressure on them; these long fusions also change the biomechanical environment and load-sharing ability of their adjacent segments or joints

[19–21]. These abnormal pressures caused by long-segment fusions fixed to the sacrum or ilium can also be transferred to the pelvis and hip joints [22, 23]. These could be a reasonable explanation for the results of our study.

Several limitations of this study should be acknowledged. First, this was a single-centre retrospective study and our sample size was relatively small. Therefore, the generalizability of our findings could also be limited. Second, the symptoms of hip pain were reported subjectively, mainly from patient medical records or postoperative follow-up. This made it difficult to objectively quantify the extent and number of hip lesions among the patients. Third, since our major goal in this study was to determine the connections between hip pain and spino-pelvic/hip parameters after long-segment spinal fusion and to explore their mechanisms, we were not able to further analyse the mechanical effects of long-segment fusion on the pelvis and the hip joint and their role in hip joint degeneration. Fourth, Boachie-Adjei et al. have reported that sacroiliac degeneration can occur in 75% of the patients who have undergone long-segment fusion [24], as the postoperative stress might be absorbed by the sacroiliac fusion or terminate in the ilium. However, whether it will cause postoperative pain needs further confirmation.

Conclusion

This study suggests that hip pain after long-segment spinal fusion in adult scoliosis patients is associated with changes in acetabular coverage and CE angle. For those who experienced postoperative hip pain, the acetabular coverage was significantly correlated with the changes in LL. A possible mechanism for this phenomenon is that long-segment spinal fusion, when wrongly performed, may change the LL angle and the biomechanical environment of the spine, thus redistributing the stress to adjacent parts; as a result, the relative position of the femoral head to the acetabulum becomes altered, reducing the stability of the hip joint and ultimately leading to painful postoperative hip degeneration among some patients.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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