Analysis of Coronal And Sagittal Spinopelvic Parameters In Developmental Dysplasia of The Hip

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Research Article

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Abstract

Background: The observational study aimed to investigate the change and correlations of the spinopelvic parameters as well as the relationships with the related symptoms in unilateral developmental dysplasia of the hip (DDH) patients.

Methods: The clinical data of 22 unilateral DDH patients and 20 healthy volunteers were collected from 2016 to 2021. All patients and volunteers were taken the antero-posterior pelvic radiograph and the frontal and lateral radiography of the whole spine as a routine examination. And the clinical symptoms, signs and functions were measured according to *Oswestry Disability Index* and *Low Back Pain Scoring System*. Then the t test and Pearson correlation were used to analyze the data.

Results: The Cobb(8.68±6.21°), L3(4.79±5.47°), CB(1.65±1.57cm), PT(15.02±9.55°) and TLK (7.69±6.66°) were significantly larger in the DDH patients, whereas LL(37.41±17.17°) were significantly smaller (P< 0.05). As for the coronal spinopelvic parameters, CB was found to be associated with L3 (R=0.58, P< 0.01). Of the sagittal spinopelvic parameters, SS was found to be associated with LL (R=0.48, P=0.02), and TLK was found to be related to ST and TK, respectively (R=0.49, P=0.02; R=-0.45, P=0.04). In terms of relations between the spinal and pelvic parameters, PI were found to be related to the SS (R=0.58, P< 0.01). An analysis of relations revealed a correlation between the Oswestry Disability Index and Cobb(R=0.59, P<0.01), PT(R=0.49, P=0.02), TK(R=-0.46, P=0.03) and TLK(R=0.44, P=0.04). Furthermore, an analysis of relations revealed a correlation between Low Back Pain Scoring System and Cobb (R=-0.44, P=0.04), L3(R=-0.53, P=0.01), PT (R=-0.44, P=0.04), TK(R=0.46, P=0.03) and TLK(R=-0.43, P=0.05).

Conclusion: The parameters are related to each other and compensate each other to maintain the balance of the coronal and sagittal planes of the spine. In addition, the change of some parameters is closely related to the quality of life of the patients, and can provide some clues for the clinical diagnosis and treatment of DDH.

Introduction

Developmental dysplasia of the hip (DDH) represents a spectrum of hip disorder and unveils a process of disease ranging from mild hip instability to dislocation [1, 2]. DDH was first described by Palletta in 1820[3]. The inability of the femoral head to maintain the proper position within the acetabulum has been regarded as the major etiology. And nearly 2% of newborns children suffered DDH at birth[4, 5]. The significant deformities, such as insufficient coverage of the femoral head, shallow acetabulum, increased femoral anteversion, coxa valga, and shortening of the femoral neck, will emerge with the DDH over time[6–9]. The common complications of DDH were myelomeningocele, arthrogryposis, osteoarthritis and low back pain[2]. However, the spinopelvic deformity of DDH patients was uncommon in clinical work, which makes it hardly reported in the previous literature.

In the previous studies, spinopelvic parameters have been researched and reported in various fields. The sagittal spinopelvic parameters were found to be related to the symptoms in cerebral palsy patients[10]. And in term of global sagittal alignment, ankylosing spondylitis patients with moderate and severe deformity were demonstrated to be significantly different [11]. However, few studies have addressed the characteristics of structure of spine and pelvic as well as possible relationships between spinopelvic parameters and clinical manifestation. Therefore, the assessment of DDH patients' spinopelvic balance was indispensable during the treatment of DDH.

The study was to explore the differences in the spinopelvic parameters between DDH patients and control group as well as to seek the relationships between the spinopelvic parameters and their related symptoms in DDH patients. In addition, we also were to analyze the correlations of the spinopelvic parameters and clarify the possible compensatory mechanism in DDH patients, which devoted to provide clues for the clinical remedy of spinopelvic malformation.

Materials And Methods

A total of 22 DDH patients (9 males and 13 females) without previous history of any a spine or a hip operation were enrolled in the prospective observational study in Xian Jiaotong University Second Affiliated Hospital from 2016 to 2021. All the patients were diagnosed as unilateral DDH, and the exclusion criteria included the following: (1) The patients who could not maintain a standing position during the X-ray exposure; (2) The patients who were unable to communicate about the severity of pain and living condition; (3) The patients whose pathogenesis includes other factors such as trauma; (4) The patients who suffered from Charcot's joint disease; (5) The patients with infection. Altogether 20 healthy volunteers (11 males and 9 females) with no previous history of spinopelvic and hip diseases were included as a control group. All hip dysplasia patients and volunteers were taken the antero-posterior (AP) pelvic radiograph as well as the frontal and lateral radiography of the whole spine as a routine examination. The volunteers with an abnormal radiogram, such as disc space narrowing or spine originating symptoms, were excluded from the present investigation.

Consequently, there were altogether 42 patients including 20 males and 22 females in the study. All the patients were divided into four types according to the Crowe classification system after estimated by measurements on the AP pelvic radiograph. In this classification, type I hips accounted for less than 10% subluxation while type II hips were about 10-15%. The type III hips took part 15-20% and type IV patients were more than 20%. All study subjects were consented to participate in the research.

Patients' disability analysis

All patients completed a questionnaire that gathered general information (medical / hospital number, name, gender, age, height, weight, occupation) and information on concurrent diseases (cardiovascular disease, pulmonary disease, and other extremity deformity). In addition, the clinical symptoms and signs of patients also were recorded. The Oswestry Disability Index (ODI) and Low Back Pain Scoring System

(JOA) were used to measure the clinical manifestation. The ODI was completed by the patient alone while JOA is filled out by the orthopedic surgeons after the examination and consultation. The patients would be excluded if their pain originated from another part of the body, such the ankles or knees.

Radiographic analysis

All radiograms were taken in the standing position, and we excluded the subjects who could not stand because of hip flexion deformity or severe scoliosis. We measured followed parameters in radiograms, defined and measured as follows (Fig. 1,2 and 3):

1. The height of pelvic(B): distance between the Ischial tuberosity and the iliac wing.
2. The distance of femoral head dislocation(A): distance between the margo inferior teardrops and the Margo medialis femoral head, the ratio of A and B is regard as Crowe type evidence.
3. Cobb angle (Cobb): calculate a Cobb angle by localizing the superior surface of the upper vertebra and inferior surface of the lowermost vertebrae.
4. Coronal balance (CB): horizontal distance traveled by a plumb line dropped from the center of the C7 body to the midperpendicular of S1.
5. L3 vertebral inclination(L3): measuring the angle between the upper endplate and a horizontal line.
6. Anteversion angle of spine(ST): the angle between a line joining the center of C7 and the middle of upper endplate and a horizontal line.
7. Pelvic incidence (PI): angle between a line perpendicular to the sacral end plate and a line joining the middle of the sacral plate and hip axis.
8. Pelvic tilt (PT): angle between the vertical line and a line joining the middle of the sacral end plate and hip axis.
9. Sacral slope (SS): angle between the sacral end plate and the horizontal line.
10. S1 overhang (OH): distance between the hip axis and the projection to this level of the midpoint of the sacral plate.
11. Thoracic kyphosis (TK): angle between the upper end plate of the T2 vertebra and the lower end plate of the T12 vertebra as determined using the Cobb method.
12. Thoracolumbar kyphosis (TLK): angle between the upper end plate of T10 and the lower end plate of L2.
13. Lumbar lordosis (LL): angles measured between the upper end plate of the L1 vertebra and the lower end plate of the S1 vertebra.

The radiographic measures of the parameters were recorded digitally using Image J.

Statistical analysis

All the measurements were independently performed twice by two orthopaedic surgeons with an interval of 2 weeks. Inter- and intra-class correlation coefficients (ICCs) were used to evaluate the reliability of intra- and inter-group measurements to reduce errors within and between groups. A comparative analysis was carried out between the DDH patients and control group using the t test and Pearson correlation analysis with the help of SPSS 23.0 software. Parameters were analyzed by linear regression to determine the relationships with ODI, JOA and other parameters.

Results

The characteristics of the unilateral DDH patients and the control group were summarized in Table 1. The age, gender, height and weight were found to no significant difference between the two groups. Patients' degree of dysplasia was grouped according to Crowe Classification and showed in Table 2. In all patients, 7 patients were □ type, 5 patients were □ type, 6 patients were □ type and 4 patients were □ type. Reliability test results showed that ICCs was 0.950 in the inter-group and the 95% confidence interval (CI) was 0.943-0.960. As for the intra-group, ICCs was 0.935 while the 95% CI was 0.936 to 0.956, indicating consistency and credibility of the measurement results.

Table 1 Comparison between DDH patients and control group in the characteristics (mean ± SD)

Parameters	Control	DDH	T/χ^2	*P*-value
Age(year)	41.4±13.9	43.3±16.9	-0.37	0.71
Male/Female(n)	11/9	9/13	0.83	0.54
Height (cm)	161.5±9.2	165.8±12.2	-1.30	0.20
Weight(kg)	72.6±9.8	69.2±8.7	1.18	0.24

The T/χ^2 test was used to determine the differences between the parameters. * *p□0.05.*

Table 2 The classification of DDH patients

Crowe Classification	B/A	N
□	□0.1	7
□	0.1-0.15	5
□	0.15-0.2	6
□	□0.2	4

In table 3, the DDH group had larger Cobb (8.68±6.21°), larger L3 (4.79±5.47°),larger CB (1.65±1.57mm), larger PT (15.02±9.55°) ,smaller LL□37.41±17.17°□and larger TLK (7.69±6.66°) than the control group.

Table 3 Comparison between DDH patients and control group in the spinopelvic parameters (mean ± SD)

Parameters	Control	DDH	T/Z	*P*-value
Cobb(°)	2.31±0.12	8.68±6.21	-4.58	<0.01*
CB(mm)	0.47±0.32	1.65±1.57	-3.28	<0.01*
L3(°)	0.83±0.51	4.79±5.47	-2.70	<0.01*
ST(°)	82.30±4.52	84.68±3.62	-1.89	0.07
PI(°)	51.44±10.98	44.41±14.28	1.78	0.11
PT(°)	9.99±2.97	15.02±9.55	-2.26	0.04*
SS(°)	37.70±8.35	39.87±13.44	-0.62	0.54
OH(cm)	2.73±1.30	2.45±1.01	0.79	0.44
TK(°)	33.61±12.03	33.23±12.56	0.10	0.92
TLK(°)	3.54±1.63	7.69±6.66	-2.71	0.01*
LL(°)	48.79±7.75	37.41±17.17	2.72	0.01*

CB, coronal balance; L3, L3 vertebral inclination; ST, anteversion angle of spine; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; OH, S1 overhang; TK, thoracic kyphosis; TLK, Thoracolumbar kyphosis; LL, Lumbar lordosis.

The *t/z* test was used to determine the differences between the parameters. * *p<0.05.*

With respect to symptoms, Cobb, PT, TK and TLK were found to be correlated with ODI in DDH patients. And Cobb, L3, PT, TK and TLK were found to be correlated with JOA in DDH patients (Table 4). However, no other parameters were found to be related to the symptoms. Moreover, the following linear regression formulate were calculated:

ODI=1.1*Cobb+2.66(R=0.59, P<0.01)   ODI=0.59*PT+3.32(R=0.49, P=0.02)

ODI=0.76*TLK+6.35(R=0.44, P=0.04)   ODI=-0.42*TK+26.2(R=-0.46, P=0.03)

JOA=-0.61*Cobb+23.67(R=-0.44, P=0.04)   JOA=-0.82*L3+22.36(R=-0.53, P=0.01)

JOA=-0.39*PT+24.26(R=-0.44, P=0.04)   JOA=-0.55*TLK+22.61(R=-0.43, P=0.05)

JOA=0.31*TK+8.05(R=0.46, P=0.03)

Correlation analysis revealed a significant relationship between the spinopelvic parameters (Fig.4). Of the coronal spinopelvic parameters, CB was found to be associated with L3 (p<0.01). As for the sagittal spinopelvic parameters, SS was found to be associated with LL (p=0.02), and TLK was found to be related to ST and TK (p=0.02; p=0.04). In terms of relations between the spinal and pelvic parameters, PI were found to be related to the SS (p<0.01).

Table 4 Associations between the spinopelvic parameters and ODI, JOA in the DDH patients (mean ± SD)

Parameters	ODI		JOA	
	r	p	r	p
Cobb(°)	0.59	<0.01*	-0.44	0.04*
CB(mm)	0.16	0.48	-0.35	0.11
L3(°)	0.41	0.06	-0.53	0.01*
ST(°)	0.04	0.86	-0.07	0.77
PI(°)	-0.03	0.90	0.03	0.91
PT(°)	0.49	0.02*	-0.44	0.04*
SS(°)	-0.01	0.98	0.01	0.99
OH(cm)	0.15	0.51	-0.14	0.53
TK(°)	-0.46	0.03*	0.46	0.03*
TLK(°)	0.44	0.04*	-0.43	0.05*
LL(°)	-0.21	0.35	0.22	0.33

CB, coronal balance; L3, L3 vertebral inclination; ST, anteversion angle of spine; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; OH, S1 overhang; TK, thoracic kyphosis; TLK, Thoracolumbar kyphosis; LL, Lumbar lordosis.

Pearson correlation analysis was used to determine the relationships between the parameters. * $p<0.05$; r, correlation coefficients.

Discussion

DDH accompanies with a continuum of deformities that involves coronal and sagittal alignment as well as pelvic and spinal balance. Spinal deformities in DDH occur secondary to the pelvic imbalances due to postural and muscular forces. Although the results of orthopaedic surgery in patients with DDH have been well reported, the focus in most studies were placed on the improvements in the reconstruction of hip joint [12], however, the spinopelvic deformity always were ignored by surgeon. Some researchers had reported that Crowe IV DDH patients may exhibited abnormal spinal-pelvic alignment, but they had not figured out the relationships between these parameters and clinical symptoms[13]. Although the studies of spinopelvic parameters have been reported in cerebral palsy, osteoporosis, ankylosing spondylitis and adolescent idiopathic scoliosis[10, 11, 14, 15], the similar research in the unilateral DDH patients were few in the literature. Therefore, we believe that a comprehensive analysis of the spinopelvic parameters, which were affected by the hip dislocation, should be a fundamental part of the patient assessment. In the present study, to identify factors that affect symptom, sign, function and pain, we evaluated the spinopelvic parameters in unilateral DDH patients and control group, relations between these parameters and the relationships between these parameters and ODI, JOA.

At the beginning of study, it was hypothesized that the parameters between control and DDH patients had significant difference. And we could find the abnormal parameters in both the coronal and sagittal planes whether in the spine or pelvis. It was speculated that the unilateral dislocation of the femoral head leads to the asymmetry of the lower limbs and causes prolonged lameness, resulting in the changes and imbalances in the pelvic structure, eventually leading to coronal imbalance.

For the pelvic parameters, only PT showed significant difference compared with the control group. According to the previous research, the increase of PT is to compensate for the loss of LL. And the patients have to keep the sagittal balance by extending the hip, which also indicates the posterior tilt of the pelvis [16]. However, the compensation mechanism of PT is limited. When the PT can no longer increase, the body will experience decompensation and sagittal imbalance. Therefore, we could speculate that the predisposing factor of increased PT is the loss of LL. The previous study had concluded that the pelvic orientation and morphology were important to correct the sagittal spinal curvature[16, 17]. As a result, the pelvic imbalance may reasonably affect spinal parameters.

Literatures have showed the structural characteristics of the pelvis fundamentally regulate and determine LL. There are many factors could cause the changes in LL, such as age-induced degeneration of the intervertebral disc, decrease in the height of the lumbar intervertebral disc, loss of lumbar disc height caused by compression fractures, source flat deformity and so on [18]. However, in patients with unilateral DDH, we speculate the limp caused by lower extremity shortening with the dislocation of the femoral head changes the pelvic structure and imbalance which may lead to the decrease of LL and increase of TLK, but the specific mechanism remains unclear.

In previous researches, several sagittal parameters have been reported and those showed correlation with symptoms and the progression of disease. In Glassman et al' research, according to ODI, the pain and reduced function is associated with the global alignment sagittal vertical axis [19, 20]. Lafage et al found that the pelvic position measured via PT affected patients' health-related quality of life [21]. In terms of symptom in DDH patients, both the coronal and sagittal parameters are related to functional problems according to ODI and JOA. And the SS, PT, PI and OH had been regarded as the representation of lumbosacral pelvic orientation [10]. Cobb and CB were regarded as the indicators of coronal balance. ST, PT and TLK were deemed as delegates of sagittal balance. These parameters seemed to reflect some structural features of the pelvis and showed the close relationship with functions, pain, coronal and sagittal alignment as well as spinopelvic balance.

In this study, the patients with unilateral DDH had larger coronal pelvic parameters and closely associations between CB and L3, which were caused by prolonged limp because of the dislocation of the hip and asymmetry of the lower extremities. Changes of the pelvic structure leads to compensatory changes in LL and causes changes of the position in the pelvis relative to the axis of the hip joint, finally results in the changes of SS. In addition, patients with unilateral DDH had a larger TLK and were positively correlated with ST and negatively associated with TK. An increase in ST indicates a relative movement of the C7 center relative to the sacrum, resulting in the decrease of TK. What’s more, due to the principle of sagittal compensation, the reduction in LL is another factor that causes the decrease in TK. In the study, Cobb and L3 are regarded as indicators of coronal balance assessment while PT, TK, and TLK are regarded as indicators of sagittal pelvic parameters according to ODI and JOA. These parameters appear to reflect the structural characteristics of the pelvis and are shown to be closely related to pain, function, and dysfunction. It is speculated that besides the sagittal spine pelvic parameters, coronal parameters such as Cobb, L3, and CB are compensated for each other and they can also serve as predictors and assessment markers for disease severity. The increasing trend of PT and its relationship with rating scale once again emphasize the importance of PT in orthopedic surgery, which remind that correcting PT remains the main goal of adult spinal orthopedic surgery. As for the vertebral physiologic curvature malformation of unilateral DDH patients, the increase of TLK also plays a similar role in addition to the reduction of LL and TK. Therefore, we are supposed to notice whether the vertebral physiologic curvature abnormality is improved to assess the patient's symptoms during the follow-up period of DDH surgery.

However, there are several limitations in the present study. Firstly, the number of unilateral DDH patients were relatively small, which reduced its power to detect correlations and the statistical ability of this study. The second, because of the lacking samples of unilateral DDH patients, it was impossible to compare the difference of spinopelvic parameters in patients with different classifications of DDH. What’s more, recently more related data of global sagittal balance was used to measure spinopelvic balance so that the measured parameters were not comprehensive.

Conclusions

The main reason for the change of unilateral spinopelvic parameters in patients with DDH is the limb shortening with limp caused by dislocation of the femoral head, and some parameters are related to each other and compensate each other to maintain the balance of the coronal and sagittal planes of the spine. In addition, the change of some parameters is closely related to the quality of life of the patients, and can provide some clues for the clinical diagnosis and treatment of DDH.

List Of Abbreviations

DDH: developmental dysplasia of the hip; AP: antero-posterior; ODI: Oswestry Disability Index; JOA: Low Back Pain Scoring System; Cobb: Cobb angle; CB: Coronal balance; L3: L3 vertebral inclination; ST: Anteversion angle of spine; PI: Pelvic incidence; PT: Pelvic tilt; SS: Sacral slope; OH: S1 overhang; TK: Thoracic kyphosis; TLK: Thoracolumbar kyphosis; LL: Lumbar lordosis; ICCs: Inter- and intra-class correlation coefficients; CI: confidence interval;

Declarations

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Not applicable.

Authors’ contributions

Ruiyu Liu, Guangyang Zhang and Mufan Li designed and performed the study. Hang Qian and Xu Wang collected and analyzed the data. Xiaoqian Dang and Ruiyu Liu interpret the results. Guangyang Zhang and Mufan Li wrote the paper. All authors reviewed the manuscript.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to privacy rules but are available from the corresponding author on reasonable request.

Ethics declarations

This study has been approved by Institutional Ethics Committee of The Second Affiliated Hospital of Xi 'an Jiaotong University, and written informed consent was obtained from all subjects. All methods performed in this study were conducted in accordance with the relevant guidelines and regulations.

Consent for publication

Not applicable.

Competing interests

All authors have no financial interests to disclose

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Figures

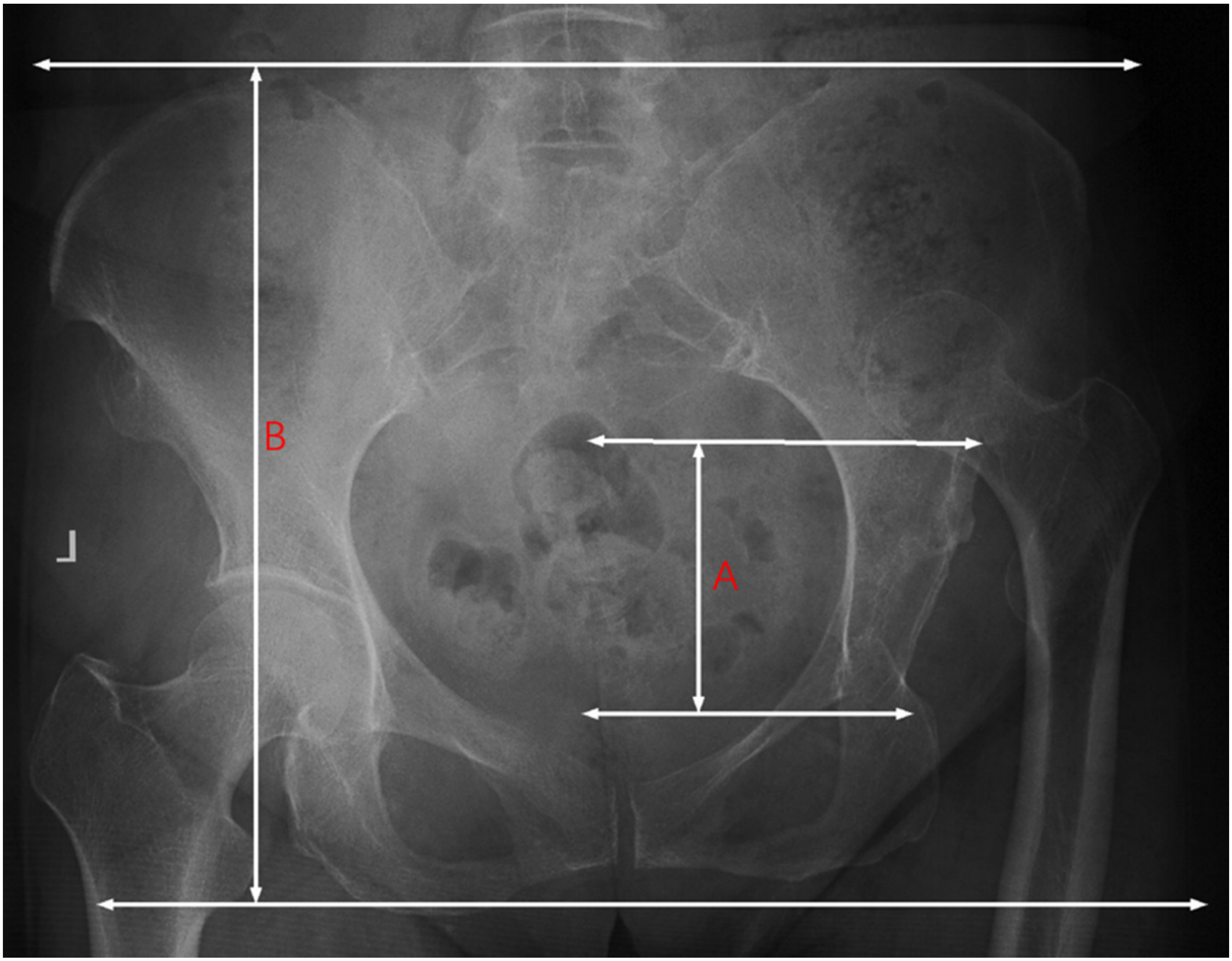

Figure 1

Crowe Classification of DDH patients

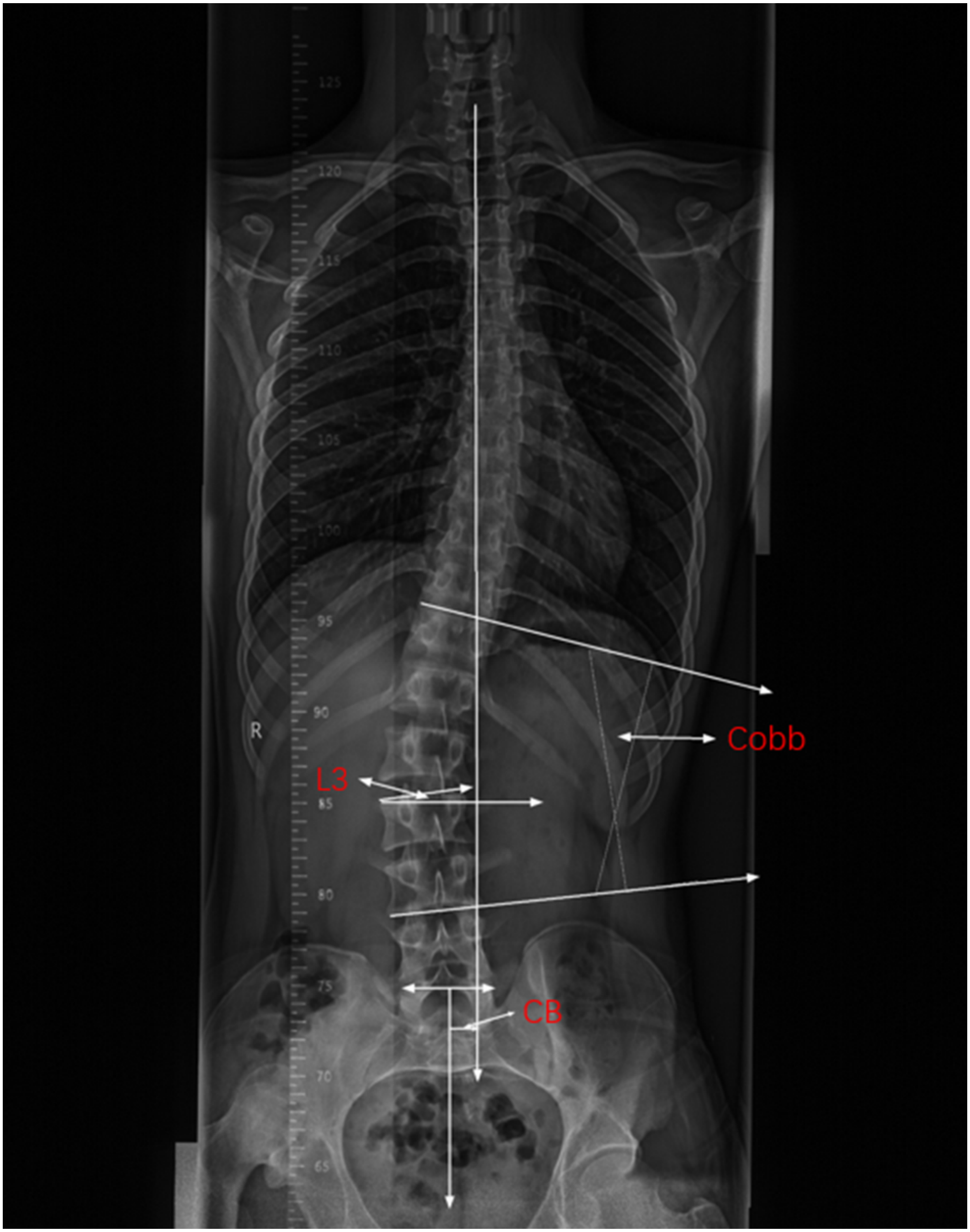

Figure 2

Illustration of coronal spinopelvic parameters. Cobb: Cobb angle; CB: Coronal balance; L3: L3 vertebral inclination

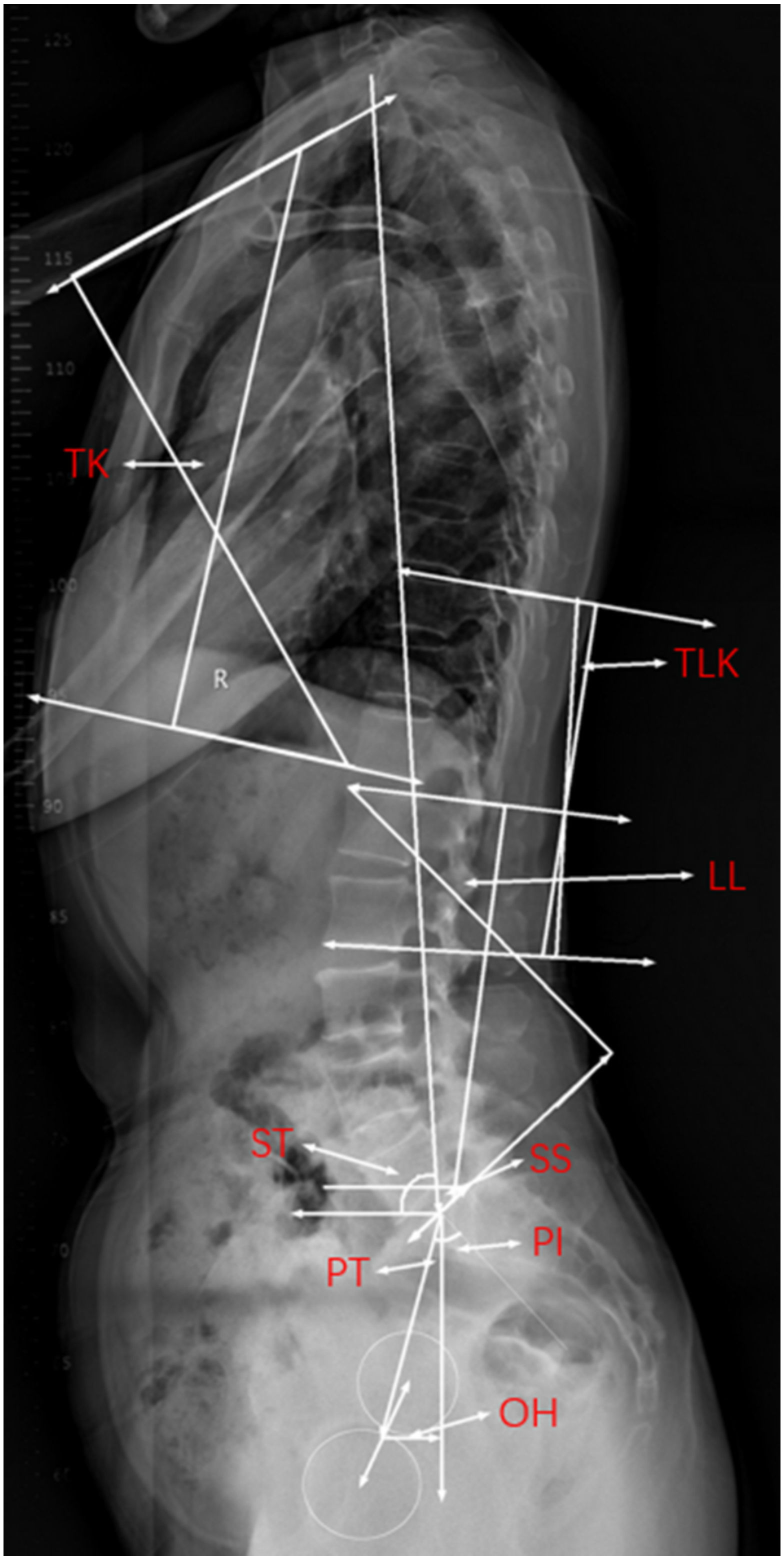

Figure 3

Illustration of sagittal spinopelvic parameters. TK: Thoracic kyphosis; TLK: Thoracolumbar kyphosis; LL: Lumbar lordosis; ST: Anteversion angle of spine; PT: Pelvic incidence; SS: Sacral slope; PI: Pelvic incidence; OH: S1 overhang

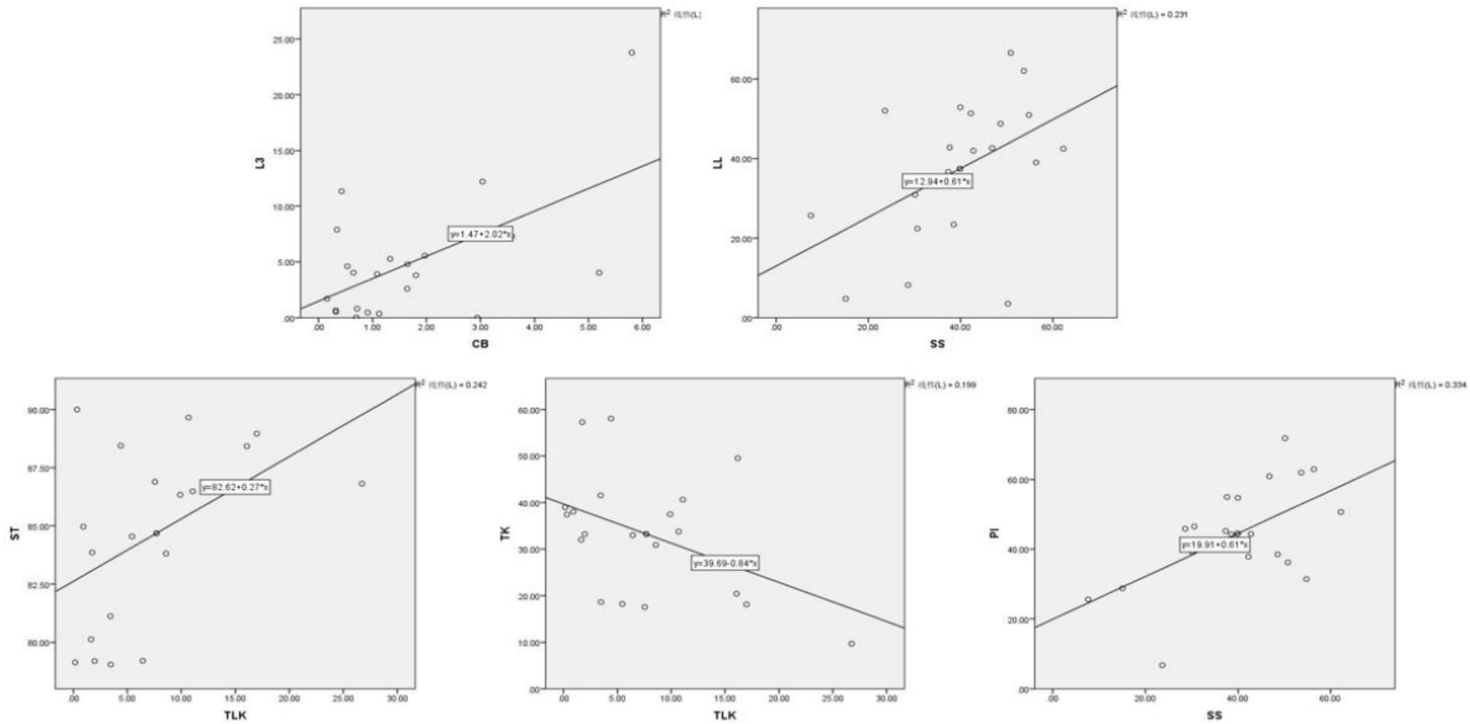

Figure 4

Correlations of the spinopelvic parameters in DDH patients.