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Original Article

The characteristics of spino-pelvic sagittal parameters and obesity factors for adolescents with lumbar disc herniation

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Abstract: Purpose: A comparative study to analyse sagittal spino-pelvic parameters and obesity valuables between adolescent patients with lumbar disc degeneration (LDH) and normal adolescent population. Methods: We divided 60 LDH adolescent patients in LDH group (LG) and 60 asymptomatic adolescent volunteers into the normal group (NG). The following parameters were measured on positive and lateral full spine radiographs, including pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), lumbar lordosis (LL), thoracic kyphosis (TK), and sacrum-femoral-pubic symphysis (SFP). Other valuables contained age, sex, height, weight, Body Mass Index (BMI), waist to hip ratio (WHR) and exercise condition. Results: The PI (44.6°±5.3°), SS (24.0°±3.4°) and LL (30.3°±3.1°) in LG were significantly lower than NG (PT=47.3°±6.3°; SS=29.2° ±6.5°; LL=31.8°±3.4°). Compared with the NG (BMI=23.7±1.0 kg/m^2; height=175.5±3.2 cm; weight=72.9±3.4 kg; WHR=0.81±0.02), the BMI (27.9±1.7 kg/m^2), height (180.7±3.5 cm), weight (91.1±7.9 kg) and WHR (0.90±0.06) for the LG were significantly higher. Adolescent with LDH lacked exercise than adolescent without LDH ($P<0.05$). Conclusions: The sagittal spino-pelvic parameters and obesity valuables reach statistically significant differences between adolescents with LDH and normal adolescents, adolescents with LDH had lower PI, SS and LL, but had higher BMI, height, weight and WHR. The spino-pelvic parameters increased significantly between normal weight and overweight, but not between overweight and obesity for adolescent with LDH. Adolescents lacking exercise have higher incidence of suffering from LDH.

Keywords: Sagittal spinopelvic parameters, adolescent, lumbar disc herniation, obesity

Introduction

In the past, the treatment for spinal diseases were focused on regional problem, as neural decompression and obtaining bony fusion. As the development of spinal surgery techniques, the concept that whole spinal alignment has been emphasized as important for managing spinal diseases [1]. Duval Beaupère G [2, 3] was the first to publish work about the importance of pelvic indexes and their relationship (PI=PT+SS). Pelvic incidence (PI) is a fundamental anatomical parameter. It is unique for each individual and does not depend on the position or spatial orientation of the pelvis. PI is closely related to sacral slope (SS) and pelvic tilt (PT), two position dependent variables which determine pelvic orientation in the sagittal plane. So that an increase in SS must be compensated by a similar reduction of PT, as shown in Duval Beaupe`re formula, PI=SS+PT. PI in the normal population remains relatively constant during childhood; it increases significantly during adolescence, reaching its maximum value in adulthood [4]. Vaz et al [5] have studied and reported the association and ranges of PI, PT, SS, LL, and TK in a normal young adult population and have shown that all these parameters are closely linked and balance themselves, by muscular activity, to maintain the global axis of gravity over the femoral heads. This means that during adolescence the value of PI varies even if only slightly. Lumbar lordosis (LL) is closely related to the orientation of the pelvis, expressed by the sacral slope, which is strongly influenced by PI. A significant chain of interdependence exists between the pelvic and spinal parameters. A low value of PI implies low values of pelvic parameters and a flattened lordosis; a high value implies well tilted pelvic orientation and pronounced lordosis [3, 6]. Thoracic kyphosis (TK) is the sum of the kyphosis above and below the apex [7, 8].

Lumbar disc herniation (LDH) is a common disorder among adults with degenerated lumbar intervertebral discs. However, its occurrence in adolescence is much less frequent [9]. Zitting et al [10] carried out an epidemiologic study aiming at estimating the true prevalence. They followed up 12,058 Finnish babies from birth until 28 years of age. Their results showed that none of their subjects was hospitalized with confirmed LDH until the age of 15 years, while this figure increased to the range of 0.1-0.2% when the subjects were 20 years old. From this point, the prevalence began to rise dramatically. By the age of 28 years, 9.5% of males and 4.2% of females were admitted to hospital with a diagnosis of LDH, respectively. This is mostly because adolescents tend to have a healthier lumbar spine as compared with adults.

The importance of the sagittal spino-pelvic balance of the spine on both the sagittal and coronal planes is now widely known. Many works have been published in the literature about the importance of the relationship between pelvic indexes and sagittal profile. Though many authors pay more attention on adolescent patients with LDH, to the best of our knowledge, this is the first literature to focus on sagittal spino-pelvic parameters and obesity factors for adolescent patients with LDH.

Patients and methods

Ethics statement

This is approved by Ethics Committee of The Third Hospital of HeBei Medical University. Written informed consent was obtained from all the subjects along with approved by the Ethics Committee of the Third Hospital of HeBei Medical University.

Patients

We included 60 adolescent patients with LDH from the Third Hospital of HeBei Medical University in this study, from January 2010 to September 2015. The inclusion criteria were as follows: (1) age under 21; (2) were diagnosed with LDH by MRI; (3) have radioactive pain of leg. Exclusion criteria: (1) have history of any spinal surgery (including simple lumbar discectomy); (2) have spinal deformities (including scoliosis, isthmic spondylolisthesis, irregular endplate, sacralization or lumbarization); (3) have acute spinal trauma or tumours; (4) have no symptom. Another 60 asymptomatic adolescent volunteers as controls group were recruited based on the following inclusion criteria: (1) age under 21; (2) no history of back or leg pain. Exclusion criteria: (1) have history of any spinal surgery (including simple lumbar discectomy); (2) have spinal deformities (including scoliosis, isthmic spondylolisthesis, irregular endplate, sacralization or lumbarization); (3) have history of acute spinal trauma or tumours.

Radiological assessment

All subjects had a full spine positive and lateral X ray including the spine and pelvis from which sagittal spino-pelvic alignment. The following variable were measured:

Pelvic incidence (PI) Angle between superior endplate of S1 and line joining hip axisa to center of superior endplate of S1.

Pelvic tilt (PT) Angle between vertical line and line joining hip axisa to center of superior endplate of S1.

Sacral slope (SS) Angle between superior endplate of S1 and horizontal line.

Lumbar lordosis (LL) Segmental angle of superior endplate of L1 and superior endplate of S1.

Thoracic kyphosis (TK) Segmental angle of superior endplate of T1 and inferior endplate of T12.

Sacrum-femoral-pubic-symphysis (SFP) Angle between line from midpoint of sacrum to femoral and line from femoral to midpoint of pubic symphysis.

The Body Mass Index (BMI) was calculated by dividing weight (kg) by the square of height (m). Normal weight status ranges from 18.5 kg/m^2 to 24.9 kg/m^2, and overweight status ranges from 25 kg/m^2 to 29.9 kg/m^2 of BMI. A BMI that is greater than 30 kg/m^2 is considered to reflect obesity. The obese category is further subdivided into class I (30-34.9 kg/m^2), class II (35-39.9 kg/m^2), and class III (40 kg/m^2). A BMI that is greater than 40 kg/m^2 is considered as "morbid" obesity.

Table 1. Spino pelvic parameters and other variables for Chinese adolescent patients between two groups

	LDH	NORMAL	*P*
Age (years old)	17.9±1.6	17.8±1.6	0.798
Sex (Male/Female)	54/6	49/11	0.191
Height (cm)	178.8±7.0	172.8±6.7	<0.001
Weight (kg)	88.3±11.5	68.7±9.6	<0.001
BMI (kg/m^2)	27.5±2.0	22.9±2.0	<0.001
WHR	0.89±0.07	0.80±0.03	<0.001
Exercise (Normal/Lack)	13/47	29/31	0.002
PI (°)	44.6±5.3	47.3±6.3	0.035
PT (°)	20.6±2.1	18.1±1.5	<0.001
SS (°)	24.0±3.4	29.2±6.5	<0.001
LL (°)	30.3±3.1	31.8±3.4	0.029
TK (°)	31.1±5.1	31.5±5.5	0.981
SFP (°)	75.2±3.2	75.8±3.1	0.486

PI = pelvic incidence; PT = pelvic tilt; SS = sacral slope; LL = lumbar lordosis; TK = thoracic kyphosis; SFP = sacrum femoral pubic symphysis; BMI = body mass index; WHR = waist to hip ratio.

Waist to hip ratio (WHR)=waist circumference/hip circumference [11]. Waist circumference was measured by waistline under navel. Hip circumference was measured by largest hipline.

We regarded 7 hours per one week as normal exercise for adolescents, less than 7 hours per one week as lack of exercise.

All measurement data are presented as the mean ± SD. (standard deviation) when data satisfied criteria for normality with $P>0.05$. The data of spinopelvic sagittal parameters (PI, PT, SS, LL, TK, SFP) and other valuables (Age, Height, Weight, BMI, WHR) meet normality and homogeneity of variance, so statistical analysis for these data between groups were performed using independent samples t test. Otherwise, count data like sex (male/female) and exercise (normal/lack) between groups were performed using Chi square test. Statistical significance levels were considered to be $P<0.05$. All statistical analyses were carried out using SPSS, version 21.0 (SPSS Inc., Chicago, IL).

Results

Parameters between LG and NG for adolescents

No significant differences in the age, gender, TK, SFP between LG and NG were noticed. The PI (44.6°±5.3°), SS (24.0°±3.4°) and LL (30.3°±3.1°) for LG were significantly smaller than the PI (47.3°±6.3°), SS (29.2°±6.5°), and LL (31.8°±3.4°) for the NG. Compared with the NG (BMI=23.7±1.0 kg/m^2; height=175.5±3.2 cm; weight=72.9±3.4 kg; WHR=0.81±0.02), BMI (27.9±1.7 kg/m^2), height (180.7±3.5 cm), weight (91.1±7.9 kg) and WHR (0.90±0.06) for the LG were significantly higher (**Table 1**, **Figures 1**, **2**).

Parameters between LG and NG for male adolescents

No significant differences in the age, PI, TK, SFP between LG and NG were noticed for the male adolescents. The SS (24.0°±3.3°), LL (30.0°±2.8°) for LG were significantly smaller than SS (28.8°±6.4°) and LL (31.9°±3.5°) for NG, however, PT (20.6°±2.1°) for LG were significantly larger than PT (17.9°±1.5°) for NG. And BMI (27.9±1.7 kg/m^2), height (180.7±3.5 cm), weight (91.1±7.9 kg) and WHR (0.90±0.06) for LG was significantly higher than the BMI (23.7±1.0 kg/m^2), height (175.5±3.2 cm), weight (72.9±3.4 kg) and WHR (0.81±0.02) for the NG (**Table 2**).

Parameters between LG and NG for female adolescents

The data for the female adolescents between LG and NG were not the same as for the male adolescents. There were no significant difference in age, height, PT, TK, SFP for the female adolescents between LG and NG. The PI (46.5°±6.0°), SS (22.3°±3.0°) and LL (27.5°±2.6°) value for LG were significantly smaller than PI (49.8°±6.3°), SS (30.5°±6.9°) and LL (31.2°±2.8°) value for NG. The BMI (24.2±1.5 kg/m^2), weight (62.7±5.7 kg) and WHR (0.79±0.02) for LG were significantly higher than the BMI (19.5±1.6 kg/m^2), weight (50.2±4.3 kg) and WHR (0.74±0.03) for the NG (**Table 3**).

Discussion

Sagittal spinopelvic alignment accompanied with biomechanical changes has been demonstrated in previous studies in the pathogenesis and development of lumbar degenerative diseases [12, 18]. Several studies have compared the sagittal spinopelvic alignment in LDH patients with the asymptomatic volunteers, suggesting that the sagittal profile in these patients was characterized by a straight spine

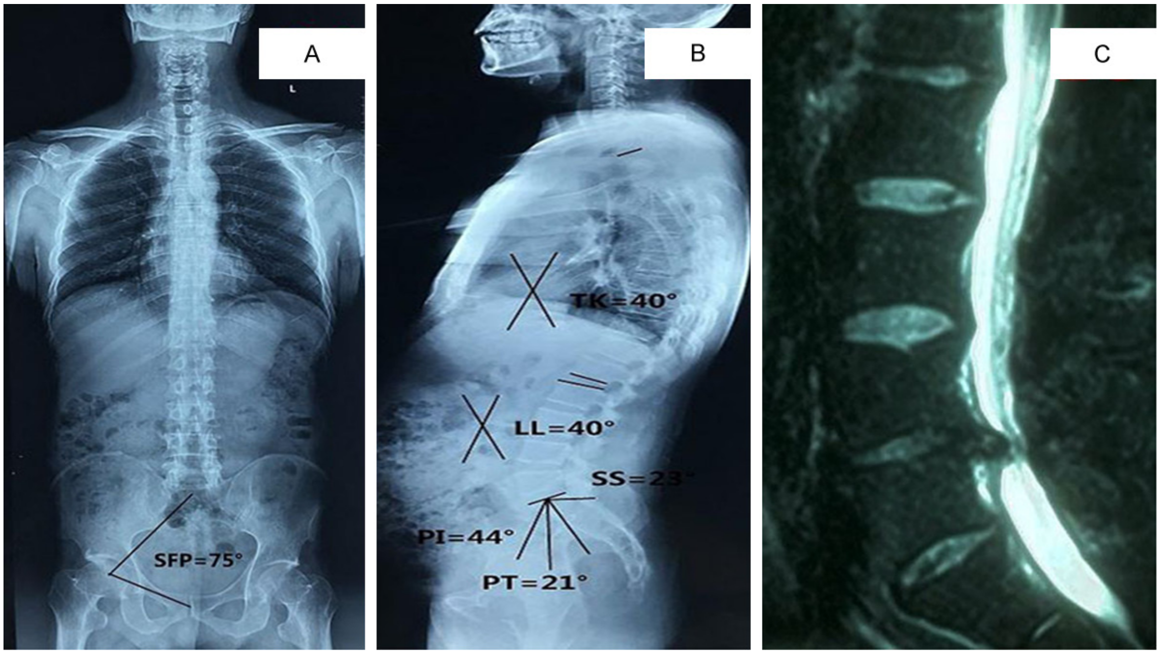

Figure 1. A male adolescent, 17 years old, height=180 cm, weight=89 kg, BMI=27.5 kg/m^2, WHR=0.89, SFP=75°, PI=44°, PT=21°, SS=23°, LL=40°, TK=40°. A. Postive full spine X ray; B. Lateral full spine X ray; C. Lateral lumbar MRI. (PI = pelvic incidence, PT = pelvic tilt, SS = sacral slope, LL = lumbar lordosis, TK = thoracic kyphosis, SFP = sacrum femoral pubic symphysis, BMI = body mass index, WHR = waist to hip ratio).

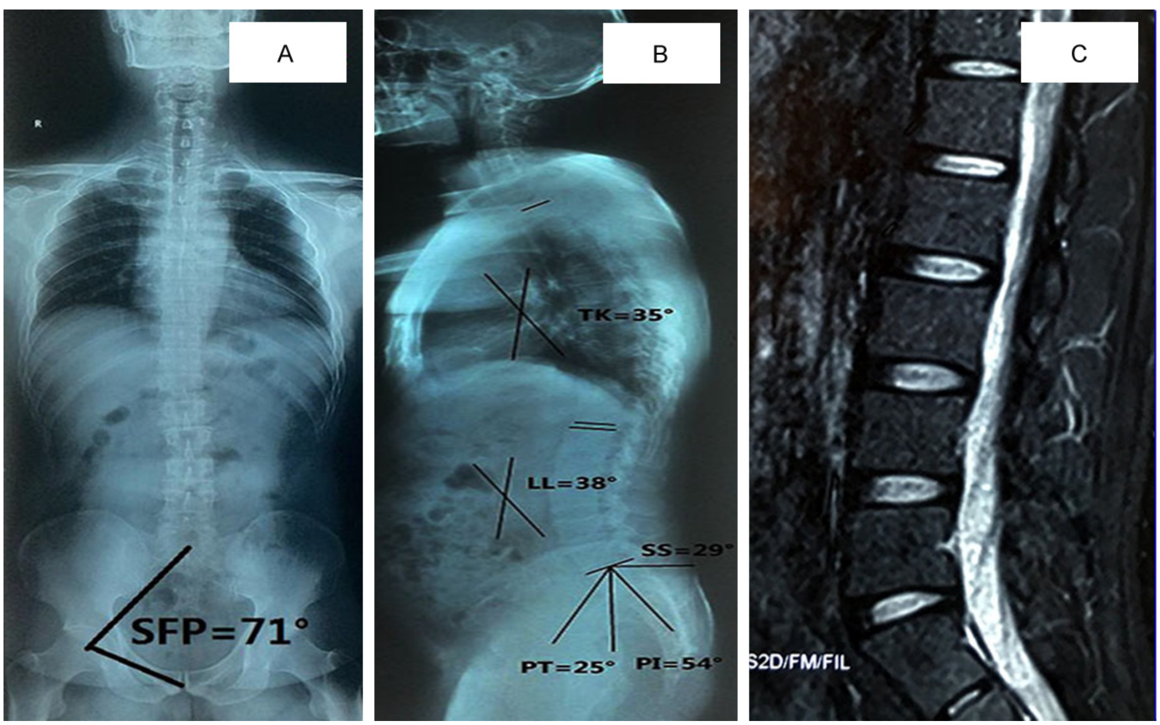

Figure 2. A male adolescent, 18 years old, height: 173 cm, weight: 68 kg, BMI: 22.7 kg/m^2, WHR: 0.80, SFP=71°, PI=54°, PT=25°, SS=29°, LL=38°, TK=35°. A. Postive full spine X ray; B. Lateral full spine X ray; C. Lateral lumbar MRI. (PI = pelvic incidence, PT = pelvic tilt, SS = sacral slope, LL = lumbar lordosis, TK = thoracic kyphosis, SFP = sacrum femoral pubic symphysis, BMI = body mass index, WHR = waist to hip ratio).

Table 2. Spino pelvic parameters and other variables for male adolescent patients between two groups

	LDH	NORMAL	*P*
Age (years old)	17.9±1.6	17.8±1.6	0.798
Height (cm)	180.7±3.5	175.5±3.2	<0.001
Weight (kg)	91.1±7.9	72.9±3.4	<0.001
BMI (kg/m^2)	27.9±1.7	23.7±1.0	<0.001
WHR	0.90±0.06	0.81±0.02	<0.001
PI (°)	44.1±5.7	46.7±6.3	0.077
PT (°)	20.6±2.1	17.9±1.5	<0.001
SS (°)	24.0±3.3	28.8±6.4	<0.001
LL (°)	30.0±2.8	31.9±3.5	0.016
TK (°)	31.1±5.2	31.0±5.7	0.981
SFP (°)	75.3±3.2	75.8±3.1	0.486

PI = pelvic incidence; PT = pelvic tilt; SS = sacral slope; LL = lumbar lordosis; TK = thoracic kyphosis; SFP = sacrum femoral pubic symphysis; BMI = body mass index; WHR = waist to hip ratio.

Table 3. Spino pelvic parameters and other variables for female adolescent patients between two groups

	LDH	NORMAL	*P*
Age (years old)	17.9±1.6	18.0±1.4	0.908
Height (cm)	161.0±4.2	160.5±3.5	0.778
Weight (kg)	62.7±5.7	50.2±4.3	0.002
BMI (kg/m^2)	24.2±1.5	19.5±1.6	0.002
WHR	0.79±0.02	0.74±0.03	0.001
PI (°)	46.5±6.0	49.8±6.3	0.001
PT (°)	20.0±2.1	19.3±1.2	0.460
SS (°)	22.3±3.0	30.5±6.9	0.010
LL (°)	27.5±2.6	31.2±2.8	0.026
TK (°)	27.5±2.6	30.3±2.7	0.126
SFP (°)	74.8±3.2	76.2±3.4	0.438

PI = pelvic incidence; PT = pelvic tilt; SS = sacral slope; LL = lumbar lordosis; TK = thoracic kyphosis; SFP = sacrum femoral pubic symphysis; BMI = body mass index; WHR = waist to hip ratio.

(lower LL and TK), vertical Sacrum [13, 15]. Few studies focused on the spino-pelvic parameters for adolescent patients with LDH. The purpose of this study is to compare the sagittal spino-pelvic parameters and obesity factors between adolescents affected by LDH and normal adolescent.

The sagittal balance with respect to the center of gravity is represented by spinopelvic balance, which consists of spinal balance and sacropelvic balance [19]. Spinal balance means the position of trunk on L5 or sacrum, that represents overall spinal curvature. It is dependent on L5 S1 lordosis as well as total lumbar lordosis, sacropelvic angle or translation. Sacropelvic balance means the position of pelvic over the hip, that represents pelvic orientation. The spine and pelvis align around the hip axis in an attempt to maintain the overall spinopelvic balance. PI is an important anatomic parameter that describes the anatomic configuration of the pelvis and greatly influences the sagittal configuration of the spine [20, 22]. It is relatively constant during childhood. Thereafter, PI increases significantly during adolescence until reaching its maximum value in adulthood [21]. It is not affected by posture or the pelvic position, and is considered to be invariable at the end of growth [23]. PI represents the algebraic sum of the SS and the PT: PI=SS+PT.

In the present study, no matter in LG (PI=44.6°±5.3°, SS=24.0°±3.4°) or in NG (PI=47.3°±6.3°, SS=29.2°±6.5°) was lower, compared to PI (48.7°±9.5°) and SS (38.1°±7.0°) of adult reported by Xi Yang [24]. And PI and SS in LG were lower than that in NG. However, PT was different from PI and SS. Previous studies reported the LL closely correlated with SS [2, 7], LL were no significance between LG (30.0°±2.8°) and NG (31.8°±3.4°), and both smaller than LL (53.0°±9.6°) of normal adult reported by Xi Yang [24]. The small SS and PI found in LG suggest that the spatial orientation of the sacrum is more vertical than that in NG. The small degree of LL, the lumbar angle and the amplitude of the curvatures, together with the high value of the inclination of the spine, show that the sagittal shape of the spine in these patients is straight with only small curvatures. In this situation the compressive force component of gravity increases and these greater compressive forces accelerate the degeneration of the disc. This increase of the compressive forces is probably one of the many pathognomonic conditions that lead to herniation.

Nevertheless, PI had a negative relationship for male adolescent with LDH. And PT, LL, SS had a close relationship for male adolescent with LDH. But for female adolescent, PI, SS and LL were statisticly smaller in LG than these in NG. We speculated that the height, weight and BMI might cause these difference. As we know,

Table 4. Spino pelvic values, distributed by BMI groups

BMI		18.5-24.9 (kg/m^2)	25.0-29.9 (kg/m^2)	>29.9 (kg/m^2)	*P*
LDH	PI (°)	39.6±5.0	44.8±5.1	48.0±4.7	P1=0.035, P2=0.181
	PT (°)	18.4±2.1	20.7±2.1	21.6±2.1	P1=0.022, P2=0.344
	SS (°)	21.2±2.9	24.1±3.4	26.4±3.2	P1=0.070, P2=0.143
	LL (°)	26.4±1.3	30.4±2.9	32.6±3.3	P1=0.004, P2=0.113
NORMAL	PI (°)	41.0±6.2	50.5±7.9		
	PT (°)	18.1±1.6	17.5±0.6		
	SS (°)	28.9±6.3	33.0±8.2		
	LL (°)	31.8±3.4	31.5±8.2		
P (PI)		0.010	0.043		
P (PT)		0.862	0.008		
P (SS)		0.004	<0.001		
P (LL)		<0.001	0.907		

PI = pelvic incidence; PT = pelvic tilt; SS = sacral slope; LL = lumbar lordosis; TK = thoracic kyphosis; BMI = body mass index. *P1, comparison between BMI (18.5-24.9 kg/m^2) and BMI (25.0-29.9 kg/m^2) for LDH adolescent; P2, comparison between BMI (25.0-29.9 kg/m^2) and BMI (>29.9 kg/m^2) for LDH adolescent.

male adolescents usually were higher, fatter than the female, implying that spine of male have to bear more force.

Biomechanics play an important role in the initiation and progression of several spine pathologies, it is imperative to have an understanding of spino-pelvic parameters between adolescent with LDH and without LDH. S.Romero Vargas [25] try to assess if BMI was associated with modifications on spino-pelvic parameters, but failed to find the positive difference between BMI and spino-pelvic parameters. The present study also provides an objective analysis of the correlation between height, weight, BMI and WHR and spino-pelvic parameters. We amazedly found that adolescents in LG have higher height (178.8±7.0 cm), more weight (88.3±11.5 kg), larger BMI (27.5±2.0 kg/m^2) and WHR (0.89±0.07) than these (height=172.8±6.7 cm; weight=68.7±9.6 kg ; BMI=22.9±2.0 kg/m^2; WHR=0.80±0.03) in NG, suggesting that adolescent with more weight, height and BMI mean their need to endure more stress compared to less weight, height and BMI. It is easier to understand generally degeneration of disc under more press for adolescent with more weight, height and BMI and eventually lead to disc herniation.

Adolescent in LG and NG were classified depending on BMI, normal weight status ranges from 18.5 kg/m^2 to 24.9 kg/m^2, and overweight status ranges from 25 kg/m^2 to 29.9 kg/m^2 of BMI. A BMI that is greater than 30 kg/m^2 is considered to reflect obesity. The results showed that adolescent with normal weight in LG, compared to NG (PI=41.0°±6.2°, SS=28.9°±6.3°, LL=31.8°±3.4°), has lower PI (39.6°±5.0°), SS (21.2°±2.9°) and LL (26.4°±1.3°); adolescent with overweight in LG, compared to NG (PI=50.5°±7.9°, SS=33.0°±8.2°), has lower PI (44.8°±5.1°) and SS (24.1°±3.4°). We also found PI, PT, SS, LL were larger and larger with increasing BMI in LG, there were significant difference between normal weight and overweight in LG, but not between overweight and obesity (**Table 4**). Patients with increasing BMI show a more hyperextension of the lumbar spine, similar to the anterior translation of the center of mass descrimbed by Whitcome [25] in pregnant women. Obese adolescents, as women at early stages of pregnancy, seem to compensate the forward translation of the center of mass only with increases of LL and PI. The elevated abdominal circumference and gravity effect could influence the spino-pelvic parameters, resulting parameters increase. Besides, adolescent with more height and weight implied that patients need to endure more pressure from themselves compared to normal adolescents.

Another factors leading to LDH for adolescents in our study was lacking exercise. In China, lacking exercise for adolescents was well known. There were some reasons explaining this. First, adolescent endure more pressure from college entrance examination, which was of great importance for the Chinese adolescent, so more attention must be paid to study and ignore exercise. Second, adolescent prefer to junk food resulting in obesity, fatty people usually are lazy and lack exercise. Third, even though they have time to relax, they would like to choose to play computer games rather than do some sports.

The present study had several limitations. First, because of lower incidence of adolescent with LDH, leading to a small sample size; secondly, this was just a retrospective study, we also need a prospective study. However, to the best of our knowledge, this is the first report to sagittal spino-pelvic parameters and obesity factors between adolescents with or without LDH.

Conclusion

This is the first accurate and general analysis to compare spino-pelvic parameters and obesity factors between adolescent with and without LDH. We found adolescents with LDH have lower PI, SS and LL. And adolescent with more BMI, weight, height and WHR were more likely to suffer from LDH. The spino-pelvic parameters increase significantly between normal weight and overweight, but not between overweight and obesity for adolescents with LDH. Adolescents do more exercise could decrease incidence of suffering from LDH.

Disclosure of conflict of interest

None.

Authors' contribution

Conceived and designed the study: DWY; collected data: T.W, H.W, FYL; analyzed the data: T.W, DLY and L.M; wrote the paper: Tao Wang and Hui Wang.

Abbreviations

LDH, lumbar disc degeneration; LG, LDH group; NG, normal group; PI, pelvic incidence; PT, pelvic tilt; SS, sacral slope; LL, lumbar lordosis; TK, thoracic kyphosis; SFP, sacrum femoral pubic symphysis; BMI, body mass index; WHR, waist to hip ratio.

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