ACTA
ORTHOPAEDICA
et
TRAUMATOLOGICA
TURCICA

Acta Orthop Traumatol Turc 2010;44(4):293-299
doi:10.3944/AOTT.2010.2375

The relation between sagittal morphology of the lumbosacral spine and the degree of lumbar intervertebral disc degeneration

Tarkan ERGUN, Hatice LAKADAMYALI, Mehmet Şükrü ŞAHİN*

Başkent University, Alanya Practice and Research Hospital,
*Departments of Radiology and *Orthopedics and Traumatology, Antalya*

Objectives: We investigated the relationship between the lumbosacral morphology and degree of intervertebral disc degeneration in a large sample of young patients. In addition, the relation between various morphological parameters (sacral table angle and sacral kyphosis) and lumbar disc herniation or degeneration was also evaluated.

Methods: The magnetic resonance imaging (MRI) of low back pain patients referred to our department in 2008-2009 were retrospectively evaluated. Patients with prior lumbar spinal surgery, serious congenital anomalies on MRI, incomplete or complete lumbosacral trancision, severe scoliosis, spondylolysis, or spondylolisthesis were excluded from the study. A sample of 131 females between 20-30 years of age was studied. Patients were evaluated for the presence of intervertebral disc herniation or degeneration, and the degree of degeneration was assessed. Angles of lumbar lordosis, sacral table, and sacral kyphosis were also measured for each patient.

Results: The degree of intervertebral disc degeneration increased in parallel to the decrease in the sacral kyphosis and lumbar lordosis angles, and to the increase in sacral table angle. A statistically significant difference with regard to the angles of lumbar lordosis, sacral kyphosis, and sacral table was determined between individuals with (23.37±7.09°, 163.09±9.48°, 104.34±5.47°, respectively) and without intervertebral disc degeneration (26.94±7.39°, 168.94±10.52°, 100.83±4.32°; p=0.006, p=0.001, p=0.0001, respectively). In addition, a statistically significant difference with regard to the angles of lumbar lordosis, sacral kyphosis, and sacral table was determined between individuals with (22.82±6.94°, 162.23±9.53°, 104.94±5.19°, respectively) and without intervertebral disc herniation (27.25±7.26°, 169.39±9.96°, 100.48±4.33°; p=0.001, p=0.0001, p=0.0001, respectively).

Conclusion: The degree and risk of intervertebral disc degeneration and herniation increases in parallel to the decrease in sacral kyphosis and lumbar lordosis, and to the increase in sacral surface angle.

Key words: Degeneration; intervertebral disc; lumbosacral spine; morphology.

Low back pain is one of the most frequently observed symptoms in the human musculoskeletal system. The frequency of low back pain increases with age and its frequency in the adult population is reported to vary between 60-90%.[1] Of the many causes of back pain, discogenic origin is assumed to be one of the most important.[2,3] In a recent study conducted by Cheung et al.,[4] it was reported that there is a close relationship between the level of low back pain and the degree of disc degeneration.

Correspondence: Tarkan Ergun, MD. Başkent Üniversitesi Alanya Uygulama ve Araştırma Hastanesi, Radyoloji Anabilim Dalı, 07400 Alanya, Antalya, Turkey. Tel: +90 242 - 511 25 11 e-mail: tarkanergun@yahoo.com

Submitted: November 1, 2009 **Accepted:** April 26, 2010

©2010 Turkish Association of Orthopaedics and Traumatology

There are numerous studies analyzing the frequency of intervertebral disc degeneration in magnetic resonance imaging (MRI) and the relationship between the intervertebral disc degeneration and low back pain. However, there are a limited number of publications analyzing differences in lumbosacral morphology associated with the tendency to develop intervertebral disc degeneration.

The normal orientation of lumbosacropelvic structure plays an important role in the determination of shear and compressive forces applied on the anterior (corpus vertebrae and intervertebral discs) and posterior (facet joints) elements of lumbar vertebral column.[5] This has led to an increase in interest in morphologic analysis of lumbosacropelvic structure.

Studies in this area have generally been conducted on individuals with low back pain[6-8] or on populations with isthmic spondylolisthesis.[9-11] On the other hand, the number of studies on individuals with intervertebral disc degeneration or disc herniation is considerably low and in all of these studies, the differences of sagittal morphology on normal individuals and patients with either disc degeneration or disc herniation have been analyzed.[12,13] Barrey et al.[12] and Rajnics et al.[13] have reported that lumbar lordosis and sacral slope differ in individuals with disc degeneration or disc herniation and normal individuals. Nonetheless, there are no publications in the literature analyzing the relationship between the degree of intervertebral disc degeneration and the lumbosacral morphology. It is essential to understand what lumbosacral morphology predisposes to intervertebral disc degeneration and determine the degree of this degeneration to detect those individuals who have tendency to develop severe low back pain.

The purpose of this study was to investigate the relationship between the lumbosacral morphology and the degree of intervertebral disc degeneration (the level of mechanical loads on the anterior elements of the vertebrae), using MRI. Additionally, the study aimed to analyze the connection between two different lumbosacral morphologic parameters (angles of the sacral table and sacral kyphosis) and the presence of lumbar disc herniation or disc degeneration on a large sample of adult patients.

Patients and methods

Lumbar MRI examinations of patients sent to our clinic for investigation of low back pain between 2008 and 2009 were retrospectively evaluated. Patients with a history of any lumbar spinal operation and patients diagnosed with lumbar or sacral tumor, diffuse bone metastasis, severe congenital anomaly, incomplete or complete lumbosacral transition, severe scoliosis, discitis, osteomyelitis, lumbar vertebrae fracture, and spondylolysis or spondylolisthesis during the MRI examination were excluded from the study. A sample was selected from the remaining patients, which included 131 females, 20 to 30 years of age (mean age 25.9±2.4 years).

Lumbosacral morphology and intervertebral discs of all patients were evaluated on MRI. All examinations were conducted by using an MRI device at 1 Tesla (Signa, GE Medical System, Milwaukee, WI, USA). Sagittal T1 weighted spin echo (SE) (TR/TE: 440-10 ms, matrix: 256x224, FOV: 28x28 cm and slice thickness: 4 mm), sagittal T2 weighted fast SE (TR/TE: 3300-106 ms, matrix: 448x224, FOV: 28x28 cm and slice thickness: 4 mm), and axial T2 weighted SE (TR/TE: 4000-110 ms, matrix: 256x224, FOV: 20x20 cm and slice thickness: 4 mm) sequences were used in the imaging protocol.

Presence and degree of intervertebral disc degeneration can be assessed on direct radiograph or MRI. In their study on cadavers, Christe et al.[14] detected a better correlation between histological phase of intervertebral disc degeneration and MRI phase than direct radiograph findings. In our study, the presence and degree of intervertebral disc degeneration was assessed on sagittal T2 weighted MRI passing through the midsagittal line, since lateral radiograph images of all patients in upright posture were not available. Lumbosacral parameters were also analyzed on the same image. Presence of intervertebral disc herniation was assessed on the axial and sagittal T2 weighted images. All measurements were done in a virtual electronic environment. To minimize random errors, each measurement was repeated twice and the average was used.

All pathological changes and measurements detected during lumbar MRI examination were reached by joint decision of a radiologist experienced in neuroradiology and an orthopedic surgeon experi-

enced in spinal surgery. For each patient, the presence of intervertebral disc herniation and degeneration was examined and the disc degree of degeneration was noted. Additionally, for each patient, lumbar lordosis, the sacral table, and sacral kyphosis angles were measured and recorded.

The degree of intervertebral disc degeneration was classified by using modified Pfirrmann scale.[15] Five grades of degeneration were described as follows:

Grade 1: Disc height is normal; distinction between nucleus and annulus is clear; disc with bright white internal structure.

Grade 2: Disc height is normal; distinction between nucleus and annulus is clear; disc with inhomogeneous internal structure.

Grade 3: Disc height is normal or slightly decreased; distinction between nucleus and annulus is not entirely clear, but shape of annulus is still traceable, grey disc with inhomogeneous internal structure.

Grade 4: Disc height is either normal or moderately decreased; distinction between nucleus and annulus is not clear; grey-black disc with inhomogeneous internal structure.

Grade 5: Disc height is severely decreased; distinction between nucleus and annulus is not clear; black disc with inhomogeneous internal structure.

The Pfirrmann scale was modified because cerebrospinal fluid (CSF) has higher signals than the disc in the used MR sequences, and this criterion was not used to evaluate the intensity difference of intervertebral disc with respect to the CSF. Grades 1 and 2 were classified as normal discs, while grades 3, 4, and 5 were defined as degenerated discs. For cases in which multiple intervertebral disc degenerations were present, the most advanced phase was taken into consideration. Disc herniation was classified as either present or absent for each patient. Negative indicated either minimal bulging disc or normal disc; positive indicated either diffuse disc bulging, herniation, or sequestered disc.

The L1-L5 lumbar lordosis angle was concordant with the angle formed by the lines passing through the midpoints of the L1 and L5 vertebrae. The sacral table angle described by Osterman et al.[16] was concordant with the angle formed by the sacral endplate's upper and posterior surfaces. The sacral kyphosis angle was concordant with the angle formed by the line connecting the midpoints of the upper and lower endplates of S1 and the line connecting the midpoints of the upper endplate of S2 and the lower endplate of S4 (Fig. 1).

For each measurement, median and standard deviation values were calculated using the t-test.

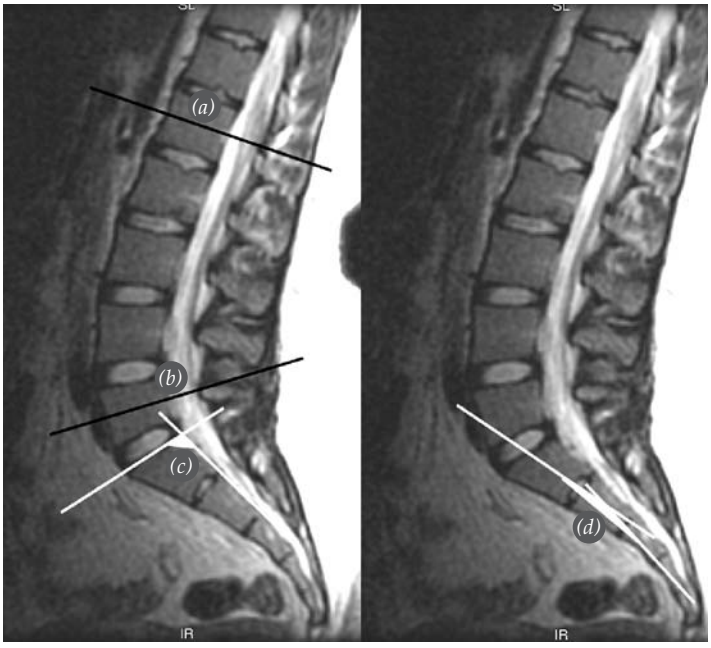

Fig. 1. Measurement of lumbosacral parameters. L1-L5 lumbar lordosis angle was concordant with the angle formed by the lines passing through the midpoints of the L1 **(a)** and L5 **(b)** vertebrae. Sacral table angle **(c)** was concordant with the angle formed by the sacral endplate's upper and posterior surfaces. Sacral kyphosis angle **(d)** was concordant with the angle formed by the line connecting the midpoints of S1's upper and lower endplates, and the line connecting the midpoints of S2's upper endplate and S4's lower endplate.

Data of the groups with and without disc degeneration and the groups with and without disc herniation were compared using the t-test. The relationship between the degree of intervertebral disc degeneration and lumbosacral parameter values was assessed by using Mann-Whitney U test. A p-value less than 0.5 was considered significant. Statistical analyses were carried out using SPSS 11.0. The study was approved by the hospital ethics committee. The signed patient consent form was not necessary.

Results

Intervertebral disc degeneration was observed in 72 patients. Stage 1 degeneration was present in 33 cases, stage 2 in 26 cases, stage 3 in 24 cases, and stage 4 in 48 cases (Fig. 2). Stage 5 degeneration was not observed in any of the cases. The relationship of the three lumbosacropelvic anatomic parameters to the degree of intervertebral disc degeneration is shown in Table 1. The level of intervertebral disc degeneration increased parallel to the increase in sacral table angle and the decrease in sacral kyphosis and L1-L5 lumbar lordosis angle (Fig. 3 and 4).

The mean sacral table angle was measured to be 104.34±5.47° and 100.83±4.32° in individuals with and without disc degeneration, respectively; this difference was statistically significant (p=0.0001).

Sacral kyphosis angle, which is the fundamental indicator of sacrum's sagittal configuration, was 163.09±9.48° and 168.94±10.52° for those individuals with and without disc degeneration, respectively; this difference was statistically significant (p=0.001).

The mean L1-L5 lumbar lordosis angle was lower in those individuals with intervertebral disc degeneration (23.37±7.09°) than those individuals without intervertebral disc degeneration (26.94±7.39°); the difference was statistically significant (p=0.006).

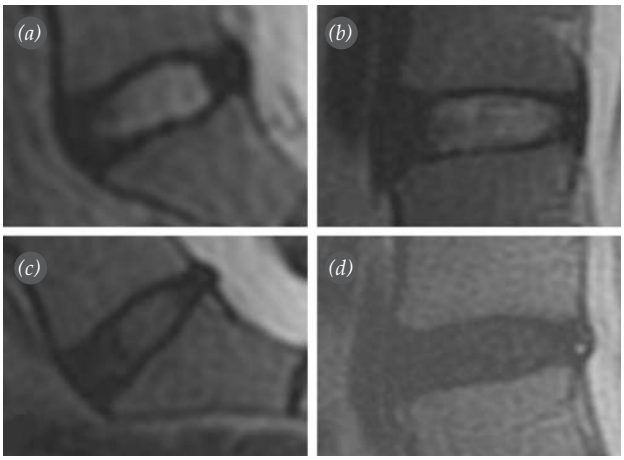

Fig. 2. **(a)** Grade 1, **(b)** grade 2, **(c)** grade 3, and **(d)** grade 4 disc degenerations were observed on midsagittal T2 weighted images.

Intervertebral disc herniation was detected in 51% of the cases. There were statistically significant differences between individuals with (22.82±6.94°, 162.23±9.53°, 104.94±5.19°) and without (27.25±7.26°, 169.39±9.96°, 100.48±4.33°) intervertebral disc herniation with regard to L1-L5 lumbar lordosis, sacral kyphosis, and sacral table angle (p=0.001, p=0.0001, p=0.0001).

Discussion

The age- and sex-related differences of spinal structure have been researched by many authors. In their study on middle-aged and advanced-aged asymptomatic volunteers, Gelb et al.[17] reported that the degree of lumbar lordosis decreased with advanced age. Mac-Thiong et al.[18] and Hanson et al.[10] found that the pelvic incidence increases with advanced

Table 1

Relation between the degree of intervertebral disc degeneration and lumbosacral anatomic parameters (mean±SD)

Degeneration	L1-L5 lumbar lordosis angle (°)		Sacral table angle (°)		Sacral kyphosis angle (°)	
Grade 1	27.33±7.36	} p=0.598	100.15±4.14	} p=0.193	171.9±10.65	} p=0.007
Grade 2	26.46±7.54	} p=0.572	101.69±4.47	} p=0.402	165.19±9.24	} p=0.992
Grade 3	24.83±4.71	} p=0.324	102.91±5.05	} p=0.130	164.66±7.17	} p=0.159
Grade 4	22.64±7.96		105.06±5.59		162.31±10.43	

age. In addition, various studies of young and elderly populations have reported meaningful differences in C7 plumb line, sacral inclination, and thoracic kyphosis.[6,19-21] Mac-Thiong et al.[22] carried out research on lumbosacral morphology of 341 normal individuals and noticed higher values in females than males. Moreover, it was noticed that there is a meaningful statistical difference in thoracic tilt and pelvic tilt between the two genders. Thus, in order to avoid probable age- and gender-related differences, the present study was performed with individuals of a specific age group and same gender; a close relation between lumbosacral structure and presence and degree of disc degeneration as well as the presence of disc herniation has been observed.

According to the study of Bernhardt and Bridwell,[23] the center of gravity force of the body is approximately located on the T9 vertebra. This force passes through thoracic vertebrae and reaches to the lumbar and lumbosacral junction level. At this level, biomechanical stress caused by the force of gravity leads to degeneration of intervertebral discs. There is a direct proportional relationship between the amount of mechanical force on the intervertebral disc and the level of intervertebral disc degeneration.[24,25] In this study, the intervertebral disc degeneration level, namely the amount of mechanical force on the anterior elements of the lumbar vertebra was classified and its relationship to lumbosacral morphology evaluated. In the 132 patients, we found that as sacral table angle increases or sacral kyphosis and L1-L5 lumbar lordosis angles decreases, the spinal load on anterior elements of the vertebrae (the level of disc degeneration) increases.

Barrey et al.[12] and Rajnics et al.[13] detected decreases in lumbar lordosis and sacral slope in those patients with disc degeneration and disc herniation when compared to the normal individuals. Although normal individuals were selected as control group in these two studies, recent studies have shown that spinopelvic morphology depicts important differences between individuals with low back pain and normal individuals (individuals with low back pain have less distal segmental lordosis, more proximal lumbar lordosis, and a more distinct vertical sacrum than normal individuals).[7,26] In the studies of Barreyet al.[12] and Rajnicset al.[13] the differences in age and gender, which affect spinopelvic morphology, were not taken into consideration. Our findings were similar to the results of these two studies. Our findings indicate that lumbosacral structure with a more vertical orientation causes a tendency to develop disc degeneration and herniation.

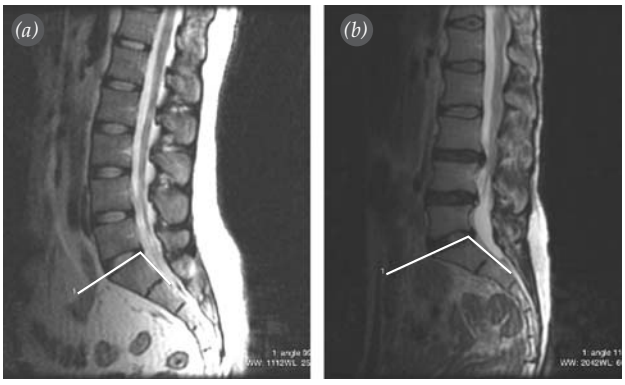

Fig. 3. Sacral table angle in patients with **(a)** Grade 1 and **(b)** grade 4 disc degeneration was measured to be 99° and 115°, respectively.

Another important result that could be derived from our study is the close relationship detected between the sacral table and sacral kyphosis angle and presence of intervertebral disc degeneration or herniation. The fact that this relationship has not been reported in the literature also enhances the originality of our study. Sacral table angle and sacral kyphosis angle are parameters that can be easily assessed in routine MR sequences; these parameters are not affected by the posture of the patient and are determined genetically.[27] Our results indicate that the risk of developing disc degeneration and hernia-

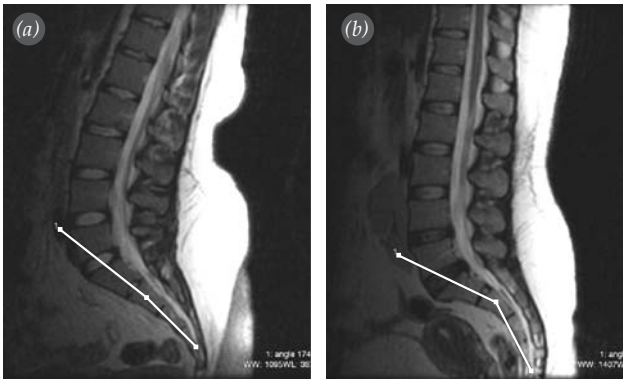

Fig. 4. Sacral kyphosis angle in patients with **(a)** Grade 1 and **(b)** grade 4 disc degeneration was measured to be 174° and 143°, respectively.

tion increases with increasing sacral table angle and decreasing sacral kyphosis angle.

In this study, disc degeneration and disc herniation were observed frequently in the MRI findings of young adult women. Degeneration in intervertebral disc is a part of normal aging and is associated with additional risk factors (e.g., genetic factors, obesity, physical loads on lumbar vertebrae, atherosclerosis, and smoking). The frequency of intervertebral disc degeneration associated with aging has been reported at different ratios in different studies.[4] Salminen et al.[3] reported the presence of degenerative disc in at least one level in individuals 15 and 18 years of age to be 31% and 42%, respectively. In their study conducted in Southern Chinese society, Cheung et al.[4] detected the frequency of degenerative disc in individuals aged 18-29 years to be 42%. Paajanen et al.[28] reported findings similar to ours: in a study conducted using MRI, they found the frequency of disc degeneration in individuals 20 years of age with low back pain to be 57%.

Intervertebral disc herniation and disc degeneration are not infrequent conditions; they can be seen in asymptomatic individuals. However, in their study of 1,043 individuals, Cheung et al.[4] detected a strong relation between low back pain and disc degeneration or disc herniation. Moreover, they found that the level of low back pain increases with increasing degree of internal disc degeneration. Waris et al.[29] determined that with increasing age disc herniation developed with high frequency in those individuals with disc degeneration. The present study shows that intervertebral discs are subject to degeneration more easily and at a more distinct level as the lumbosacral column gets straighter. Those individuals with a straighter vertebral column have a greater risk of low back pain complaints and more severe symptoms throughout their lives than individuals with normal lumbosacral slope. Moreover, individuals with such morphology have a greater risk of developing disc herniation throughout their lives than individuals with normal lumbosacral slope.

Our study had several limitations. The first limitation is that the socio-demographic status (sports activities and medical information), occupational information (repetitive bending, sedentary work, lifting of heavy objects), and body mass index of a patients with a tendency to develop disc degeneration and disc herniation were not evaluated. The second limitation is that, although sagittal parameters such as low lumbar lordosis angle and sacral slope, which are affected by the posture of the patient, were not analyzed, because MRI examination was performed with the patients in the supine position. The last limitation is that, although all measurements were performed using consensus of two experts, intra-observer and inter-observer variability were not evaluated.

In conclusion, despite these limitations, our study is of critical importance, since it shows that biomechanical loads on intervertebral discs increase parallel to the decrease in the normal sagittal inclination of the lumbosacral vertebral column; it also shows that, in addition to other parameters analyzed in sagittal morphology, the sacral table and sacral kyphosis angles are important predisposing anatomical factors for the development of intervertebral disc degeneration and herniation.

References

1. Altınel L, Köse KC, Ergan V, Işık C, Aksoy Y, Özdemir A, et al. The prevalence of low back pain and risk factors among adult population in Afyon region, Turkey. [Article in Turkish] Acta Orthop Traumatol Turc 2008;42:328-33.
2. Bezer M, Erol B, Kocaoğlu B, Aydın N, Güven O. Low back pain among children and adolescents. [Article in Turkish] Acta Orthop Traumatol Turc 2004;38:136-44.
3. Salminen JJ, Erkintalo MO, Pentti J, Oksanen A, Kormano MJ. Recurrent low back pain and early disc degeneration in the young. Spine (Phila Pa 1976) 1999;24:1316-21.
4. Cheung KM, Karppinen J, Chan D, Ho DW, Song YQ, Sham P, et al. Prevalence and pattern of lumbar magnetic resonance imaging changes in a population study of one thousand forty-three individuals. Spine (Phila Pa 1976) 2009;34:934-40.
5. Roaf R. Vertebral growth and its mechanical control. J Bone Joint Surg Br 1960;42-B:40-59.
6. Jackson RP, McManus AC. Radiographic analysis of sagittal plane alignment and balance in standing volunteers and patients with low back pain matched for age, sex, and size. A prospective controlled clinical study. Spine (Phila Pa 1976) 1994;19:1611-8.
7. Jackson RP, Kanemura T, Kawakami N, Hales C. Lumbopelvic lordosis and pelvic balance on repeated

standing lateral radiographs of adult volunteers and untreated patients with constant low back pain. Spine (Phila Pa 1976) 2000;25:575-86.

8. Korovessis P, Dimas A, Iliopoulos P, Lambiris E. Correlative analysis of lateral vertebral radiographic variables and medical outcomes study short-form health survey: a comparative study in asymptomatic volunteers versus patients with low back pain. J Spinal Disord Tech 2002;15:384-90.
9. Rajnics P, Templier A, Skalli W, Lavaste F, Illés T. The association of sagittal spinal and pelvic parameters in asymptomatic persons and patients with isthmic spondylolisthesis. J Spinal Disord Tech 2002;15:24-30.
10. Hanson DS, Bridwell KH, Rhee JM, Lenke LG. Correlation of pelvic incidence with low- and high-grade isthmic spondylolisthesis spine. Spine (Phila Pa 1976) 2002;27:2026-9.
11. Antoniades SB, Hammerberg KW, DeWald RL. Sagittal plane configuration of the sacrum in spondylolisthesis spine. Spine (Phila Pa 1976) 2000;25:1085-91.
12. Barrey C, Jund J, Noseda O, Roussouly P. Sagittal balance of the pelvis-spine complex and lumbar degenerative diseases. A comparative study about 85 cases. Eur Spine J 2007;16:1459-67.
13. Rajnics P, Templier A, Skalli W, Lavaste F, Illes T. The importance of spinopelvic parameters in patients with lumbar disc lesions. Int Orthop 2002;26:104-8.
14. Christe A, Läubli R, Guzman R, Berlemann U, Moore RJ, Schroth G, et al. Degeneration of the cervical disc: histology compared with radiography and magnetic resonance imaging. Neuroradiology 2005;47:721-9.
15. Pfirrmann CW, Metzdorf A, Zanetti M, Hodler J, Boos N. Magnetic resonance classification of lumbar intervertebral disc degeneration. Spine (Phila Pa 1976) 2001;26:1873-8.
16. Osterman K, Osterman H. Experimental lumbar spondylolisthesis in growing rabbits. Clin Orthop Relat Res 1996; (332):274-80.
17. Gelb DE, Lenke LG, Bridwell KH, Blanke K, McEnery KW. An analysis of sagittal spinal alignment in 100 asymptomatic middle and older aged volunteers. Spine (Phila Pa 1976) 1995;20:1351-8.
18. Mac-Thiong JM, Berthonnaud E, Dimar JR 2nd, Betz RR, Labelle H. Sagittal alignment of the spine and pelvis during growth. Spine (Phila Pa 1976) 2004;29:1642-7.
19. Vedantam R, Lenke LG, Keeney JA, Bridwell KH. Comparison of standing sagittal spinal alignment in asymptomatic adolescents and adults. Spine (Phila Pa 1976) 1998;23:211-5.
20. Korovessis PG, Stamatakis MV, Baikousis AG. Reciprocal angulation of vertebral bodies in the sagittal plane in an asymptomatic Greek population. Spine (Phila Pa 1976) 1998;23:700-5.
21. Schwab F, Lafage V, Boyce R, Skalli W, Farcy JP. Gravity line analysis in adult volunteers: age-related correlation with spinal parameters, pelvic parameters, and foot position. Spine (Phila Pa 1976) 2006;31:E959-67.
22. Mac-Thiong JM, Labelle H, Berthonnaud E, Betz RR, Roussouly P. Sagittal spinopelvic balance in normal children and adolescents. Eur Spine J 2007;16:227-34.
23. Bernhardt M, Bridwell KH. Segmental analysis of the sagittal plane alignment of the normal thoracic and lumbar spines and thoracolumbar junction. Spine (Phila Pa 1976) 1989;14:717-21.
24. Andersson GBJ. Epidemiology of spinal disorders. In: Frymoyer JW, editor. The adult spine: principles and practice. New York: Raven Press; 1997. p. 93-141.
25. Videman T, Battié MC. Epidemiology of disc disease. In: Wiesel SW, Weinstein JN, Herkowitz HN, editors. The lumbar spine. Philadelphia: WB Saunders; 1996. p. 16-27.
26. Vaz G, Roussouly P, Berthonnaud E, Dimnet J. Sagittal morphology and equilibrium of pelvis and spine. Eur Spine J 2002;11:80-7.
27. Whitesides TE Jr, Horton WC, Hutton WC, Hodges L. Spondylolytic spondylolisthesis: a study of pelvic and lumbosacral parameters of possible etiologic effect in two genetically and geographically distinct groups with high occurrence. Spine (Phila Pa 1976) 2005;30:S12-21.
28. Paajanen H, Erkintalo M, Kuusela T, Dahlstrom S, Kormano M. Magnetic resonance study of disc degeneration in young low-back pain patients. Spine (Phila Pa 1976) 1989;14:982-5.
29. Waris E, Eskelin M, Hermunen H, Kiviluoto O, Paajanen H. Disc degeneration in low back pain: a 17-year follow-up study using magnetic resonance imaging. Spine (Phila Pa 1976) 2007;32:681-4.