Difference of Disk Degeneration and Segmental Range of Motion due to Lumbar Disk Level among Age and Gender: 639 Asymptomatic Volunteer Data

Tomohiro Yamada[1)2)], Hiroaki Nakashima[3)], Masaaki Machino[3)], Yukihiro Matsuyama[2)], Fumihiko Kato[1)] and Yasutsugu Yukawa[1)4)]

1) Department of Orthopedic Surgery, Nagoya Kyoritsu Hospital, Nagoya, Japan
2) Department of Orthopedic Surgery, Hamamatsu University School of Medicine, Hamamatsu, Japan
3) Department of Orthopaedic Surgery, Nagoya University Graduate School of Medicine, Nagoya, Japan
4) Department of Orthopedic Surgery, Wakayama Medical University, Wakayama, Japan

Abstract:

Introduction: There is limited evidence between lumbar disk degeneration and normal lumbar segmental range of motions (SRMs), because previous studies were skewed by age and lacked large cohort of asymptomatic data. We aimed to characterize the normal lumbar SRMs according to age and gender and determine its association with disk degeneration.

Methods: A total of 639 healthy Japanese volunteers (≥50 individuals of each decade of age from 20 to 79) without any symptom or morphological spinal abnormalities, who underwent lumbar radiograph and magnetic resonance image (MRI), were selected retrospectively. SRMs were evaluated by the flexion-extension radiographs taken in the recumbent position. Disk degenerations were assessed according to the Pfirrmann grade using MRI T2 imaging.

Results: The mean SRMs became larger in the lower lumbar level. The range of the mean SRMs was smallest at L1-2 and largest at L4-5: 6 to 9 degrees at L1/2, to peaking at 11-14 degrees at L4/5 in male, and 6-8 degrees at L1/2, to peaking at 11-17 degrees at L4/5 in female. Lumbar disk degeneration progressed faster with age in the lower lumbar spine than in the upper lumbar level. SRM did not change depending on the severity of disk degeneration in upper lumbar spine, but significantly decreased with progressive disk degeneration in the lower lumbar spine.

Conclusions: These findings could help to identify the normal lumbar SRMs that might be useful to evaluate the instability or inflexibility in the clinical situation. Furthermore, our results demonstrated the transition of the normative lumbar SRMs based on age, gender, and lumbar level.

Keywords:

Lumbar segmental range of motion, Disk degeneration, Age and gender difference, Normal volunteers

Spine Surg Relat Res 2025; 9(1): 87-92
dx.doi.org/10.22603/ssrr.2024-0087

Introduction

Examining lumbar segmental range of motions (SRMs) is important in evaluating the instability and inflexibility of the lumbar spine[1)]. Increased SRMs lead to facet instability, following to the recurrent disk herniation[2)], and spinal range of motion has been related with elderly quality of life[3)]. More than 40 years ago, Kirkaldy-Willis et al. described a pathology of low back pain and the cascade of degenerative instability through three stages: temporary dysfunction, unstable phase, and re-stabilization[4)]. Others report a negative correlation between lumbar SRMs and disk degeneration[5,6)]. To verify those cadaveric studies, a considerable amount of the clinical literature has also been published on the lumbar SRMs[7,8)]. In addition to disk degeneration, age and body mass index (BMI) have a negative impact on lumbar SRMs[9)].

However, the relationship between normal SRMs and disk degeneration remains unclear, because previous studies included symptomatic patients with low back pain and morphological spine abnormalities[9-11)]. Furthermore, there has been a limited analysis of the gender difference in SRMs

Corresponding author: Tomohiro Yamada, cordial27@gmail.com
Received: April 4, 2024, Accepted: May 21, 2024, Advance Publication: July 10, 2024

because most studies consist of male or female gender-biased ratio[10,11]. We believe that it is crucial to clarify for the relation between SRMs and aging disk degeneration using normal volunteers' lumbar radiograph and MRI image.

We hypothesized that there may be differences in the relationship between SRM and disk degeneration depending on the level of the disk and gender. In other words, the impact of progressive disk degeneration on SRM may differ depending on whether the subject is male or female and whether the disk level is upper or lower lumbar. This study aimed to investigate the relationship between the normal lumbar SRMs with disk degeneration using MRI image in each male and female, ranging from the 20s to 70s.

Table 1. Subjects' Age and Gender Distribution.

Age (year)	Male	Female	Total
20-29	51	53	104
30-39	52	52	104
40-49	51	60	111
50-59	59	53	112
60-69	50	60	110
70-79	49	49	98
Total	312	327	639

Materials and Methods

Study participants

Healthy Japanese volunteers were recruited after the study purpose was officially announced and approval was obtained from the institutional review board of author's hospital (IRB approval no. 2009-2). Written informed consent was obtained from all subjects. The exclusion criteria were as follows: symptoms related to sensory and motor disorders, such as numbness, clumsiness, and gait disturbance, history of spinal trauma or congenital spinal deformity, and history of brain or spine surgery, such as stroke or neuropathy. Pregnant women, those who received compensation for work-related injuries, and those who presented symptoms after an automobile accident were also excluded. Moreover, subjects with lumbar morphological abnormalities, such as spondylolisthesis, spondylolysis, morphological vertebra fracture, and transitional vertebra were excluded. Finally, 639 healthy subjects with appropriate images were enrolled; the study population included at least 50 subjects from each age decade (20s-70s) (Table 1).

Radiological and magnetic resonance imaging examinations

Lumbar lateral, flexion-extension radiographs were taken in the recumbent position (Fig. 1). Experienced radiation technologists used imaging software (Osiris4; Icestar Media Ltd., Essex, UK) to measure each parameter under the supervision of a certified spine surgeon. We performed MRI scan on a 1.5-Tesla superconducting magnet (Sigma Horizon

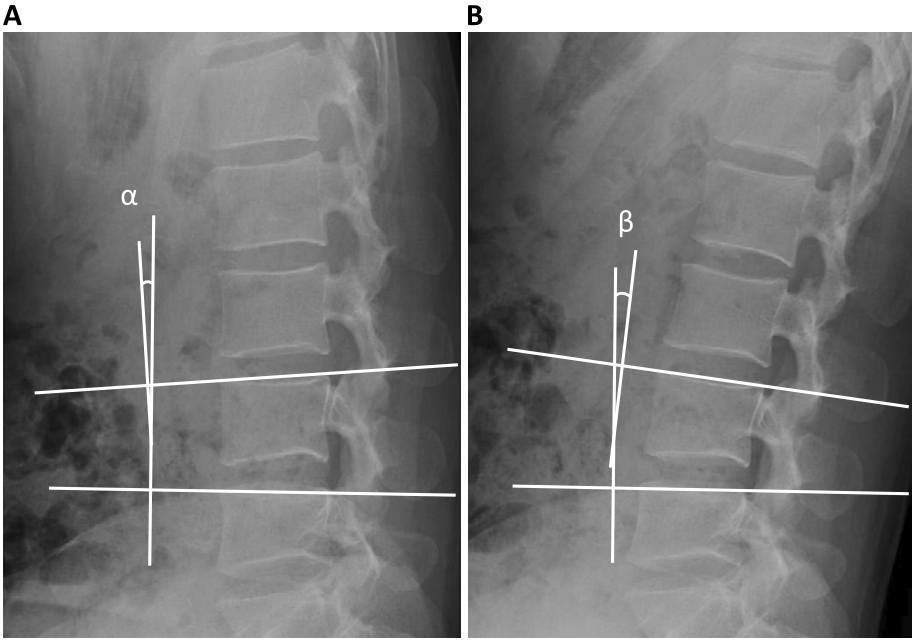

Figure 1. Lateral lumbar radiograph in the recumbent position.
(A). Lumbar flexion radiograph. α indicates the flexion angle.
(B). Lumbar extension radiograph. β indicates the extension angle.
β–α=segmental range of motion.

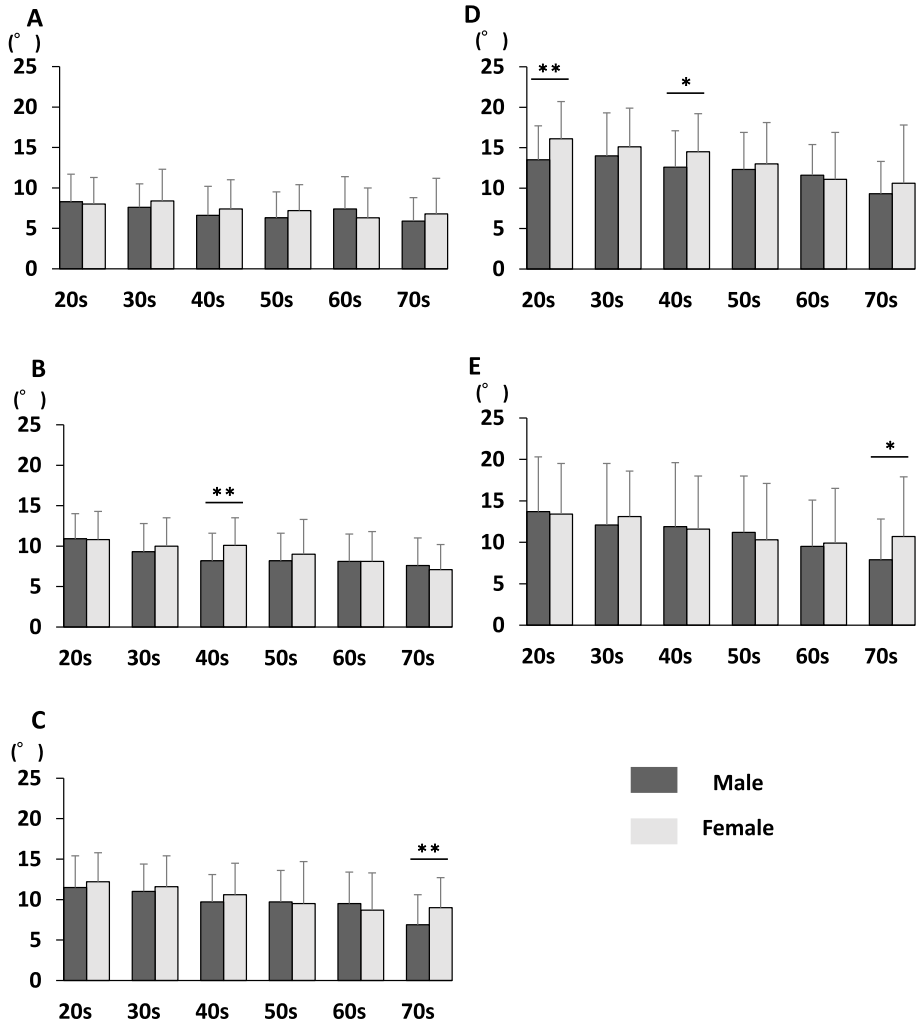

Figure 2. Lumbar segmental range of motion at each level in both male and female. (A). L 1/2. (B). L 2/3. (C). L 3/4. (D). L 4/5. (E). L5/S1. *Statistically significant. * $p<0.05$, ** $p<0.01$.

Excite HD version 12; GE Healthcare, UK). Disk degenerations were evaluated according to the Pfirrmann grade (1-5) using MRI T2 imaging[12].

Statistical analysis

Descriptive statistics, such as means and standard deviations, were calculated from demographic data and radiographic parameters. Differences in individual parameters based on BMI and radiographic parameters were assessed using unpaired *t* test and ANOVA and post hoc test. Differences in disk degeneration were assessed using chi-square test and Fisher's exact test. All statistical analyses were performed using the IBM SPSS software ver. 26.0 (IBM Corp., Armonk, NY, USA). A *p*-value of <0.05 was considered statistically significant.

Results

Lumbar segmental range of motion at each lumbar level

Fig. 2 shows lumbar SRMs at each decade in both male and female. In male, the range of mean SRM was 6-9 degrees at L1/2, increased, as it went to caudally, to peaked 10-14 degrees at L4/5. Each level of SRM gradually decreased with aging. In female, the range of mean SRM was 6-8 degrees at L1/2, increasing, as it went to caudally, to peaked 11-17 degrees at L4/5. Each level of SRM gradually decreased with aging in 20s-60s. Females in 40s at L2/3, 70s at L3/4, 20s at L4/5, 40s at L4/5, and 70s at L5/S1 significantly showed higher SRMs than males in the same decades.

Disk degeneration and segmental range of motion at each lumbar level

Fig. 3 shows disk degeneration that gradually increased with aging in both male and female. Disk degeneration more rapidly progressed in the lower lumbar spine than in the upper lumbar spine. Females in 50s at L1/2, 50s at L3/4, 30s at L4/5, 20s at L5/S1, and 30s at L5/S1 showed significantly higher degeneration than males in the same decade.

We then investigated the difference of SRMs based on disk degeneration at each level (Table 2). SRM based on the

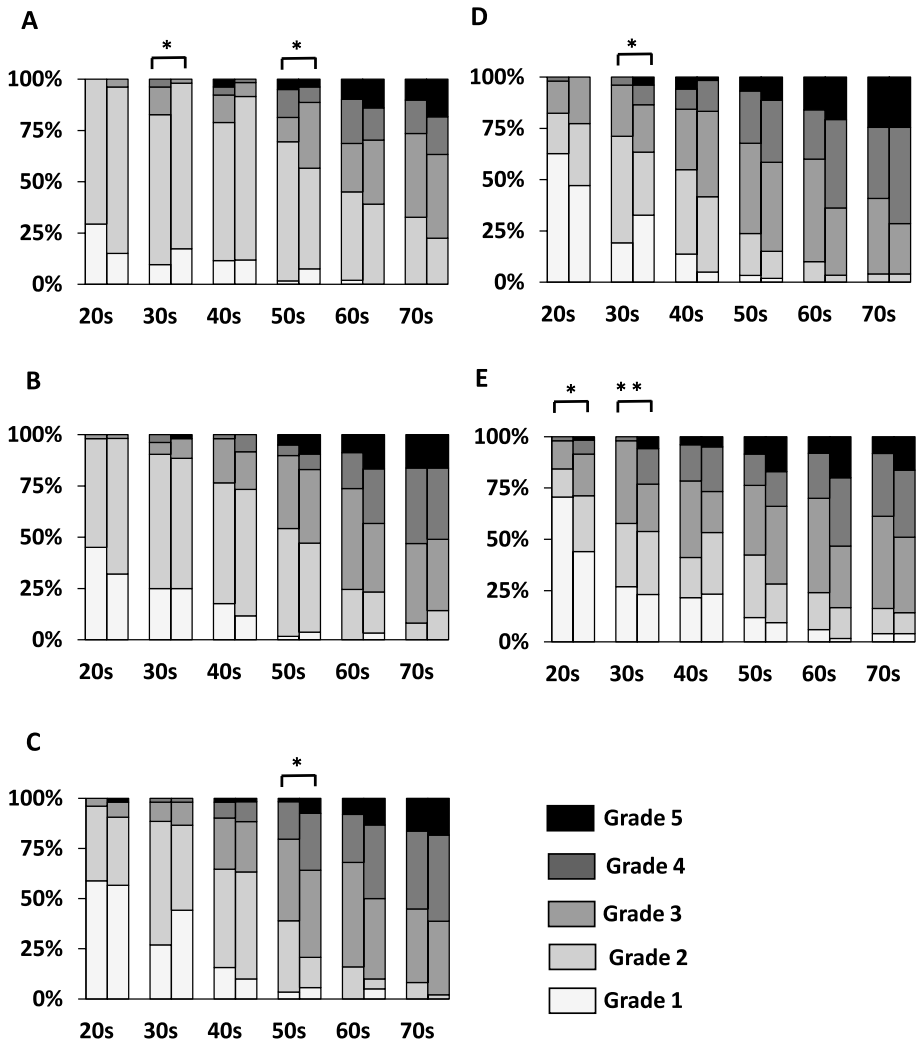

Figure 3. Disk degeneration at each level in both male and female.
(A). L 1/2. (B). L 2/3. (C). L 3/4. (D). L 4/5. (E). L5/S1. *Statistically significant.
* $p<0.05$, ** $p<0.01$.

disk degeneration did not change in L1/2 level. However, as it went to the lower level, SRM showed decrease as the disk degeneration progressed. Females with grades 1 and 5 at L3/4, grades 2 and 4 at L4/5, and grade 4 at L5/S1 showed significantly higher SRMs than males.

Discussion

This study aimed to describe the difference of the normative range of each lumbar segment and its association for disk degeneration between both genders per each generation. The result of this study showed that SRMs decreased at each lumbar level with aging and disk degeneration progression appeared earlier in the lower lumbar level and that a higher disk degeneration was associated with SRM decrease in the lower lumbar level.

Recent evidence suggests that the presence of lumbar disk degeneration, evaluated using MRI, has been associated with decreased range of motion in healthy adult[8,13]. Age has been the strongest factor for prediction of SRMs, and that SRMs decreased with aging, amounting to an approximate 3 degrees decrease in total SRMs in the cranial 4 lumbar segments every decade[9]. Adding to disk degeneration and aging, BMI has been useful for predicting each lumbar range or motion[9]. Using the same cohort analysis, Machino et al. reported that L3/4-L5/S1 were outstanding as mobile segments[14]. Unlike males, females had already developed disk degeneration in their 20s and 30s[15]. Consistent with those previous studies, disk degeneration progressed and each SRM decreased with aging except the 70s female at L5/S.

Interestingly, female SRMs were preserved at certain levels than male SRMs of the same decades, even though there was no difference in disk degeneration. It seems possible that old gender difference of the spinal shape or pelvic flexibility would cause the difference of L5/S1 SRM between male and female. In terms of the spinal shapes, recent evidence suggested that older females are more likely to become kyphosis at thoracic than males[16], which exhibited compensatory increase of lumbar lordosis[17]. The same cohort analysis suggested that flexion ROM was less affected than the extension ROM[18]. Given under the same state of the disk degeneration, a higher lordosis would then be asso-

Table 2. Segmental Range of Motions in Each Lumbar Level Based on Disk Degeneration in Male and Female.

		Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	P (ANOVA)	Post hoc
L1/2	Male	7.2±3.5	7.1±3.4	6.9±3.6	6.7±3.5	6.6±3.3	0.597	
	Female	6.8±3.4	7.5±3.7	6.4±3.5	7.2±3.9	9.3±5.2	0.059	
	P	0.704	0.213	0.422	0.637	0.112		
L2/3	Male	9.8±3.3	9.1±3.6	8.2±3.6	7.3±3.6	6.6±3.9	0.01*	d; 0.013*
	Female	10.8±3.9	9.4±3.8	8.7±3.6	8.7±3.7	7.6±4.1	0.013*	d; 0.013*
	P	0.233	0.472	0.301	0.105	0.429		
L3/4	Male	10.4±4.1	10.6±3.7	9.7±3.7	8.7±3.8	4.4±2.4	0.000***	d, g, i, j; 0.000***
	Female	12.1±4.0	10.8±3.9	9.7±4.3	9.1±4.7	8.1±3.7	0.000***	b; 0.06*, c; 0.001**, d; 0.002**
	P	0.019*	0.511	0.932	0.596	0.000***		
L4/5	Male	12.9±4.1	13±4.9	13.2±4.6	10.5±4.2	8.6±3.7	0.000***	d, g, h; 0.001*, i; 0.000***
	Female	14.7±5.1	14.8±4.8	12.8±5.5	13.3±7	8.9±4.1	0.000***	d; 0.000***, g; 0.000***, i; 0.001**, j; 0.001**
	P	0.072	0.006**	0.569	0.0049**	0.759		
L5/S1	Male	12.8±6.5	12.8±7.6	10.4±6.1	9.1±7.1	6.8±5.3	0.001**	c; 0.029*, d; 0.014*, f; 0.041*, g; 0.017*
	Female	12.5±6.3	11.1±5.6	12.1±7.8	12.8±7.4	8.1±5.9	0.060*	d; 0.027*, i; 0.027*, j; 0.009**
	P	0.783	0.136	0.079	0.0099**	0.458		

a; Grade 1 vs. Grade 2, b; Grade 1 vs. Grade 3, c; Grade 1 vs Grade 4, d; Grade 1 vs. Grade 5,
e; Grade 2 vs. Grade 3, f; Grade 2 vs. Grade 4, g; Grade 2 vs. Grade 5,
h; Grade 3 vs. Grade 4, i; Grade 3 vs. Grade 5, j; Grade 4 vs. Grade 5,
*P<0.05, **P<0.01, ***P<0.001

ciated with a more capability of the flexion ROM. For the pelvic flexibility, Ohmori et al. have declared that the iliolumbar ligaments have an influence on lumbosacral stability[19], mainly regulated by iliolumbar ligaments, especially their posterior band[20]. Fujiwara et al. elucidated that the posterior iliolumbar ligaments were significantly longer in females than in males using human cadavers[6]. Those morphological difference of the spine to pelvis may enable females to yield higher lower lumbar SRMs than males.

To our knowledge, this study is the first to clarify lumbar SRMs with enough volunteers to compare and evaluate the SRMs depending on disk degeneration. There have been several attempts to elucidate lumbar SRMs with cohort analysis. Miyasaka et al. analyzed the data from 90 adults, aged 20-39 years, and concluded that the greatest SRMs, shifting gradually from the upper to lower lumbar levels, appeared at L4/5 when performing maximal motion[21]. Similarly, Yanlin et al. demonstrated that lumbar SRMs gradually increased in the lower lumbar levels from 7.3 degrees at L1/2 to 8.9 degrees at L4/5 using kinematic MRI[13]. This study differs from other studies in that it evaluated disk degeneration and SRM at each age for both men and women and found that the relationship between disk degeneration and SRM varied with lumbar disk level.

This study has some limitations. First, the flexion-extension radiographs were taken in the recumbent position because it is easier for the radiologist to control the film positioning and obtain appropriate X-rays. Second, we did not focus on the facet joint osteoarthritis affecting facet mobility. However, some studies have found that disk degeneration generally precedes facet joint osteoarthritis[22]. We then believe that assessing disk degeneration would be a prerequisite for intervertebral mobility. Third, due to the number of measurements and the sheer number of subjects, measurements were taken only once. However, the measurements were taken in an authoritative manner by an experienced radiological technician with good knowledge of the lumbar bone structure. We believe that the result of this study is potentially important in that morphologically normative subjects presented lumbar SRMs affected by aging, gender, and lumbar level.

Conclusion

Our data presented lumbar SRM change between age and gender and lumbar level based on disk degeneration in normal volunteers. Our findings emphasized the fact that SRMs in both genders gradually decreased with aging and that correlation between SRMs and disk degeneration in L2/3-L5/S. We believe that these normal SRMs by age and gender will assist in the evaluation of the motor segments in clinical practice.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

Sources of Funding: This study was supported by institutional and grant research funds, which are intended for promoting hospital functions, of the Japan Labor Health and Welfare Organization (Kawasaki, Japan). No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

Author Contributions: Tomohiro Yamada wrote and prepared the manuscript, and all of the authors participated in the study design. All authors have read, reviewed, and approved the article.

Ethical Approval: This study was reviewed and approved by Chubu Rosai Hospital Institutional Review Board (IRB approval no. 2009-2).

Informed Consent: Informed consent for publication was obtained from all participants in this study.

References

1. Alqarni AM, Schneiders AG, Hendrick PA. Clinical tests to diagnose lumbar segmental instability: a systematic review. J Orthop Sports Phys Ther. 2011;41(3):130-40.
2. Kim KT, Park SW, Kim YB. Disc height and segmental motion as risk factors for recurrent lumbar disc herniation. Spine. 2009;34 (24):2674-8.
3. Imagama S, Matsuyama Y, Hasegawa Y, et al. Back muscle strength and spinal mobility are predictors of quality of life in middle-aged and elderly males. Eur Spine J. 2011;20(6):954-61.
4. Kirkaldy-Willis WH, Wedge JH, Yong-Hing K, et al. Pathology and pathogenesis of lumbar spondylosis and stenosis. Spine. 1978; 3(4):319-28.
5. Mimura M, Panjabi MM, Oxland TR, et al. Disc degeneration affects the multidirectional flexibility of the lumbar spine. Spine. 1994;19(12):1371-80.
6. Fujiwara A, Lim TH, An HS, et al. The effect of disc degeneration and facet joint osteoarthritis on the segmental flexibility of the lumbar spine. Spine. 2000;25(23):3036-44.
7. Aizawa T, Kokubun S, Ozawa H, et al. Increasing incidence of degenerative spinal diseases in Japan during 25 years: the registration system of spinal surgery in Tohoku University spine society. Tohoku J Exp Med. 2016;238(2):153-63.
8. Lee SH, Daffner SD, Wang JC. Does lumbar disk degeneration increase segmental mobility in vivo? Segmental motion analysis of the whole lumbar spine using kinetic MRI. J Spinal Disord Tech. 2014;27(2):111-6.
9. Bible JE, Simpson AK, Emerson JW, et al. Quantifying the effects of degeneration and other patient factors on lumbar segmental range of motion using multivariate analysis. Spine. 2008;33(16): 1793-9.
10. Boden SD, Wiesel SW. Lumbosacral segmental motion in normal individuals. Have we been measuring instability properly? Spine. 1990;15(6):571-6.
11. Burton AK, Battié MC, Gibbons L, et al. Lumbar disc degeneration and sagittal flexibility. J Spinal Disord. 1996;9(5):418-24.
12. Pfirrmann CW, Metzdorf A, Zanetti M, et al. Magnetic resonance classification of lumbar intervertebral disc degeneration. Spine. 2001;26(17):1873-8.
13. Yin R, Lord EL, Cohen JR, et al. Distribution of Schmorl nodes in the lumbar spine and their relationship with lumbar disk degeneration and range of motion. Spine. 2015;40(1):E49-53.
14. Machino M, Nakashima H, Ito K, et al. Age-related degenerative changes and sex-specific differences in osseous anatomy and intervertebral disc height of the thoracolumbar spine. J Clin Neurosci. 2021;90:317-24.
15. Machino M, Nakashima H, Ito K, et al. Influence of age and gender on intervertebral disk degeneration and height in the thoracolumbar spine. Spine Surg Relat Res. 2022;6(4):379-87.
16. Fon GT, Pitt MJ, Thies AC, Jr. Thoracic kyphosis: range in normal subjects. AJR Am J Roentgenol. 1980;134(5):979-83.
17. Kao FC, Huang YJ, Chiu PY, et al. Factors predicting the surgical risk of osteoporotic vertebral compression fractures. J Clin Med. 2019;8(4):501.
18. Yukawa Y, Matsumoto T, Kollor H, et al. Local sagittal alignment of the lumbar spine and range of motion in 627 asymptomatic subjects: age-related changes and sex-based differences. Asian Spine J. 2019;13(4):663-71.
19. Ohmori K, Ishida Y, Takatsu T, et al. Vertebral slip in lumbar spondylolysis and spondylolisthesis. Long-term follow-up of 22 adult patients. J Bone Joint Surg Br. 1995;77(5):771-3.
20. Leong JC, Luk KD, Chow DH, et al. The biomechanical functions of the iliolumbar ligament in maintaining stability of the lumbosacral junction. Spine. 1987;12(7):669-74.
21. Miyasaka K, Ohmori K, Suzuki K, et al. Radiographic analysis of lumbar motion in relation to lumbosacral stability. Investigation of moderate and maximum motion. Spine. 2000;25(6):732-7.
22. Moore RJ, Crotti TN, Osti OL, et al. Osteoarthrosis of the facet joints resulting from anular rim lesions in sheep lumbar discs. Spine. 1999;24(6):519-25.