A Longitudinal Study of Lumbar Sagittal Change in Middle-Aged Healthy Volunteers

Kenyu Ito[1)2)], Kei Ando[1)], Kazuyoshi Kobayashi[1)], Hiroaki Nakashima[1)], Yukihiro Hasegawa[3)] and Shiro Imagama[1)]

1) Department of Orthopedic Surgery, Nagoya University Hospital, Graduate School of Medicine, Aichi, Japan
2) Department of Orthopedic Surgery, Konan Kosei Hospital, Aichi, Japan
3) Department of Rihabilitation, Kansai University of Welfare Sciences, Osaka, Japan

Abstract:

Introduction: Recent research has shown that spinal sagittal alignment plays a critical role in health-related quality of life. However, most of these studies were cross-sectional in nature, and longitudinal studies of lumbar lordosis (LL) in healthy subjects were few. This study aims to evaluate the change in lumbar sagittal parameters during a 10-year period.

Methods: The study population included 45 individuals (mean age, 65.7 years; male, n=20; female, n=25) who underwent sagittal lumbar radiography and a basic health checkup during a 10-year period. The radiologic parameters were LL, disc angle, sacral slope angle (SS), and pelvic incidence (PI). The change of LL during the 10-year period was defined as ΔLL. The subjects were divided into the LL maintenance group (n=33) and the LL non-maintenance group (n=12) based on their LL values.

Results: The radiologic baseline/final parameters were as follows: LL, 45/34 degrees (P<0.001); L1/L2 disc angle, 4.5/2.5 degrees; L2/L3 disc angle, 5.5/2.7 degrees; L3/L4 disc angle, 6.2/4.2 degrees; L4/L5 disc angle, 8.1/5.1 degrees; L5/S disc angle, 14.2/12.2 degrees; and SS, 32.0/32.1 degrees.

The mean PI (50.5 degrees) was tended to be associated with the final LL (R=0.31, P=0.044) and was correlated with the ΔLL (R=0.43, P<0.01).

The data of the LL maintenance/non-maintenance groups were as follows: age, 65.0/67.0; primary LL, 43.2/50.2 degrees (P<0.05); final LL, 36.2/27.8 degrees (P<0.05); and PI, 52.8/43.8 degrees (P<0.01).

Conclusions: During the 10-year study period, the LL in middle-aged and elderly volunteers decreased by 11 degrees. The factor of maintenance of LL was PI.

Keywords:

lumbar lordosis, pelvic incidence, sacral slope, longitudinal, volunteer, bone mineral density, back muscle, long follow

Spine Surg Relat Res 2021; 5(3): 160-164
dx.doi.org/10.22603/ssrr.2020-0123

Introduction

The improvement of living standards and increased usage of medical care has led to an aging society[1)]. In this setting, the incidence of low back pain, which is prevalent in elderly individuals, is increasing[2-4)]. Recent research has shown that spinal sagittal alignment plays a critical role in health-related quality of life[5-7)]. Thus, normal or ideal lumbar lordosis (LL) has been well studied[8-12)]. However, most studies on this topic were cross-sectional in nature, and longitudinal studies on LL in healthy subjects were few. Accordingly, the present study aimed to investigate the change in the lumbar sagittal parameters in middle-aged and elderly volunteers over a 10-year period and to evaluate the relationships among LL, back muscle strength, and bone mineral density (BMD).

Materials and Methods

The subjects were community-living Japanese volunteers who attended a basic health checkup in the town of Yakumo in Hokkaido, Japan[13)]. The checkup program included voluntary orthopedic and physical functional examinations. A total of 303 individuals underwent a health checkup in 2005, and

Corresponding author: Shiro Imagama, imagama@med.nagoya-u.ac.jp
Received: July 7, 2020, Accepted: August 22, 2020, Advance Publication: September 23, 2020

323 underwent a health checkup in 2015. Of these participants, 45 (male, n=20; female, n=25) underwent health checkups in both 2005 and 2015. The average age of these subjects at the baseline examinations was 65.7 years (range, 50-75 years). None of the subjects had low back pain, vertebral compression fracture, and rheumatoid arthritis or were receiving hemodialysis. Lumbar lateral standing radiographs, the T-score of the BMD, back muscle strength, and 10-m gait time were examined as described below.

Lateral lumbar X-ray imaging

The lumbar lateral standing radiographs were obtained in a free-standing position with the subject's fists on his or her clavicle[14]. The radiologic parameters that were evaluated included T12-S1 LL, disc angle, sacral slope angle (SS), and pelvic incidence (PI)[15]. The PI was measured once at the final follow-up examination, because PI is a constant in each indivual[15,16]. The PI was classified into the following categories: low PI, <40; middle-low PI, 40-49; middle-high PI, 50-59; and high PI, ≥60. Changes in LL and in the disc angle over the 10-year period were defined as ΔLL and Δdisc angle, respectively. Two observers, board-certified spine surgeon with >10 years of experience, performed measurements.

Bone mineral density, back muscle strength, and 10-m gait time

Quantitative ultrasound of the left calcaneus was estimated using an Achilles Insight system (GE Medical Systems Ultrasound, GE Healthcare, Chalfont St Giles, UK). The system measures the bone stiffness, which can also be expressed as a T-score[17].

The back muscle strength was determined from the maximal isometric strength of the trunk muscles in a standing position with 30° lumbar flexion using a digital back muscle strength meter (T.K.K.5402, Takei Co., Japan)[18-20].

The 10-m gait time is used as a measure of the physical ability of elderly people. It was measured by a therapist who accompanied each subject to evaluate his or her maximum speed without running[18,21].

The determinants of non-maintenance of lumbar lordosis

Subjects were stratified into quartile groups based on the ΔLL[22]. Subjects in the quartile group with the greatest decrease were classified into the non-maintenance of LL group; the remaining three quartile groups were classified into the maintenance of LL group.

Statistical analysis

All of the statistical analyses were performed using the SPSS software program (ver. 17.0 for Windows; SPSS Inc., Chicago, IL, USA). The Mann-Whitney U test and Student's t-test were used to analyze the differences between the two groups. Correlations were analyzed using Pearson's correlation test. P-values of <0.05 indicate statistical significance.

Table 1. Longitudinal Data for Each Parameter.

		Baseline	10-year follow-up	P-value
Age (yrs)		65.7±5.3	75.7±5.3	
LL (°)		45.1±9.7	34.1±12.1	<0.001
SS (°)		32.0±7.0	32.1±14.2	N.S.
Disc angle (°)	L1/2	4.5±2.6	2.8±2.3	<0.01
	L2/3	5.5±2.7	3.7±2.8	<0.01
	L3/4	6.2±3.0	4.2±3.2	<0.01
	L4/5	8.1±3.9	5.1±4.3	<0.01
	L5/S	14.2±5.0	12.2±5.1	0.055

Data are presented as the mean±standard deviation of the mean.

Results

The intraclass and interclass correlation coefficients for the measurements of the X-ray were 0.93 (95% confidence interval, 0.89-0.95) and 0.87 (95% confidence interval, 0.83-0.91), respectively. The mean LL was 45.1 degrees at baseline and 34.1 degrees at the 10-year follow-up examination. The analysis of the longitudinal data revealed that the SS at the baseline and 10-year follow-up examinations did not differ significantly. The longitudinal data revealed that the disc angle had decreased at all levels (Table 1).

The mean PI was 50.5 degrees, which did not correlate with the primary LL (R=0.01, P=0.97), tended to be associated with the final LL (R=0.31, P=0.044), and was correlated with the ΔLL (R=0.43, P<0.01) (Fig. 1). The ΔLL in the low PI subjects was −19.0 degrees, which is significantly lower than the ΔLL in the high PI subjects (−2.5 degrees; P=0.03) (Table 2).

During the 10-year follow-up period, LL increased in seven cases and decreased in 38 cases. The subjects were divided into the LL maintenance group and the LL non-maintenance group based on the ΔLL of −16 degrees as quartiles (Fig. 2). The LL values of the subjects in the maintenance group were smaller at the baseline examination and became larger at the final follow-up examination, because of their lower ΔLL values (Table 3). No statistically significant differences were found in the age, SS, Δdisc angle, T-score, back muscle strength, and 10-m gait time. The only statistically significant difference was in the PI (maintenance group, 52.8 degrees vs. non-maintenance group, 43.8 degrees; P<0.01).

Discussion

This study demonstrated that the LL of middle-aged and elderly volunteers decreased by 11 degrees over a 10-year longitudinal period. The PI was a factor in the maintenance of LL and was correlated with the ΔLL. This study was the first to describe a relationship between the PI and LL in a longitudinal study of asymptomatic volunteers.

One study investigated a longitudinal study of sagittal spinal alignment in adult volunteers[23]. The LL decreased 7.6

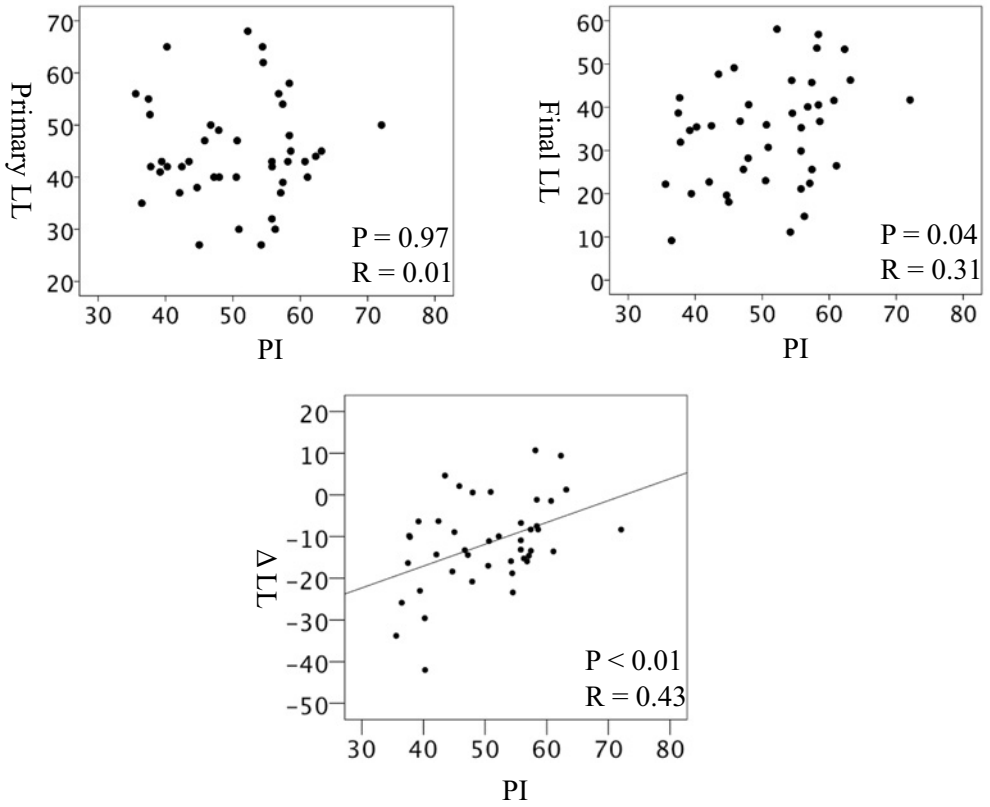

Figure 1. The relationship between LL and PI.
Primary LL and PI were not correlated. The final LL and PI showed a trend toward correlation. The change in LL (ΔLL) and PI were significantly correlated.

Table 2. Comparison of Low, Middle-low, Middle-high, and High PI.

PI classification	Low (PI<40)	Middle-low (40≦PI<50)	Middle-high (50≦PI<60)	High (60≦PI)
N	8 (M5, F3)	15 (M6, F9)	17 (M7, F10)	5 (M2, F3)
PI (°)	37.7±1.4	46.2±5.1	55.3±2.7	63.9±4.7
Primary LL (°)	47.0±7.7	45.2±9.9	44.3±11.9	44.4±3.6
Final LL (°)	28.0±10.9	34.8±10.3	34.1±13.9	41.9±9.9
ΔLL (°)	−19.0±9.8	−12.8±12.3	−10.2±7.9	−2.5±8.8

Data are presented as the mean±standard deviation of the mean.
ΔLL=the change in LL over the 10-year period.
Primary LL had no difference in each group. The final LL had a tendency, but no significant difference in each group. LL decreased most in the low PI, which had a significant difference with that of high PI (P=0.03).

degrees and the SS decreased 7.5 degrees during 10 years in this previous study. However, PI was not measured in this study. Several authors have investigated the age-related LL decrease in healthy volunteers in cross-sectional studies[24,25]. A cross-sectional study of asymptomatic individuals mentioned that a sudden decrease in LL was seen in individuals of between 60 and 70 years of age[8]. Similarly, our longitudinal study showed that the LL decreased in the same age group (60-70 years). Previous studies have demonstrated that aging induces an anterior shift in the C7 plumb line and a decrease in LL[8,24,25]. This might reflect compensatory changes that help maintain the sagittal balance[26].

The PI-LL match is an important factor for a harmonious spine[27]. In our study, the mean primary LL in the low to high PI groups was almost the same (approximately 45 degrees). The PI matched the primary LL in the middle-low PI group, and the PI was larger than the primary LL in the middle-high and high PI groups. In contrast, the PI was smaller than the primary LL in the low PI group. Finally, the LL became smaller than the PI in all groups, and the PI-LL was mismatched by 10-20 degrees (Table 2). A cross-sectional study demonstrated that the PI-LL gradually increased with age (PI-LL in 50s, 2.3°; 60s, 4.7°; 70s, 9.6°; 80s, 15.9°)[28]. These results and past reports suggest that a decrease in the LL and PI-LL mismatch occurred from the 60s in asymptomatic volunteers. The natural history of the sagittal spino-pelvic alignment is important when considering treatment for adult spinal disorders.

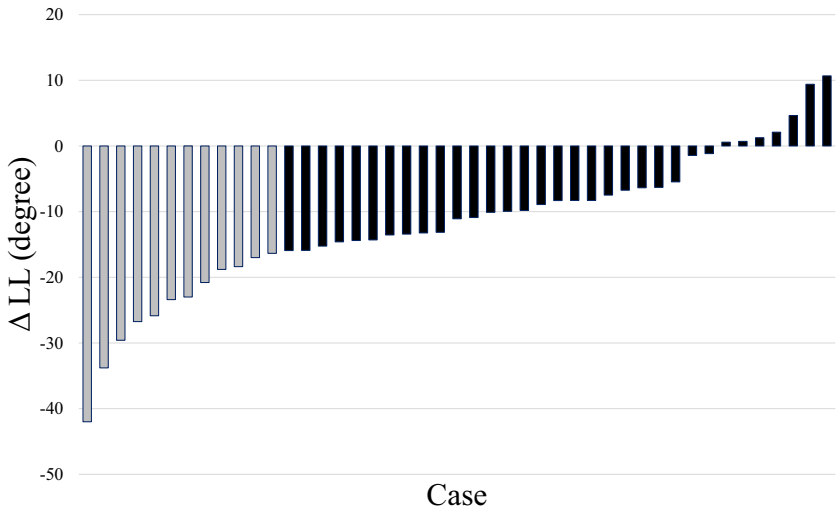

Figure 2. All cases of the change of LL (ΔLL) during the 10-year follow-up.
LL increased in 7 cases and decreased in 38 cases. Patients were stratified into quartile groups defined by ΔLL. The most decreased 1/4 group was determined as non-maintenance of the LL group (gray), and the rest of the 3/4 groups were determined as maintenance of the LL group (black).

Table 3. Comparison of the Lumbar Lordosis Maintenance and Non-maintenance Groups.

Lumbar lordosis		Maintenance	Non-maintenance	P-value
Number		33 (M12, F21)	12 (M8, F4)	
Age (yrs)		65.0±4.8	65.7±6.5	N.S.
Primary LL (°)		43.2±8.8	50.2±10.7	<0.05
Final LL (°)		36.1±12.0	27.8±10.8	<0.05
ΔLL (°)		−7.1±7.2	−24.6±7.6	<0.01
Primary SS (°)		31.7±7.5	32.9±5.6	N.S.
Final SS (°)		32.7±13.9	30.4±15.5	N.S.
PI (°)		52.8±8.2	43.8±7.0	<0.01
Δ Disc angle (°)	L1/2	−1.1±2.9	−3.0±4.5	N.S.
	L2/3	−1.3±2.6	−2.9±3.5	N.S.
	L3/4	−2.0±4.1	−2.0±2.3	N.S.
	L4/5	−2.7±4.7	−3.5±4.9	N.S.
	L5/S	−1.4±6.6	-4.0±6.0	N.S.
Primary T-score		−2.0±1.3	−2.5±1.8	N.S.
Final T-score		−2.0±1.2	−2.4±1.2	N.S.
Back muscle strength (kg)		80.1±38.6	83.0±32.4	N.S.
10-m gait time (sec)		4.7±0.6	4.7±0.8	N.S.

Data are presented as the mean±standard deviation of the mean.
ΔDisc angle=the change in the disc angle over the 10-year period.

The present study is associated with several limitations. First, the sample size was small, and gender differences were not investigated. Previous studies reported that there was no gender difference in the PI or LL values[10,29]. On the other hand, other studies have reported that female subjects had higher PI and LL values[8,11]. A larger sample size is needed to investigate the impact of gender in a longitudinal study. Second, whole spine radiographs were not evaluated. Whole spine X-ray examinations result in much greater radiation exposure than lumbar X-rays[30]. A slot scanning 3D X-ray imager can examine the whole spine with a low dose of radiation; however, such a large device would not allow for a cohort study of healthy subjects[31]. Further studies are necessary to solve these problems. However, few longitudinal studies of this length (10 years) have investigated healthy elderly subjects. Thus, this study is worthwhile and can provide a base for further studies.

Conclusion

In the present 10-year longitudinal study, the LL decreased 11 degrees in middle-aged and elderly healthy subjects. The factor of maintenance of LL was PI. The low PI volunteers decreased LL most.

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

Ethical Approval: This study was approved by the Institutional Review Board of Nagoya University Graduate School of Medicine (approval code: 355-3).

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