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Relationship between Knee Osteoarthritis and Spinopelvic Sagittal Alignment in Volunteers over 50 Years of Age

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Study Design: Large cohort study of volunteers.

Purpose: The purpose of this study was to investigate the relationship between the severity of knee osteoarthritis, assessed using the Kellgren-Lawrence (KL) grading scale, and spinopelvic sagittal alignment in older adult volunteers.

Overview of Literature: The relationship between spinopelvic alignment in the sagittal plane and knee osteoarthritis in the coronal plane is unclear.

Methods: Volunteers over 50 years of age underwent radiographic analysis. Radiographic parameters including pelvic tilt (PT), pelvic incidence (PI), lumbar lordosis (LL), thoracic kyphosis, and sagittal vertical axis (SVA) were measured. The the three Scoliosis Research Society-Schwab sagittal modifiers (PT, SVA, PI–LL) were categorized and the KL grade was assessed. Differences in spinopelvic parameters and Oswestry Disability Index (ODI) scores among KL grades were evaluated.

Results: A total of 396 volunteers (160 men, 236 women; mean age, 74.4 years) were analyzed. PI–LL and PT in KL4 were significantly higher compared to that in the other KL grades. However, there were no significant group differences in SVA. In women, but not in men, higher frequencies of the worst modifier grade (++) were observed for PI–LL and PT in the KL3 and KL4 groups compared to those for the other KL grades. In women, the ODI score in KL4 was worse compared to that in the other KL grades.

Conclusions: Individuals over 50 years of age with severe knee osteoarthritis had poor lumbo-pelvic sagittal alignment. Moreover, the progression severity of knee osteoarthritis had more impact onstronger relationship with lumbo-pelvic malalignment and disability-related low back pain in women than in men.

Keywords: Knee osteoarthritis; Spinopelvic alignment; Knee-spine syndrome; Kellgren-Lawrence grading scale; Sagittal alignment

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Introduction

Recently, many studies investigating the impact of sagittal malalignment on health-related quality of life (HRQOL) have reported normative values of sagittal alignment of the whole spine and pelvis [1-3]. As research continues, it has become increasingly clear that radiographs of the cervical, thoracic, and lumbar spine are insufficient to fully describe the impact of spinal deformity on the whole body [4]. In cases of spinal deformity, in order to maintain a horizontal gaze in the erect posture, compensatory mechanisms are recruited not only in the spinal column but also in the pelvis and lower limbs [4,5]. Some studies have investigated the relationship between spinopelvic alignment and the lower extremities, including the knee joint [6,7]. Knee flexion is documented as an important compensatory mechanism to maintain standing balance in spinopelvic malalignment cases [4,5,8,9].

Recently, a new classification system known as Schwab classification has been proposed by the Scoliosis Research Society (SRS) [10,11]. This classification includes sagittal radiographic parameters, and the cutoff values for adult spinal deformity are based on HRQOL. The classification enables an evaluation of severity in adult spinal deformity.

Knee osteoarthritis is one of the main causes of knee joint disorder. Its severity is assessed with Kellgren-Lawrence (KL) grading, which is based on anteroposterior radiograph results [12]. To our knowledge, no studies to date have evaluated a relationship between spinopelvic alignment on the sagittal plane and knee osteoarthritis on the coronal plane. The purpose of this study is to investigate the relationship between severity of knee osteoarthritis and spinopelvic sagittal alignment. We also analyze how disability relates to low back pain, and the prevalence of low back pain, in each KL grade.

Materials and Methods

1. Patient selection

This study was approved by the clinical Ethics Committee of Hamamtsu University School of Medicine (IRB approval no., 14-324). The subjects were volunteers who participated in a health screening program in 2014. Inclusion criteria were as follows: (1) age 50 years or more; (2) available whole spine and pelvic radiographs taken in the standing position; and (3) informed consent for participation in this study. Volunteers who met the following criteria were excluded from the study: (1) presence of orthopedic pathologies (e.g., Scheuermann kyphosis, tumor, infection); (2) undergoing implant surgery on lower extremities; (3) undergoing instrumented spinal surgery; (4) inability to stand without assistance; (4) unclear radiographic image and/or incomplete questionnaire data; or (5) sacralization and lumbarization of the spine.

2. Radiographic measurements

Radiographic data were taken with the volunteer in a free-standing position, staring straight ahead with their fingers on their clavicles. Whole spine lateral radiograph, pelvic lateral radiograph, and full-length lower extremity anteroposterior radiographs were taken.

In the whole spine lateral radiograph and pelvic lateral radiograph, spinopelvic parameters including pelvic tilt (PT), pelvic incidence (PI), lumbar lordosis (LL), thoracic kyphosis (TK), and sagittal vertical axis (SVA) were measured by computer software (Surgimap Spine; Nemaris Inc., New York, NY, USA). PI minus LL (PI–LL) was also calculated. The three sagittal modifiers (PT, SVA, PI–LL) were categorized according to SRS-Schwab classification. Based on the full-length lower extremity anteroposterior radiograph, KL grades of bilateral knee joints were assessed and more severe grade side were selected.

3. Quality of life measurement and assessment of prevalence of pain

The Oswestry Disability Index (ODI) was obtained for each volunteer as HRQOL outcomes. The ODI is a scale for measuring degree of disability due to low back pain. The presence of low back pain and knee pain was assessed by questionnaire.

4. Data analysis

IBM SPSS statistical software ver. 21.0 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. The unpaired *t*-test was used to analyze differences between sexes (male versus female). Analysis of variance, followed by the Tukey multiple comparison, was used to detect differences between each KL grade. A probability (p) value <0.05 was considered statistically significant.

Table 1. Radiographic parameters in different genders

Variable	Sample size	PT	PI	LL	TK	SVA	PI–LL
All	396	21.3±9.4	49.8±10.5	40.3±15.4	34.0±13.7	22.0±47.2	9.6±15.9
Male	160	17.2±7.8	47.4±9.1	40.9±12.6	33.7±11.8	21.7±44.5	6.5±13.5
Female	236	24.0±9.4	51.5±11.0	39.8±17.1	34.2±14.9	22.3±48.9	11.6±17.0
p-value (male:female)		<0.001	<0.001	0.99	0.98	0.62	0.004

Values are presented as mean±standard deviation.
PT, pelvic tilt; PI, pelvic incidence; LL, lumbar lordosis; TK, thoracic kyphosis; SVA, sagittal vertical axis.

Table 2. The distribution of KL grade evaluation of knee joint

Variable	All	Male	Female
KL1	40 (10.1)	29 (18.1)	11 (4.7)
KL2	93 (23.5)	48 (30.0)	45 (19.1)
KL3	154 (38.9)	48 (30.0)	106 (44.9)
KL4	109 (27.5)	35 (21.9)	74 (31.3)
Total	396 (100.0)	160 (100.0)	236 (100.0)

Values are presented as number (%).
KL grade, Kellgren-Lawrence grade.

Results

1. Study sample

Three hundred and ninety-six volunteers (160 males, 236 females) aged 50–93 years (mean age, 74.4 years) met our inclusion criteria.

2. Spinopelvic parameters

Average, standard deviation, and range of each radiographic parameter for each gender is shown in Table 1. The average values of spinopelvic parameters for the entire study group were; 21.3° for PT, 49.8° for PI, 40.3° for LL, 34.0° for TK, and 22.0 mm for SVA. Average PI–LL was 9.6°. Average values of PT, PI, and PI–LL were significantly higher in females than in males ($p<0.001$, $p<0.001$, and $p=0.004$, respectively).

3. Kellgren-Lawrence grade evaluation of knee joint

The distributions of KL grades for male and female volunteers is shown in Table 2. Of the entire study group, 40 volunteers were classified as KL1, 93 as KL2, 154 as KL3, and 109 as KL4. KL grades in females tended to be more severe compared to males. The average ages of individuals in each KL group (KL1, 2, 3, 4) were 74.1, 75.1, 72.7 and 76.3, respectively. The age difference between groups was not significant.

4. Spinopelvic parameter in each Kellgren-Lawrence grade

Radiographic parameters of sagittal modifiers, subdivided based on KL grade and gender, are summarized in Table 3. The average PT for subjects classified as KL1, 2, 3, and 4 were 15.8°, 20.1°, 21.4°, and 24.7°, respectively. PT for volunteers in KL4 was significantly higher than for other groups, and PT for volunteers in KL3 was significantly higher than for the KL1 group. PT for males in KL4 was significantly higher than in the KL1 group. PT for females in KL4 was significantly higher than in the KL2 and 3 groups.

The averages of PI–LL for volunteers in KL1, 2, 3, and 4 were 3.6°, 6.2°, 9.0°, and 14.4°, respectively. PI–LL for volunteers in KL4 was significantly higher compared to other groups. There was no significant difference between males and females. The averages of SVA for volunteers in KL1, 2, 3, and 4 were 9.7, 21.7, 18.7, and 31.5 mm, respectively, and there were no significant differences between groups.

5. Sagittal modifiers in each Kellgren-Lawrence grade

The distribution of sagittal modifiers in each KL grade and for each gender is summarized in Table 4. In all three sagittal modifiers as KL grade was severe volunteers with sagittal modifier "0" were decreased and "++" were increased. Particularly, PI–LL and PT were progressed of deformity in volunteers with knee osteoarthritis (KL3 and 4). PI–LL and PT were progressed of deformity in volunteers with knee osteoarthritis (KL3 and 4). We observed higher frequencies of the worst modifier grade (++) in females for PI–LL and PT in grades KL3 and 4. In male volunteers, the frequency of the worst modifier grade (++) did not increase with the progression of KL grade.

Table 3. Radiographic parameters of sagittal modifiers in each KL grade

Variable	KL1	KL2	KL3	KL4	*p*-value (ANOVA)	*p*-value (Tukey)
PT						
All	15.8±7.5	20.1±8.8	21.4±9.2	24.7±9.5	<0.001	b, f*, c, e**
Male	13.6±6.6	16.8±8.3	18.0±8.0	19.7±6.9	0.02	c*
Female	21.6±7.0	22.1±8.5	23.0±9.3	27.1±9.7	0.007	e, f*
p-value (male:female)	0.003	0.002	0.005	<0.001		
SVA						
All	9.7±35.4	20.5±41.4	18.7±48.3	31.5±52.5	0.06	
Male	48.4±9.5	20.0±33.7	19.5±48.0	32.6±58.0	0.4	
Female	15.9±4.9	23.6±48.6	18.4±48.6	31.0±50.1	0.09	
p-value (male:female)	0.06	0.97	0.47	0.56		
PI–LL						
All	3.6±10.9	6.2±14.4	9.0±117.2	14.4±15.6	0.003	f*, b, c, e**
Male	3.0±11.5	5.3±11.6	6.1±16.2	11.6±12.6	0.06	
Female	4.9±9.2	9.6±16.8	10.3±17.5	15.7±16.8	0.07	
p-value (male:female)	0.51	0.26	0.16	0.42		

Values are presented as mean±standard deviation. Multiple comparison: a, KL1 vs. KL2; b, KL1 vs. KL3; c, KL1 vs. KL4; d, KL2 vs. KL3; e, KL2 vs. KL4; and f, KL3 vs. KL4.
KL grade, Kellgren-Lawrence grade; ANOVA, analysis of variance; PT, pelvic tilt; SVA, sagittal vertical axis; PI, pelvic incidence; LL, lumbar lordosis.
*p<0.05. **p<0.01.

Table 4. Distribution of volunteers in the Scoliosis Research Society-Schwab classification (sagittal modifier) in each KL grade

3 Sagittal modifiers	Category	All				Male				Female			
		KL1	KL2	KL3	KL4	KL1	KL2	KL3	KL4	KL1	KL2	KL3	KL4
PI–LL	0 (<10°)	72.5	55.9	57.8	37.6	79.4	66.7	62.5	42.9	72.7	62.2	56.6	41.9
	+ (10°–20°)	20.0	29.0	22.1	29.4	10.3	25.0	22.9	40.0	27.3	17.8	20.8	17.6
	++ (>20°)	7.5	12.9	20.1	33.0	10.3	8.3	14.6	17.1	0	20.0	22.6	40.5
SVA	0 (<40 mm)	87.5	76.3	79.2	64.2	79.4	72.9	77.1	68.6	90.9	71.1	79.2	62.2
	+ (40–95 mm)	12.5	19.4	12.3	26.6	20.6	25.0	16.7	20.0	9.1	22.2	11.3	29.7
	++ (>95 mm)	0	4.3	8.5	9.2	0	2.1	6.2	11.4	0	6.7	9.5	8.1
PT	0 (<20°)	67.5	48.4	43.5	31.2	82.8	62.5	58.4	54.3	27.3	33.3	36.8	20.3
	+ (20°–30°)	30.0	44.1	40.9	42.2	17.2	33.3	33.3	37.1	63.6	55.6	43.4	44.6
	++ (>30°)	2.5	7.5	15.6	26.6	0	4.2	8.3	8.6	9.1	11.1	19.8	35.1

Values are presented as %.
KL grade, Kellgren-Lawrence grade; PI, pelvic incidence; LL, lumbar lordosis; SVA, sagittal vertical axis; PT, pelvic tilt.

6. Health-related quality of life (Oswestry Disability Index) and frequency of low back and knee pain in each Kellgren-Lawrence grade

ODI scores in each KL grade for males and females are shown in Table 5. In all volunteers, ODI score in the KL4 group was significantly higher than in the KL1 group. For female volunteers, the increase in ODI score was positively correlated with progression of KL grade, and ODI score in the KL4 group was significantly higher than ODI in the KL2 group. In contrast, ODI scores in male volunteers showed no difference between each KL grade.

The prevalence of low back pain, knee pain, and both low back and knee pain in each KL grade for each gender

Table 5. ODI score in each KL grade

ODI score	KL1	KL2	KL3	KL4	*p*-value (ANOVA)	*p*-value (Tukey)
All	9.9±10.8	12.2±11.9	13.1±12.1	16.1±13.0	0.02	c*
Male	10.2±11.8	12.3±13.0	12.0±13.7	12.6±13.1	0.89	
Female	8.9±7.9	11.6±10.4	13.6±11.3	17.7±12.6	0.01	e*

Values are presented as mean±standard deviation. Multiple comparison: a, KL1 vs. KL2; b, KL1 vs. KL3; c, KL1 vs. KL4; d, KL2 vs. KL3; e, KL2 vs. KL4; and f, KL3 vs. KL4.
ODI, Oswestry Disability Index; KL grade, Kellgren-Lawrence grade; ANOVA, analysis of variance.
*p<0.05. **p<0.01.

Table 6. Prevalence of pain in each KL grade

	All			Male			Female		
	LBP	Knee pain	LBP+knee pain	LBP	Knee pain	LBP+knee pain	LBP	Knee pain	LBP+knee pain
KL1	42.5	10.0	7.5	44.8	13.8	10.3	36.4	0	0
KL2	48.4	25.8	4.3	52.1	22.9	12.5	44.4	28.9	4.4
KL3	53.2	32.5	15.6	52.1	25.0	16.7	52.8	35.8	15.1
KL4	53.2	45.0	24.8	45.7	22.9	8.6	56.8	55.4	32.4

Values are presented as %.
KL grade, Kellgren-Lawrence grade; LBP, low back pain.

is shown in Table 6. For females, prevalence of low back pain and both low back and knee pain increased concurrently with progression of KL grade. The prevalence of low back pain, knee pain, and both low back and knee pain in males was not related to KL grade.

Discussion

Recently, knee flexion has become well known as a compensation mechanism for spinopelvic sagittal alignment [4,5,8]. However, there have been no reports concerning the relationship between spinopelvic alignment on the sagittal plane and knee joint degeneration on the coronal plane. This is the first study to investigate the relationship between sagittal spinopelvic alignment and severity of knee osteoarthritis.

In this study older volunteers (aged 50 years or more) with severe knee osteoarthritis (KL4) had poor lumbopelvic sagittal alignment. Knee osteoarthritis in these volunteers showed an especially strong relationship with pelvic retroversion. This result indicates that pelvic retroversion might lead to progression of knee osteoarthritis. Alternately, knee joint degeneration may affect pelvic retroversion. According to kinematic chain reaction, pelvic retroversion is related to hip external rotation and varus knee deformity in standing position [13]. Varus knee alignment increases the medial tibio-femoral load, and is associated with knee osteoarthritis [14,15]. Thus, sagittal lumbo-pelvic malalignment, especially pelvic retroversion, could lead to progression of knee osteoarthritis.

A previous study reported that more than half of patients with knee osteoarthritis had generalized osteoarthritis [16]. This suggests that many elderly people with knee osteoarthritis also have lumbar degeneration. Some previous studies reported that LL in individuals with lumbar degeneration was significantly lower than for those without lumbar degeneration [17,18]. These reports suggest that generalized osteoarthritis influences not only progression of knee osteoarthritis, but also decreases LL. Therefore, generalized osteoarthritis rather than interplay of knee and spine might explain the correlation between knee osteoarthritis and PI–LL in this study.

For SVA, we found no significant difference between volunteers in each KL grade. This result indicates that knee joint osteoarthritis impacted lumbo-pelvic sagittal alignment, not global spinal balance. There are many compensation mechanisms other than knee joint which relate to global spinal balance [5,19]. Knee joint degeneration impacts lumbo-pelvic alignment directly because the pelvis, which includes the hip joint, is adjacent to the knee

joint. However, the global spinal balance can adjust by other compensation mechanisms such as reduction of TK. Therefore, knee joint degeneration had limited impact on SVA.

In this study, we found differences between male and female volunteers for the distribution of SRS-Schwab classification in PI–LL and PT. Progression of knee osteoarthritis had more impact on deterioration of PI–LL and PT in females compared with males. Moreover, progression of knee osteoarthritis had more impact on disability related low back pain and prevalence of low back pain in females compared with males. These results suggest that the relationship between the knee joint and lumbar region is stronger in females than in males. In a previous report, authors found that worsening of sagittal alignment originated in the pelvis in females and the cervical spine in males [20]. Therefore lumbo-pelvic malalignment might be rarer in males than in females even when knee joint osteoarthritis is severe.

This study has some limitations because it is cross-sectional. We had no clinical score about knee, dates such as range of motion. Furthermore, lateral knee radiographic date was lacking. Because the subjects of this study were volunteers who participated in a health screening program, there was a limit on obtaining dates. A large study evaluating knee radiographic grading reported that inter-observer and intra-observer reliability were moderate to good (κ=0.56 and 0.61) [21]. However, we have no data on intra-observer and inter-observer reliability for KL grading. This was one limitation of our study. We also lacked data on whether knee joint degeneration or lumbo-pelvic malalignment occurred first in the volunteers. Therefore, the causal relationship between knee osteoarthritis and lumbo-pelvic alignment could not be fully elucidated. Further investigation in a longitudinal study is required to clarify this point.

Conclusions

Severity of knee osteoarthritis is related to lumbo-pelvic sagittal alignment but not global spinal balance. Pelvic retroversion demonstrated an especially strong relationship. Severity of knee osteoarthritis had a stronger relationship with lumbo-pelvic malalignment in females compared with males. Moreover, severity of knee osteoarthritis had a stronger relationship with disability low back pain and prevalence of low back pain in females compared with males.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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