



Impact of pelvic incidence on change in lumbo-pelvic sagittal alignment between sitting and standing positions

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Abstract

Purpose Lumbo-pelvic sagittal alignment is affected by pelvic incidence (PI), and the PI represents the compensatory capacity of lumbo-pelvic sagittal alignment. The purpose of this study was to analyze changes in lumbo-pelvic sagittal alignment between the standing and sitting positions and to analyze its association with PI.

Methods This study included 253 subjects (160 men and 93 women; age 53.6 ± 7.4 years). The subjects were divided into three groups (younger age group (YG), from 20 to 49 years; middle age group, from 50 to 69 years, and older age group (OG), of 70 years and above). Lumbar lordotic angle (LL), sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI), and the associations between the changes in LL (ΔLL), SS (ΔSS), PT (ΔPT), and PI were analyzed.

Results In the YG, the amount of change in LL, SS, and PT was larger than in the OG. These parameters correlated with age in the standing position but not in the sitting position. On the other hand, in all groups, there were positive correlations between PI and changes between the standing and sitting positions. Multiple logistic regression analysis demonstrated that $\Delta LL = 3.81 - 0.72 \times PT + 0.52 \times PI$, $\Delta SS = -4.50 - 5.3 \times PT + 0.34 \times PI$, and $\Delta PT = -9.1 + 3.5 \times PT - 0.21 \times PI$.

Conclusions Change in lumbo-pelvic parameters between the sitting and standing positions correlated with PI.

Graphical abstract

These slides can be retrieved under Electronic Supplementary Material.

Key points

1. Sagittal lumbar alignment
2. Pelvic incidence
3. Sitting position

Correlation of lumbo-pelvic parameters between the standing position and the change.

	ΔLL	ΔSS	ΔPT
LL	0.27 (<0.01)	0.24 (<0.01)	-0.22 (<0.01)
SS	0.30 (<0.01)	0.33 (<0.01)	-0.30 (<0.01)
PT	-0.75 (<0.01)	-0.76 (<0.01)	0.65 (<0.01)
PI	0.71 (<0.01)	0.69 (<0.01)	-0.58 (<0.01)

Take Home Messages

1. Change in lumbo-pelvic parameters between the sitting and standing positions correlated with PI.
2. PI is an important parameter to estimate the amount of changes in lumbo-pelvic alignment between the sitting and standing positions.

Keywords Sagittal lumbar alignment · Pelvic incidence · Sitting position

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Introduction

In modern society, people spend a large amount of time in the sitting position owing to advancements in various technologies, and prolonged time in the sitting position has been reported to be associated with various health problems [1, 2]. Some studies reported that the most prevalent

aggravating factor in adolescents with nonspecific lower back pain is being in the sitting position [3]; in particular, it was reported that younger people had a tendency to feel lower back pain while sitting [4]. Under such social circumstances, it is important to understand the difference in spinal alignment between the standing and sitting positions and effects of aging.

Sagittal lumbo-pelvic alignment in the sitting position has previously been studied [5–9], and it has become clear that lumbar lordosis (LL) and pelvic tilt (PT) are decreased in the sitting position compared to the standing; however, these studies did not clarify the association of positional change to pelvic incidence (PI) and aging. PI is an individual and constant parameter for each person and reflects the compensation of lumbo-pelvic sagittal alignment to some positional change [10]. Lumbo-pelvic sagittal alignment is affected by PI, and the amount of PI was demonstrated to be associated with the compensation of sagittal spinal deformity [10]. However, practical data of pelvic compensation following specific lumbo-pelvic movement have not been investigated in detail. We therefore hypothesized that there is a theoretical association of the PI and age to changes in lumbo-pelvic sagittal alignment between the standing and sitting positions. The purpose of this study was to investigate the difference in lumbo-pelvic sagittal alignment between the standing and sitting positions and to analyze its association with PI and aging.

Materials and methods

This study included 253 subjects (160 men and 93 women; age 53.6 ± 7.4 years). The subjects were divided into three groups (younger age group [YG], from 20 to 49 years; middle age group [MG], from 50 to 69 years, and older age group [OG], of 70 years and above) (Table 1).

All subjects who visited our hospital for spinal degenerative disease from 2015 to 2016 provided written informed consent after receiving the experimental protocol, and this study was approved by the institutional review board of

our institution. Subjects with ossification of the posterior longitudinal ligament (OPLL), diffuse idiopathic skeletal hyperostosis (DISH), patients with a history of previous spine surgery, Parkinson's disease, hip, knee, or ankle disorder, neuromuscular disease, or patients who could not stand up without assistance were excluded. The anthropometric characteristics of the subjects are summarized in Table 1. All subjects underwent frontal and lateral radiography of the lumbar spine, including the hip joints, in both the standing and sitting positions. The sitting position was an upright position with the head and trunk positioned vertically, in which the lower legs were bent at about 90° at the hips and knees (Fig. 1). Collimation was set superiorly to include T12, inferiorly to include S3, and slightly laterally to include the greater trochanter. The backrest of the chair was fixed at an angle of 90° . Whole spine anteroposterior and lateral radiographs were obtained using the digital slot-scanning radiography mode of the Socialvision Safire fluoroscopy system (Shimadzu Corporation, Kyoto, Japan). The following radiographic parameters were measured by computer-associated measurement as described previously [5, 11–13]: lumbar lordosis (LL, the angle from the upper endplate of L1 to the upper sacral endplate), sacral slope (SS, the angle between the sacral plate and the horizontal plane), pelvic tilt (PT, the angle between the line connecting the midpoint of the sacral plate to the axis of the femoral heads, and the gravity line), and pelvic incidence (PI, the angle between the line perpendicular to the sacral plate from its midpoint and the line connecting the point to the middle axis of the femoral heads) in the standing and sitting positions, and the difference between the standing and sitting (standing minus sitting) positions in LL (Δ LL), SS (Δ SS), and PT (Δ PT). The intraobserver and interobserver agreement rates of measurements have been described previously [5].

Values were expressed as mean \pm standard deviation (SD). Statistical analyses were performed using SPSS version 19 software (SPSS Institute, Chicago, IL, USA). The Kruskal–Wallis test was used to determine intergroup differences among the three different age groups. The *t* test was used to analyze differences in lumbo-pelvic parameters between the standing and sitting positions. Correlations between the variables of lumbo-pelvic parameters were analyzed using the Spearman rank correlation coefficient. To identify changes in lumbo-pelvic parameters between the standing and sitting positions, lumbo-pelvic parameters were analyzed by multivariate logistic regression with a forward stepwise procedure. A *p* value of less than 0.05 was considered to indicate a statistically significant difference between two groups.

Table 1 Anthropometric characteristics of the patients

	Younger	Middle	Older
Total	105	80	68
Age (years)	33.3 ± 8.4	61.6 ± 5.4	75.6 ± 4.6
Gender (M/F)	71/34	54/26	35/33
BMI	24.0 ± 7.5	24.6 ± 5.0	23.1 ± 3.3

Fig. 1 Photographs of standing and sitting positions



Table 2 Lumbar and pelvic parameters in the standing and sitting positions

	LL (°)	SS (°)	PT (°)
(1) Younger age group			
Standing	49.3 ± 14.2	34.6 ± 7.7	19.7 ± 16.4
Sitting	23.3 ± 13.4	18.1 ± 10.1	32.5 ± 12.7
Change	10.6 ± 27.1	7.7 ± 17.6	-11.2 ± 12.8
(2) Middle age group			
Standing	40.8 ± 11.5	31.3 ± 8.5	22.2 ± 15.1
Sitting	24.9 ± 16.2	18.8 ± 10.1	33.3 ± 14.0
Change	7.6 ± 19.3	5.9 ± 14.3	-9.1 ± 11.8
(3) Older age group			
Standing	42.1 ± 14.1	31.6 ± 8.9	24.3 ± 15.8
Sitting	27.1 ± 14.8	20.1 ± 9.6	33.2 ± 14.7
Change	4.3 ± 17.2	2.8 ± 14.2	-6.9 ± 10.3

Results

Age and change in lumbo-pelvic alignment between the standing and sitting positions

In all three groups, the LL and SS in the sitting position were smaller and the PT in the sitting position was larger than the respective values in the standing position. In the YG, changes in LL, SS, and PT were larger than those in the MG and OG groups (Table 2). The correlation between

Table 3 Correlation between lumbo-pelvic parameters and age in the standing and sitting positions

	LL	SS	PT
Age versus			
Standing	-0.28 (<0.01)	-0.19 (<0.01)	-0.14 (0.02)
Sitting	0.093 (0.14)	0.067 (0.29)	-0.01 (0.88)
Change	-0.07 (0.28)	-0.07 (0.24)	0.12 (0.05)

All values indicate the correlation rate (*p* value)

age and changes in lumbo-pelvic sagittal alignment between the sitting and standing positions was not found, but these parameters correlated with age at the standing but not in the sitting position (Table 3).

Standing lumbo-pelvic sagittal parameters and lumbo-pelvic sagittal alignment in the sitting position

Univariate analyses demonstrated that the LL, SS, PT, and PI associated with the Δ LL, Δ SS, and Δ PT (Table 4). Multiple logistic regression analyses demonstrated that only PT and PI reflected Δ LL, Δ SS, and Δ PT. The PT and PI affected the changes in lumbo-pelvic parameters between the standing and sitting positions as follows: Δ LL = $3.81 - 0.72 \times PT + 0.52 \times PI$, Δ SS = $-4.50 - 5.3 \times PT + 0.34 \times PI$, and Δ PT = $-9.1 + 3.5 \times PT - 0.21 \times PI$.

Table 4 Correlation of lumbo-pelvic parameters between the standing position and the change

	ΔLL	ΔSS	ΔPT
LL	0.27 (<0.01)	0.24 (<0.01)	-0.22 (<0.01)
SS	0.30 (<0.01)	0.33 (<0.01)	-0.30 (<0.01)
PT	-0.75 (<0.01)	-0.76 (<0.01)	0.65 (<0.01)
PI	0.71 (<0.01)	0.69 (<0.01)	-0.58 (<0.01)

All values indicate the correlation rate (*p* value)

Discussion

It was reported that the sitting position demonstrated lower LL and SS and higher PT than in the standing position in young normal [5, 9, 14] and elderly subjects [6, 7], and changes in these parameters were significantly smaller in the elderly group, when the subjects were divided into two groups by age [6]. The present study also demonstrated that changes were smaller with increasing age, even when divided into three groups by age. These results indicate that in older persons, lumbo-pelvic alignment in the sitting position is close to that in the standing position, owing to the loss of lumbar lordosis and posterior pelvic rotation [15]. However, when correlation analysis was performed, age did not significantly correlate with either lumbo-pelvic parameters (LL, SS and PT) in the sitting position nor value of change between the sitting and standing positions, and rather the amount of PI correlated with lumbo-pelvic

parameters in the standing position (Tables 2, 3). Aging effects changes between the standing and sitting positions [6]; however, changes in lumbo-pelvic alignment between the sitting and standing positions appeared to reflect the alignments in standing position more closely than age.

Multiple logistic regression analyses demonstrated that only PT and PI reflected ΔLL , ΔSS , and ΔPT , as follows: $\Delta LL = 3.81 - 0.72 \times PT + 0.52 \times PI$, $\Delta SS = -4.50 - 5.3 \times PT + 0.34 \times PI$, and $\Delta PT = -9.1 + 3.5 \times PT - 0.21 \times PI$ (Δ is the value of standing minus sitting). From those results, changes in sagittal lumbo-pelvic alignment were found to be regulated by the amount of PT and PI, not by age. PT is known to correlate with PI [9], and therefore, PI is the most important factor that affects the change in lumbo-pelvic sagittal alignment between the sitting and standing positions. For example, a person with low PI in the standing position would be less capable of performing changes in alignment between the sitting and standing positions (Fig. 2). PI has also been reported to be positively associated with age in childhood; however, it is the only fixed spino-pelvic parameter in adulthood [16]. People with large PI are capable of compensating for the spinal alignment by inducing a large posterior tilt and reducing the sacral slope (Fig. 3). Conversely, those with small PI do not have the adequate capacity for lumbo-pelvic motion [17]. Therefore, pelvic compensatory capacity depends on the size of PI. A previous study demonstrated the association between the size of PI and the incidence of lumbar degenerative spondylolisthesis [18], hip osteoarthritis [19], and femoroacetabular impingement [20]. PI can also predict lumbar segmental angulation [21].

Fig. 2 The X-ray findings in the sitting and standing positions of patients with large PI. Standing: LL, 66°; SS, 45°; PT, 20°; PI, 65°. Sitting: LL, 26°; SS, 23°; PT, 32°; PI, 65°

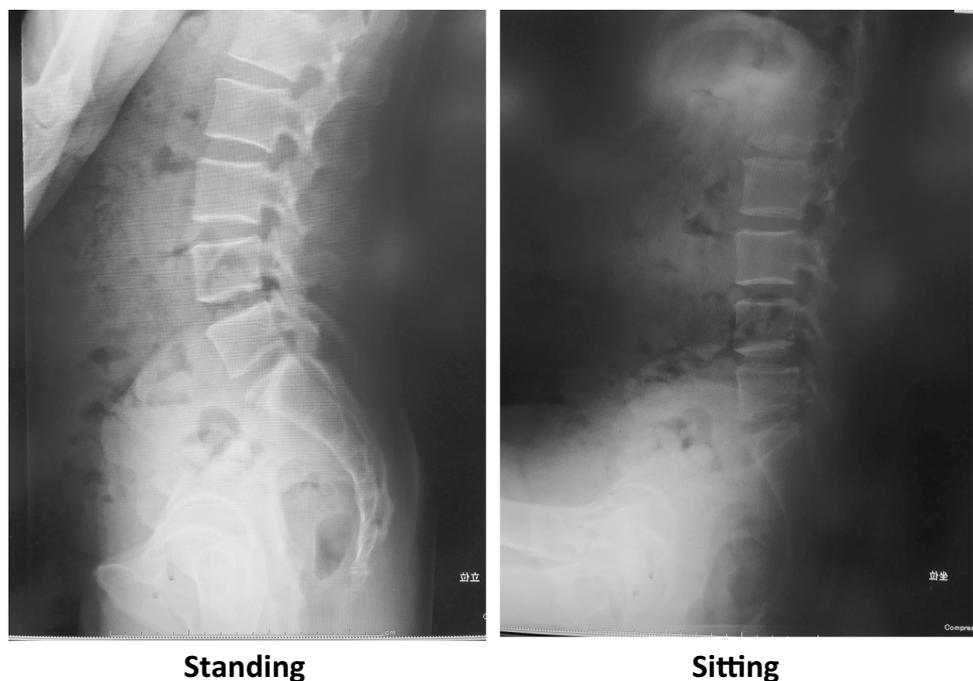
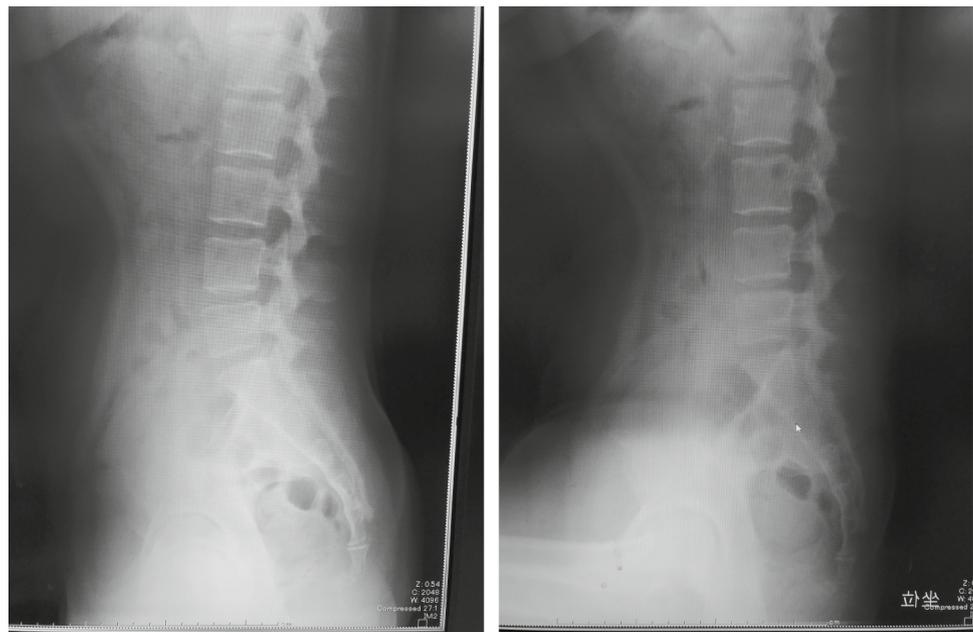


Fig. 3 The X-ray findings in the sitting and standing positions of patients with small PI. Standing: LL, 26°; SS, 28°; PT, 10°; PI, 38°. Sitting: LL, 18°; SS, 18°; PT, 20°; PI, 38°



Standing

Sitting

However, all of these studies were evidential and lacked quantitative analysis. To the best of our knowledge, this is the first quantitative analysis of the association between the size of PI and changes in sagittal lumbo-sacral alignment between the standing and sitting positions in normal subjects. The present study showed the effect of PI on changes in sagittal lumbo-sacral alignment between the standing and sitting positions, which suggests people with small PI may have limited pelvic compensatory capacity when moving from sitting to standing.

This study has several limitations. The study was a cross-sectional study. The older subjects included those with degenerative disorders, not only in the lumbo-pelvic region but also in other regions. Despite these limitations, our study demonstrated the importance of PI for changes in lumbo-pelvic alignment between the sitting and standing positions.

Conclusions

Change in lumbo-pelvic parameters between the sitting and standing positions correlated with PI, but not directly with age. PI is an important parameter to estimate the amount of changes in lumbo-pelvic alignment between the sitting and standing positions.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This study was approved by the institutional review board of our institution.

Informed consent All subjects provided written informed consent after explanation of the experimental protocol.

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