

# Radiographic Assessment of Spinopelvic Sagittal Alignment from Sitting to Standing Position

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## Abstract:

**Introduction:** Most people in modern societies spend the majority of their time sitting. However, sagittal spinal alignment is usually analyzed in the standing position. For understanding the symptoms associated with postural changes, this alignment is better to be analyzed in various positions. The purpose of this study was to investigate lumbo-pelvic relationships between standing up and sitting (sit-to-stand) motion.

**Methods:** The study subjects were 25 healthy young adult volunteers without any spinal symptoms. The following parameters were measured, namely, intervertebral range of motion (IV ROM), lumbar lordotic angle (L1L5), sacral slope (SS), pelvic tilt (PT), and pelvic incidence (PI), on lateral whole-spine radiographs while sitting upright, sitting anterior flexed (anteflexed), standing anteflexed, and standing upright.

**Results:** The measurements of spinopelvic parameters during sit-to-stand motion (sitting upright, sitting anteflexed, standing anteflexed, standing upright, respectively) were as follows: L1L5 (7.9, -4.4, 3.1, 31.9) and PT (31.5, 26.5, 11.9, 7.7). Regarding IV ROM, the lumbar segmental ROM after seat-off was wider than before seat-off (sitting anteflexed). In particular, the L4-L5 segments had a wide ROM from standing anteflexed to standing upright.

**Conclusions:** The pelvis was retroverted in the sitting upright position and gradually anteverted during sit-to-stand motion. Lumbar lordosis decreased in the sitting upright position, temporarily decreased further (sitting anteflexed), and then increased in the standing position (standing anteflexed and standing upright). The mechanical loads on lumbosacral segments were greater after seat-off due to the reverse movement between upper lumbar and pelvic segments.

## Keywords:

Sagittal spinal alignment, Sitting position, Stand-up, lumbar movement, pelvic movement

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## Introduction

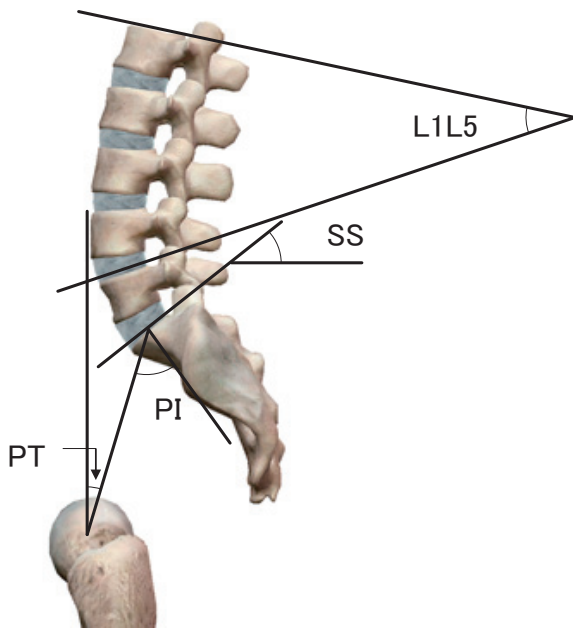
In modern society, most office workers spend their time indoors, sitting on a chair. Elderly persons also spend a lot of time sitting due to weakness of locomotive function. Standing up from sitting (sit-to-stand; STS) is a functionally important activity for daily life. STS is a dynamic unstable motion that requires extensive joint movement in the lower extremities and trunk<sup>1</sup>. Therefore, elderly persons often fall during transfers from the sitting position<sup>2</sup>. Sagittal spinal alignment is usually analyzed in the standing position<sup>3</sup>; however, to understand the spinal sagittal alignment associated with postural changes, it must be analyzed in various positions. For the treatment of spinal disease, the individual

evaluation of dynamic spinopelvic motion on the sagittal alignment is important. Previously, several studies have documented normal spinal sagittal alignment in the sitting and standing positions<sup>4,7</sup>. Lord et al.<sup>8</sup> reported that the occurrence of lumbar lordosis while standing was nearly 1.5 times higher on average than the occurrence of lumbar lordosis while sitting. We had also reported about the difference of lumbo-pelvic alignment between the standing and sitting position<sup>9,10</sup>. Shum et al. showed that in patients with low back pain, not only the significant limitations in the range of movement of the lumbar spine and hip during sit-to-stand also the altered coordination within the lumbar spine-hip joint complex<sup>11</sup>. The purpose of this study was to investigate lumbo-pelvic relationships during sit-to-stand

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**Figure 1.** Lumbo-pelvic parameters. L1L5; L1L5angle, SS; sacral slope, PT; pelvic tilt, PI; pelvic incidence

motion in healthy young volunteer.

## Materials and Methods

This study enrolled 25 adult subjects (16 men and 9 women; age  $26.9 \pm 6.3$  years) who had neither gait disturbance nor neurological symptoms. Subjects with scoliosis of greater than  $10^\circ$  or suffering leg joints disease were excluded. All the subjects underwent frontal and lateral radiography of the whole lumbar spine, including the hip joints, in the upright sitting, anterior flexed (anteflexed) sitting, anteflexed standing, and upright standing positions. The upright sitting position was a posture with the head and trunk vertical, in which the lower legs were bent at about  $90^\circ$  at the hips and knees. The anteflexed sitting and standing positions were postures with anterior bending at about  $45^\circ$  from the upright posture. Collimation was set superiorly to include T12, inferiorly to include S3, and slightly laterally to include the greater trochanter. The chair back was fixed at an angle of  $90^\circ$ . Lateral radiographs of the lumbar spine were obtained on a vertical  $30 \times 90$  cm film with a constant distance between the subject and the radiographic source. On X-ray films, the following parameters were measured on the lateral whole-spine radiographs while upright sitting, anterior flexed (anteflexed) sitting, anteflexed standing, and upright standing on a chair: intervertebral range of motion (IV ROM), lumbar lordotic angle (L1L5, the angle from the upper end-plate of L1 to the upper end-plate of L5), 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 perpendicular to the sacral plate

at its midpoint and the line connecting that point to the middle axis of the femoral heads<sup>3,12-14</sup>) (Fig. 1). IV ROM was the difference measured by the angle between the upper and lower endplates of adjacent vertebrae during STS. To analyze the lumbar motion without pelvic effects, we used the L1L5 angle as a lumbar lordotic angle.

The radiographs were measured twice by the first observer (H.S., a board-certified orthopedic spinal surgeon), then independently measured on different days by a second observer (K.E., also a board-certified orthopedic spinal surgeon). The intra- and inter-observer agreement rates of measurements of PI and PT were high in the sitting and standing positions, and the results showed reasonable agreement as a previous paper reported<sup>11</sup>). All participants provided written informed consent after explanation of the experimental protocol, and this study was approved by the Institutional Review Board of our institution.

Values were expressed as means  $\pm$  standard deviation (SD). Statistical analyses were performed using the JMP software package version 8.0 (SAS Institute Inc., Cary, NC, USA). We used ANOVA (analysis of variance) and the Tukey-Kramer honestly significant difference (HSD) test to determine the difference in the amount of segmental lumbo-pelvic ROM between “before seat-off (sitting anteflexed)” and “after seat-off,” and to evaluate the outcome measures of L1L5 and PT among sitting upright, sitting anteflexed, standing anteflexed, and standing upright position. A *P*-value of less than 0.05 was considered to indicate a statistically significant difference.

## Results

The measurements of spinopelvic parameters at STS (sitting upright, sitting anteflexed, standing anteflexed, and standing upright, respectively) were as follows: L1L5 ( $7.9 \pm 10.8$ ,  $-4.4 \pm 12.5$ ,  $3.1 \pm 12.0$ ,  $31.9 \pm 10.4$ ), SS ( $14.9 \pm 11.7$ ,  $20.8 \pm 11.5$ ,  $39.6 \pm 8.8$ ,  $35.9 \pm 8.7$ ), and PT ( $31.5 \pm 8.5$ ,  $26.5 \pm 7.1$ ,  $11.9 \pm 13.5$ ,  $7.7 \pm 9.5$ ) (Fig. 2). Lumbar segments were forward bended before seat-off and gradually backbent to make optimal lordosis in the standing position after seat-off (sitting anteflexed). Lumbar lordosis decreased in sitting, then temporarily decreased further and increased after thighs-off. Lumbar lordosis was coordinated to pelvic tilt after seat-off. The pelvis was retroverted in the sitting position and gradually anteverted during STS. Regarding IV ROM, lumbar segments after seat-off had a wider range than before seat-off during STS ( $P < 0.05$ ) (Fig. 3).

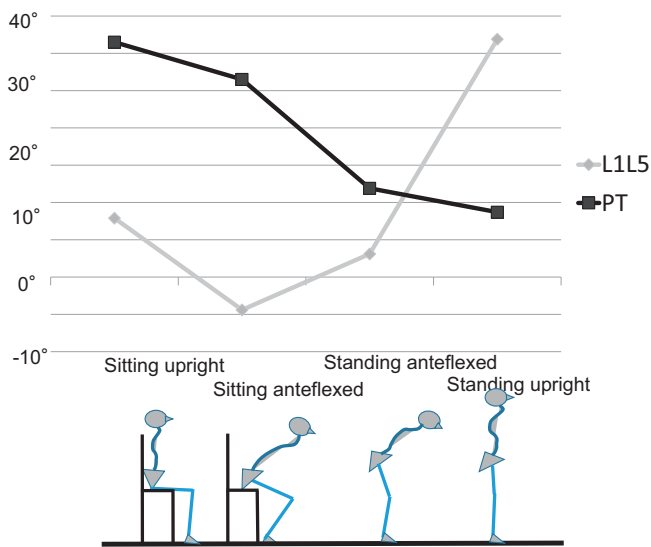
## Case Presentation

Typical X-ray findings in the sitting and standing positions were as follows. L1L5 sitting upright decreased upon sitting anteflexed, then increased in the standing position during STS. PT gradually decreased from sitting upright to standing in the upright position (Fig. 4).

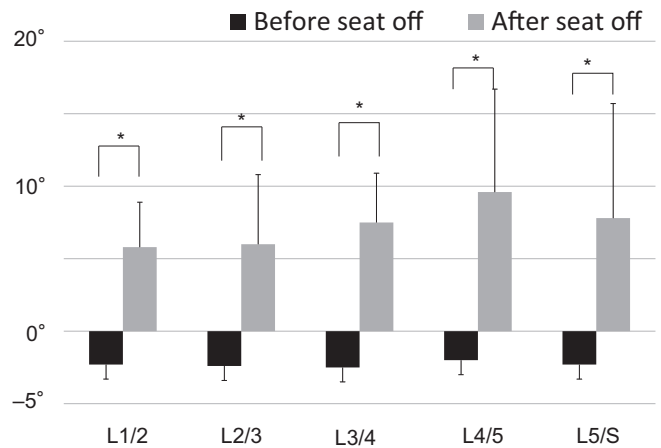
**Discussion**

The motion of STS can be divided into two phases<sup>15)</sup>. The first phase is composed of the period that the lumbar spine and hips flex, reaching their maxima shortly after seat-off, then the lumbar spine and hips extend (sitting anteflexed). The second phase is composed of lumbar spine and hips extension to become upright during STS (standing anteflexed and standing upright) (Fig. 2). Tully et al.<sup>16)</sup> pointed out that trunk lean prior to seat-off was accomplished by concurrent lumbar and hip flexion. In the first phase, from the initiation

of trunk anteflexion, the lumbar extensor muscles work eccentrically, and the lumbar spine and hips flex toward a peak. After seat-off, the lumbar spine and hip extensor muscles are concentrically active to extend the trunk<sup>15,16)</sup>. The present results revealed that the pelvis was gradually anteriorly rotated before seat-off (from sitting upright to sitting anteflexed), and the lumbar spine was forward bending accompanied with the pelvic anterior rotation. After seat-off, the movement of lumbar segments changed to be backward bending (extending), coordinating the anti-direct coupling motion of the pelvis from sitting anteflexed to standing up-

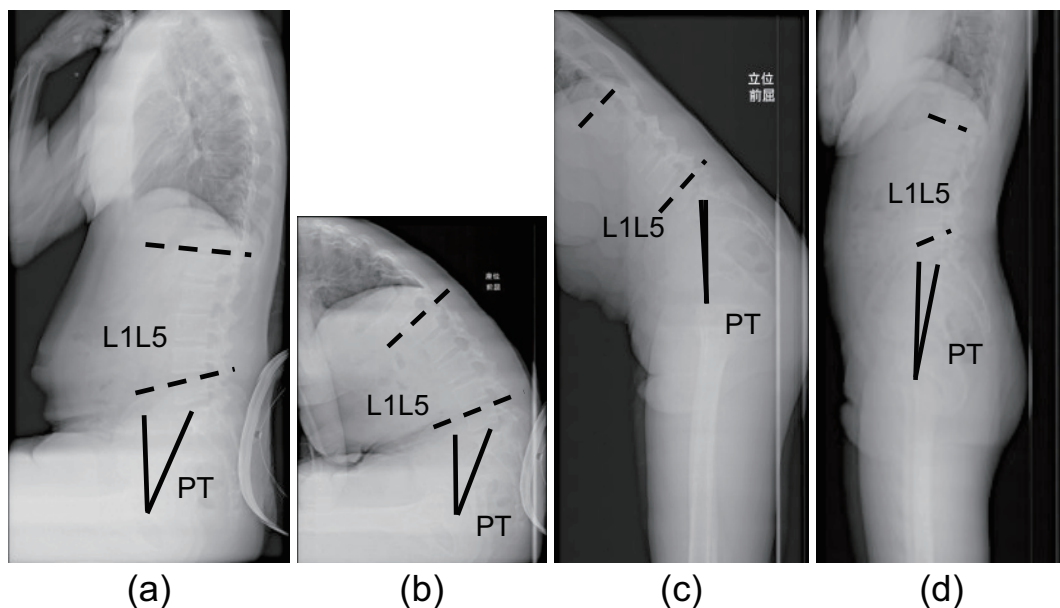


**Figure 2.** Changes in sagittal parameters during STS (sitting upright, sitting anteflexed, standing anteflexed, and standing upright).



**Figure 3.** Inter vertebral (IV) ROM during STS (sit-to-standing).

Lumbo-pelvic segments after seat-off showed a wider range of IV ROM than before seat-off during STS (sit-to-stand). The results were expressed as mean±SD, \*: significant difference between before seat-off and after seat-off



**Figure 4.** Case presentation.

(a) sitting upright; (b) sitting anteflexed; (c) standing anteflexed; (d) standing upright.

The pelvis was retroverted in the sitting position and gradually anteverted during sit-to-stand. Lumbar lordosis decreased in the sitting position, temporarily decreased further, and then increased.

right (Fig. 2). Thus, the mechanical loads on lumbosacral segments would become greater after seat-off due to the reverse movement between lumbar and pelvic motion. These results revealed that the coordination among lumbar segments, pelvis, and hip joint is especially important after seat-off. The pelvis was retroverted in the sitting position and gradually anteverted in STS. Lumbar lordosis decreased in the sitting position, temporarily decreased further, and then increased during STS. Clinically, changes in lumbo-pelvic alignment during STS are associated with the cause of low back pain (LBP) and the kinematic characteristics and load share force are altered during STS in patients with LBP<sup>15</sup>. Considering these results and our present study, the seat-off during STS would be the most influencing posture for the incidence of LBP.

This study had some limitations. The number of subjects was relatively small and there was lack of analysis about clinical low back pain. Other positions from sitting to standing were lacking because of difficulty of reproducibility. Cinematic study can offer similar results to ours. However, our methods can be easily performed routinely as stress X-ray diagnosis for many patients. These results are also valuable in considering the positions we used for this study in daily practice for the evaluation and treatment of spinal disorders affecting sagittal balance; in particular, it may be useful to analyze the motion of lumbo-pelvic alignment from the sitting to standing positions. When the consideration of standing up motion in patients with sagittal spinal deformity, the present study may be helpful. These results will assist in developing clinical strategies to consider the optimal lumbo-pelvic sagittal alignment for better lumbar and pelvic mobility.

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

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

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