Abstract. [Purpose] To investigate the effects of erect sitting, slouched posture with cross-legged sitting, and erect posture with cross-legged sitting on the lumbar and pelvic angles, and gluteal pressure. [Subjects] For the experiments, 17 healthy women were recruited. [Methods] All subjects were asked to perform three sitting postures: erect sitting, slouched posture with cross-legged sitting, and erect posture with cross-legged sitting. Lumbar and pelvic angles were measured using a three-dimensional motion-capture system, and gluteal pressure was measured using a pressure mat. [Results] Compared to erect sitting, slouched posture with cross-legged sitting showed significantly greater lumbar flexion, posterior pelvic tilt, and left pelvic tilt. Compared to erect sitting, erect posture with cross-legged sitting showed significantly greater lumbar flexion and posterior pelvic tilt. Compared to erect posture with cross-legged sitting, slouched posture with cross-legged sitting showed significantly greater left gluteal pressure; there was no significant difference in right gluteal pressure. [Conclusion] An erect posture can reduce changes in lumbar and pelvic angles, and gluteal pressure compared to a slouched posture during cross-legged sitting.

Key words: Cross-legged sitting, Lumbar and pelvic angles, Gluteal pressure
3 cm from the second lumbar spinous process. Meanwhile, to calculate the pelvic angle, markers were placed on the bilateral anterior superior iliac spines and midpoint between the bilateral posterior superior iliac spines\(^\text{11}\). The Cardan angle was used to determine the lumbar and pelvic angles\(^\text{14}\). A pressure mat (Baltube, RELIVE, Gimhae, Korea) was used to record the gluteal pressure; this mat consists of four air chambers used to measure pressure. The subjects were instructed to sit along the guide such that the right and left buttocks were on the first and third chambers, respectively, and the right and left thighs were on the second and fourth chambers, respectively.

Before the test, the pressure of each chamber in the mat was set to 10 mmHg. The subjects were subsequently instructed to sit on the mat with 90° hip and knee flexion, and a step box was placed under their feet to adjust the hip and knee angles. The subjects were then instructed to assume the following three postures in random order: erect sitting (ES), slouched posture with cross-legged sitting (SCS), and erect posture with cross-legged sitting (ECS). Each posture was held for 1 minute for three repetitions. In the cross-legged sitting postures, the right knee was crossed over the left knee. Between repetitions, the subjects were given 5 minutes to rest to reduce fatigue. The mean lumbar and pelvic angles, and gluteal pressure during the three postures were compared using repeated-measures one-way ANOVA. The level of significance was set at \(p < 0.05\). Significant differences were determined after Bonferroni corrections were performed.

### RESULTS

The means and standard deviations of the lumbar and pelvic angles, and gluteal pressures during the three postures are shown in Table 1. There were significant differences among the postures with respect to the lumbar angle \((F = 9.49, p = 0.021)\), anterior pelvic tilt \((F = 93.12, p = 0.000)\), and lateral pelvic tilt \((F = 5.05, p = 0.021)\) angles. Lumbar flexion \((p = 0.001)\), posterior pelvic tilt \((p = 0.000)\), and left pelvic tilt \((p = 0.019)\) were significantly greater in SCS than ES. Lumbar flexion \((p = 0.047)\) and posterior pelvic tilt \((p = 0.000)\) were significantly greater in SCS than ECS. There were significant differences among postures with respect to left gluteal pressure (LGP) \((F = 9.09, p = 0.003)\) but not right gluteal pressure (RGP) \((F = 1.47, p > 0.05)\). LGP was significantly greater in SCS and ECS than ES \((p = 0.001)\) and \(p = 0.010\), respectively), and LGP was significantly greater in SCS than ECS \((p = 0.047)\).

### DISCUSSION

This study evaluated the differences in the lumbar and pelvic angles, and gluteal pressure among the ES, SCS, and ECS postures. Lumbar spine flexion and posterior pelvic tilt were significantly greater in SCS than ES. The finding that the lumbar spine was more flexed in SCS can be explained by the fact that cross-legged sitting induced more posterior tilting than ES. When the pelvis is tilted anteriorly, the lumbar spine is flexed with respect to the pelvis in accordance with the “lumbo-pelvic rhythm”\(^\text{11}\). This finding is concordant with that of Snijders et al.\(^\text{12}\) who suggest the pelvis is more posteriorly tilted during cross-legged sitting than normal sitting. Furthermore, during SCS, the pelvis showed a significantly greater left tilt angle than that during ES. This could be because the leg crossed over the opposite leg is more flexed and adducted than during normal sitting\(^\text{12}\). Lumbar spine flexion and posterior pelvic tilt were significantly greater during ECS than ES but less than those during SCS. Although both ECS and ES are erect postures, the pelvis was tilted more posteriorly in ECS owing to the crossing of the leg. The finding that ECS produces a smaller lumbar flexion angle than SCS might be attributable to the fact that erect postures induce a lumbar lordotic curve\(^\text{11}\). Thus, these results indicate SCS results in greater physical changes than ECS with regard to the kinematic data for the lumbar and pelvic angles.

Gluteal pressure differed between the left and right sides. LGP was highest in SCS followed by ECS. As the pelvis was tilted toward the left during cross-legged sitting, the body weight might be transferred from the right to the left. Lee and Yoo\(^\text{13}\) report the opposite result: LGP decreased significantly and RGP increased significantly at 30 seconds during cross-legged sitting. However, their study focused on video display terminal work with cross-legged sitting in contrast to the present study. The stability of the sacroiliac joint by

### Table 1. Comparison of lumbar and pelvic angles and gluteal pressure among postures \((N = 17)\)

| Parameters                          | ES          | SCS         | ECS         |
|-------------------------------------|-------------|-------------|-------------|
| Lumbar flexion angle relative to pelvis (°) | -4.41 ± 12.70,\(^a\) | -13.22 ± 5.84,\(^b\) | -10.58 ± 8.48,\(^c\) |
| Anterior and posterior pelvic tilt angle (°) | 3.07 ± 6.02,\(^b\) | 16.66 ± 6.78,\(^c\) | 9.12 ± 5.26,\(^c\) |
| Lateral pelvic tilt angle (°)         | 4.22 ± 2.52,\(^a\) | 5.86 ± 3.19,\(^b\) | 5.57 ± 2.30,\(^b\) |
| Left gluteal pressure (mmHg)         | 34.71 ± 7.54,\(^a\) | 39.18 ± 10.26,\(^b\) | 36.80 ± 9.39,\(^b\) |
| Right gluteal pressure (mmHg)        | 35.26 ± 6.65 | 36.26 ± 6.19 | 35.14 ± 5.73   |

Data are mean ± SD. ES: erect sitting, SCS: slouched posture with cross-legged sitting, ECS: erect posture with cross-legged sitting.

\(^a\),\(^b\),\(^c\) Pairs of letters indicate significant difference between postures; repeated-measures one-way ANOVA and Bonferroni post hoc test \((p < 0.05)\).
elastic structures\textsuperscript{12, 15}) during cross-legged sitting decreases the activities of the internal and external oblique muscles\textsuperscript{10}). Thus, the mass of the upper body is supported by the passive structure instead of the muscles during cross-legged sitting\textsuperscript{13}), possibly increasing gluteal pressure. With reduced muscle activities, the increased load can affect the lumbar discs and ligaments\textsuperscript{16}). Therefore, LGP was highest in SCS, adopting this posture could result in greater loads on the lumbar discs and ligaments. Although the pelvis was tilted toward the left during cross-legged sitting, RGP did not differ significantly among postures. Snijders et al.\textsuperscript{10}) report that the activities of the bilateral internal and external oblique muscles decrease during cross-legged sitting. However, the present results suggest that because of the reduced activities of the right oblique muscles during cross-legged sitting, the RGP during cross-legged sitting could not decrease and therefore could be similar to that during ES. In addition, gluteal pressure tended to be higher in SCS, suggesting this posture may incur stress to physical structures.

In the present study, lumbar flexion angle and posterior pelvic tilt angle were lower and LGP was higher in ECS than SCS. Therefore, to reduce changes in the lumbar and pelvic angles, and gluteal pressure, the erect posture might be better than the slouched posture during cross-legged sitting. Our study has some limitations. First, the sample size was small. Second, we included only women. Therefore, our results cannot easily be generalized. Third, all subjects crossed their right legs, and not their dominant legs. Hence, further studies should consider electromyographic signals when adopting these postures. In conclusion, this study suggests that an erect posture can more greatly decrease lumbar and pelvic angles, and gluteal pressure than a slouched posture during cross-legged sitting.

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