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Original Article

A Sloped Seat Wedge Can Change the Kinematics of the Lumbar Spine of Seated Workers with Limited Hip Flexion

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Abstract. [Purpose] The purpose of this study was to determine whether a wedge type seat decreases the lumbar flexion angle of seated workers with limited hip flexion. [Subjects] Twelve sedentary workers with limited hip flexion were recruited. [Methods] Three seat surfaces were used: a level surface, a forward-inclining wedge, and a backward-reclining wedge. The angles of lumbar flexion and pelvic tilt were measured using a three-dimensional motion analysis system. Differences in kinematic data of the subjects seated on the three seat surfaces were analyzed using repeated one-way analysis of variance. [Results] The degree of lumbar flexion decreased significantly when using the forward-inclining wedge compared with the level surface and backward-reclining wedge. [Conclusion] These findings suggest that sitting on a forward-inclining wedge may be useful for minimizing the compensatory lumbar flexion of individuals with limited hip flexion who work in a seated position.
Key words: Kinematics, Limited hip flexion, Seat wedge

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INTRODUCTION

Occupations requiring prolonged periods of static sitting are associated with the development of musculoskeletal disorders, including low back pain (LBP)[1)]. Compared to the standing position, sitting may cause posterior pelvis tilt, resulting in a reduction in lumbar lordosis[2)]. Decreased lumbar lordosis places stress on vertebral discs, which may result in disc degeneration, disc herniation and pain[3, 4)]. To prevent the development of back problems while seated, the maintenance of lumbar lordosis during sedentary activities is recommended[5)].

In the sitting position, lumbar lordosis is affected by the pelvis and the muscles of the lower extremities[6)]. Several studies have demonstrated that the lengths of the hip flexor and extensor muscles are associated with spinal posture[6, 7)]. Keegan reported that lumbar lordosis is adequately maintained at a trunk-thigh angle of 135 degrees with hip flexor and extensor muscles in the resting position[7)] and the maintenance of a proper trunk-thigh angle may be important[8)].

Several authors have suggested that a decrease in hip joint mobility correlates with back pain[9, 10)]. Sedentary activities performed by individuals with greater flexibility in the lumbopelvic region than in the hip joint will result in compensatory lumbar flexion at the relatively flexible lumbopelvic joint[11)]. In contrast, an individual with limited hip flexion may not be able to maintain lordorsis. Sahrmann suggested that lumbar flexion and posterior pelvic tilt would occur when individuals with limited hip flexion were seated, and the author recommended that individuals sit with a slightly extended back and/or use back support to prevent lumbopelvic flexion when performing sitting-related activities[11)].

A number of investigators agree that sitting postures are improved by correcting postural habits and/or seating options, such as lumbar support, arm rests, neck support, and seat surfaces[12, 13)]. Many researchers have recommended the use of a tilted seat surface to preserve lumbar lordosis during prolonged sitting[14–17)]. Several authors have suggested that a forward-tilted seat pan elicits an upright position, which is associated with increased lordosis of the lumbar spine[14, 15)]. In contrast to these findings, a backward-tilted pan has been proposed to improve lumbopelvic posture because it elicits greater lordosis because of subjects' curvature with the tendency to lean against the backrest[7, 16)]. The optimal seat surface angle remains controversial because previous studies did not consider the characteristics of the

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subjects.

While methods to prevent lumbar flexion and posterior pelvic tilt have been reported, no study has yet investigated the effects of a seat wedge on the lumbar spine and pelvic motion in subjects with limited hip flexion during sitting. This study compared the angle of lumbar flexion and posterior pelvic tilt among subjects with limited hip flexion who were seated on three seat surfaces (level surface, forward-inclining wedge and backward-reclining wedge).

SUBJECTS AND METHODS

This study recruited 12 males with limited hip flexion who were sedentary workers working in a laboratory. The mean age of the participants was 23.4 ± 1.9 years, and none had any orthopedic or neurologic problems. All subjects read and signed an informed consent form approved by Inje University Ethics Committee for Human Investigations prior to their participation.

The presence of limited hip flexion was confirmed using a double armed-universal goniometer in the supine position. The normal range of hip flexion is 120 degrees, and we defined limited hip joint flexion as when the investigator felt resistance at the hip joint below 110 degrees[18].

Kinematic data of the lumbar spine and pelvis in the sagittal plane were collected using eight VICON MX-T10 motion capture systems (Vicon Motion Systems Ltd., Oxford, UK) at a sampling rate of 100 Hz. Seven reflective markers were placed at the following locations: on the first and second lumbar spinous processes, on both sides of the second lumbar spinous process, on the left and right anterior superior iliac spine, and on the mid-point of the right and left posterior superior iliac spine. Kinematic data of each segment was measured as the Cardan angle[19]. Lumbar flexion was calculated by constructing two segments representing the trunk and pelvis using Nexus 1.3 software. Posterior pelvic tilt was defined as the angle between the medio-lateral axis of the mid-point of the right and left posterior superior iliac crests and the sagittal plane of the pelvic segment. Kinematic data were obtained while the subject maintained the sitting position. For all kinematic variables, the mean of three measured angles obtained in three trials in the sitting position with the three seat surfaces was used for data analysis.

The experimental stool used in all experiments was constructed of wood and measured 381 × 381 × 420 mm. The seat wedge had a top slope of 10 degrees and was designed to fit the size of the chair. Three seat surfaces were assessed in this study: a level surface, a forward-inclining wedge, and a backward-reclining wedge. Prior to the experimental period, subjects were instructed verbally how to perform the sitting task. Each subject sat on the stool with their knees at 90 degrees, head erect, eyes focused directly ahead, feet positioned shoulder width apart, arm crossed with the hands placed on the shoulders. Subjects were asked to stand up, and then to sit down. This procedure was repeated twice. Finally, subjects were asked to sit comfortably. The sitting posture was recorded while subjects sat in the usual position. Participants sat for 30 sec on each seat surface. The order of the sitting conditions was randomized among the participants.

One-way repeated measures analysis of variance (ANOVA) the Bonferroni test as the post hoc test were conducted on the lumbar flexion and posterior pelvic tilt angles among the three seat surfaces (level surface, forward-inclining wedge, and backward-reclining wedge). Statistical analysis was performed using SPSS version 18.0 for Windows (SPSS, Inc., Chicago, IL, USA), and significance was accepted for value of $p \leq 0.05$.

RESULTS

Significant differences in the degree of lumbar flexion were observed among the seat surfaces. The degree of lumbar flexion decreased significantly when subjects sat on the forward-inclining wedge (8.68 ± 5.19°) compared with the level surface (13.03 ± 6.91°) and backward-reclining wedge (18.06 ± 4.76°) (Table 1). No significant differences in posterior pelvic tilt were observed among the three seat surfaces.

DISCUSSION

In this study, the use of a backward-reclining wedge significantly increased the angle of lumbar flexion compared to the level surface and forward-inclining wedge. Recent findings have indicated that a prolonged flexed posture is associated with flexion-related LBP[20]. If the lumbar spine is more flexible than the hip joint, compensatory motion will occur at the relatively flexible lumbopelvic joint during sitting[11]. This compensation may result in hypermobility of the lumbar spine and may ultimately be a source of flexion-related LBP[11]. Theoretically, a flexed posture can result in disorders of the lower back because it increases the load on the intervertebral discs and increases the stress on the posterior structure of the back compared with sitting upright[21]. Our results show that the backward-reclining wedge in-

Table 1. Lumbar flexion and posterior pelvic tilt values of the subjects when sitting on a level surface, forward-inclining wedge or backward-reclining wedge (Unit: degree)

Parameters	Mean ± SD		
	Level surface	Forward-inclining wedge	Backward-reclining wedge
Lumbar flexion	13.03 ± 6.91	8.68 ± 5.11[a]	18.05 ± 4.75[a]
Posterior pelvic tilt	12.06 ± 5.74	12.62 ± 6.52	14.07 ± 6.59

[a] Significantly different from level surface ($p < 0.05$)

creased flexion of the lumbar spine, and we believe that the risk of LBP is higher in individuals with limited hip flexion.

In this study, lumbar flexion decreased significantly when subjects sat on the forward-inclining wedge compared with the level surface and the backward-reclining wedge. One study showed that the use of a forward-tilted seat pan increased lumbar lordosis compared to a horizontal surface[8]. According to Keegan, limitations in hip joint mobility can change the degree of lumbar lordosis[7]. While seated, individuals with limited hip flexion cannot preserve lumbar lordosis as well as individuals with a normal hip joint angle[11]. Changes in the trunk-thigh angle may be effective at increasing lumbar lordosis in the sitting position[7]. The sitting position can be changed by the trunk-thigh angle, and to maintain the neutral position of the lumbar spine, the trunk-thigh angle should be about 135 degrees[7]. In this study, subjects had at least 10 degrees loss of hip flexion range of motion compared to normal subjects, and the use of the 10-degree forward-inclining wedge would have changed the trunk-thigh angle. Our results show that the 10-degree forward-inclining wedge increased the trunk-thigh angle, which may have reduces compensatory lumbar flexion in limited hip flexion subjects. In view of our findings, use of a forward-inclining wedge should be considered to correct sitting posture affected by limited hip flexion.

This study had several limitations. First, we did not measure the lengths of the lumbopelvic muscles, and these muscles affect lumbar lordosis and pelvic tilt. Second, we did not consider spinal load. Reduced spinal compression is recommended to minimize low back problems[22]. Third, we used reflective markers to measure the lumbar angle; therefore, we could not exclude errors arising from skin movement. Fourth, we did not measure the thorax forward-bending angle. Finally, we did not confirm the lumbar flexion and pelvic posterior tilt angles at the different seat surface angles. Future studies are required to investigate the effects of sloped seat surface angles on the kinematics of lumbar flexion and posterior pelvic tilt in subjects with limited hip flexion.

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