The effects of calcaneal posture on thoracolumbar alignment in a standing position

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Abstract. [Purpose] Severe calcaneus misalignment is correlated with low back pain, and affects pelvic alignment. However, little has been published with regard to the influence of pronation and supination on trunk alignment. Therefore, the present study aimed to investigate the influence of calcaneal inversion on pelvic and trunk alignment. [Subjects and Methods] A 3-dimensional motion analysis system was used to assess pelvic and trunk alignment in 10 healthy male subjects with unilateral and bilateral calcaneal inversion. [Results] Medial and anterior tilting of the pelvis, and posterior tilting and lateral rotation of the trunk were observed. [Conclusion] Calcaneal inversion induces changes in the alignment of the pelvis and trunk. These changes may induce lumbar lordosis and body misalignment, leading to back pain.

Key words: Motion analysis, Calcaneal inversion, Alignment

INTRODUCTION

The feet move the body forward and maintain balance by supporting body weight. Changes in the frontal plane of the foot segments affect the alignment of the lower extremity, which then leads to postural changes in the trunk and pelvis. Deformation of the feet reportedly results in an imbalance in the pelvis and lower extremity, which can lead to back pain¹ ⁵). The changes caused by deformation of the feet induce pronation of the subtalar joint, adduction and flexion of the talus, and calcaneal eversion³). Adduction of the talus induces internal rotation of the lower extremity, and reduces the functional leg length, leading to pelvic misalignment⁴). Bilateral calcaneus eversion increases the degree of pelvic anteversion by inducing internal rotation of the hip joint, and therefore increases the degree of lumbar lordosis⁵).

One study reported that when calcaneus eversion was temporarily increased by using a wedge, anterior tilting of the pelvis increased; when the wedge was used on one foot, the pelvis was abducted⁵). However, most prior studies investigated the correlation between the alignment of the lower extremity and that of the pelvis by increasing calcaneus eversion, and did not provide sufficient explanation for changes that arise due to calcaneal inversion or changes in the angle of the calcaneus. Since knowledge is lacking on the effects of calcaneal misalignment on body alignment, the present study aimed to analyze changes in the pelvis and trunk resulting from an intervention on the calcaneus, and to suggest ways to reduce body misalignment caused by calcaneus misalignment.

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the pelvis is a compensatory action that attempts to reduce body misalignment caused by calcaneus misalignment. No significant differences were observed in the internal/external rotation values of the pelvis between the two feet. On the other hand, medial tilt values were increased when the wedge was used on only one foot. Prior studies reported that calcaneus eversion induced lateral pelvic tilt by causing discrepancies in the functional length of the lower extremity, thereby shortening the ipsilateral lower limb. On the other hand, in our study, pelvic medial tilt appeared to be induced by calcaneal inversion. Wedge intervention on the calcaneus affects pelvic alignment, and these alignment changes may induce lumbar lordosis and back pain. Therefore, these changes may be clinically relevant. Posterior tilting of the trunk due to use of the wedge was observed. This observation was consistent with the report of a prior study in which calcaneal eversion led to anterior tilting of the trunk. These results suggest that anterior tilting of the pelvis and posterior tilting of the trunk may increase back pain. Changes in the anteverision angles of the pelvis are known to increase lumbar lordosis by 1°, and this increase may be a risk factor for back pain. The increased medial tilt and external rotation angle of the trunk due to the wedge interven-


to calcaneal inversion

|                  | Pelvic | Trunk | Pelvic | Trunk |
|------------------|--------|-------|--------|-------|
| Normal           | −7.19 ± 5.76 | 4.29 ± 2.83 | −0.72 ± 1.42 | −0.79 ± 0.96 |
| Uni 5deg        | −7.91 ± 6.21* | 4.24 ± 2.23* | −2.27 ± 1.55*§ | −0.29 ± 0.80 |
| Bi 5deg         | −8.39 ± 5.84* | 4.13 ± 2.31 | −0.54 ± 1.48*§ | −0.33 ± 1.07*§ |
| Uni 10deg       | −8.19 ± 6.81* | 5.81 ± 2.36* | −4.03 ± 1.39*§ | −0.55 ± 1.35*§ |
| Bi 10deg        | −6.78 ± 7.18* | 4.90 ± 2.33* | −0.39 ± 1.69*§ | −0.55 ± 1.22* |

*Significant difference between normal and the wedge, §Significant difference between the wedges degree at p<0.05

SUBJECTS AND METHODS

Ten healthy males (age: 30.5 ± 4.56 years, height: 172.9 ± 6.34 cm, weight: 72.1 ± 6.5 kg) with no history of orthopedic injuries in the lower extremity for the prior 6 months, participated in the study. Sufficient explanation about the purpose, importance, and procedures of the experiment was provided, and participants gave informed consent.

Six Oqus 100 (Qualisys, Sweden) infrared cameras were used to obtain data regarding changes in body alignment. Kinematic data were obtained through 3-dimensional (3D) motion analysis system. The sampling rate was set at 150 frames/s and 15-mm reflective markers attached to the participants were tracked.

Body alignment was measured in a standing control position without edge, and in a standing position using unilateral and bilateral wedges. Wedges were tilted 5° or 10° in the medial direction. To unify foot positions, the wedges were marked on the front and inner side, and the heights of the inner side and flat side were made equal. Thus, the medial part of the foot maintained the same height, and only calcaneal inversion was increased. All participants were asked to maintain a fixed posture on the wedge for 6 s. For standardization of unilateral wedge intervention, changes were only made on the right lower limb. Using Visual 3D V5.01 (C-motion Inc., USA) software, segment modeling was performed on the raw data, and variables were calculated. Kinematic variables were calculated using Visual 3D software. Each posture was measured twice, and the average of the 2 measurements was calculated. SPSS 18.0 software package was used to perform one-way analysis of variance (ANOVA) on the calculated means and to analyze statistical differences. Significant main effects and interactions were further evaluated using Scheffe’s test and the level of significance was set at α=0.05.

RESULTS

Comparison of changes in the pelvis for each posture showed increased anterior tilting with use of the wedge. However, differences in the anterior tilt values with an increase in the wedge angle were not statistically significant. Medial tilting of pelvic values were reduced when the wedge was used on both feet, but increased when the wedge was used on only one foot; the results were statistically significant. Significant differences were observed in the degree of internal/external rotation of the pelvis only when the wedge was used on both feet, and only when the wedge angle was 10°.

Posterior tilting of the trunk with use of the wedge was observed, and the differences were statistically significant. Regardless of the wedge angle and whether or not the wedge was used, internal/external rotation values indicated medial tilt of the trunk, and the differences were statistically significant.

External rotation of the trunk increased when the wedge was used. Statistically significant differences were observed in a comparison of when the wedge was used on one foot and when it was used on both feet, but only when the wedge angle was 10° (Table 1).

DISCUSSION

Anterior tilting of the pelvis increased as a result of calcaneal inversion. According to prior studies, anterior tilting of the pelvis is a compensatory action that attempts to reduce body misalignment caused by calcaneus misalignment. No significant differences were observed in the internal/external rotation values of the pelvis between the two feet. On the other hand, medial tilt values were increased when the wedge was used on only one foot. Prior studies reported that calcaneus eversion induced lateral pelvic tilt by causing discrepancies in the functional length of the lower extremity, thereby shortening the ipsilateral lower limb. On the other hand, in our study, pelvic medial tilt appeared to be induced by calcaneal inversion. Wedge intervention on the calcaneus affects pelvic alignment, and these alignment changes may increase lumbar lordosis and back pain. Therefore, these changes may be clinically relevant. Posterior tilting of the trunk due to use of the wedge was observed. This observation was consistent with the report of a prior study in which calcaneal eversion led to anterior tilting of the trunk. These results suggest that anterior tilting of the pelvis and posterior tilting of the trunk may increase back pain. Changes in the anteverision angles of the pelvis are known to increase lumbar lordosis by 1°, and this increase may be a risk factor for back pain. The increased medial tilt and external rotation angle of the trunk due to the wedge interven-
tion may be due to medial tilting of the pelvis as a result of calcaneus misalignment. Therefore, a long-term imbalance of the calcaneus leads to body misalignment, and may cause multiple problems in the lower extremity and lumbar region\(^{11}\).

Although the method of wedge use was different from that in prior studies, similar observations on body misalignment as a result of wedge intervention were made in our study. When calcaneal inversion was induced with a wedge on one or both feet, anterior and medial tilting of the pelvis was observed. Posterior tilting and lateral rotation of the trunk were also observed. These changes were greater when the wedge was used on only one foot than when used on both feet. These findings suggest calcaneal inversion increases lumbar lordosis, leading to increased back pain and body misalignment.

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