Abstract. [Purpose] This study aimed to identify correlations among pelvic positions and differences in lower extremity joint angles during walking in female university students. [Subjects] Thirty female university students were enrolled and their pelvic positions and differences in lower extremity joint angles were measured. [Methods] Pelvic position, pelvic torsion, and pelvic rotation were assessed using the BackMapper. In addition, motion analysis was performed to derive differences between left and right flexion, abduction, and external rotation ranges of hip joints; flexion, abduction, and external rotation ranges of knee joints; and dorsiflexion, inversion, and abduction ranges of ankle joints, according to X, Y, and Z-axes. [Results] Pelvic position was found to be positively correlated with differences between left and right hip flexion (r=0.51), hip abduction (r=0.62), knee flexion (r=0.45), knee abduction (r=0.42), and ankle inversion (r=0.38). In addition, the difference between left and right hip abduction showed a positive correlation with difference between left and right ankle dorsiflexion (r=0.64). Moreover, differences between left and right knee flexion exhibited positive correlations with differences between left and right knee abduction (r=0.41) and ankle inversion (r=0.45). [Conclusion] Bilateral pelvic tilt angles are important as they lead to bilateral differences in lower extremity joint angles during walking.

Key words: Pelvic position, Lower extremity joint angle, Walking

INTRODUCTION

Walking, which can be defined as moving the body to a target spot or destination using two legs, is a complex and integrated activity requiring low energy consumption. Although it appears to be an easy-to-perform task, it actually requires comprehensive use of all nerves and skeletal muscles. Furthermore, learning to walk requires considerable practice and effort and takes at least four years to master. The gait cycle is divided into stance and swing phases. During the stance phase, the foot is in contact with the ground, whereas during the swing phase, the same foot lifts off the ground and moves forward. These two main phases can be further divided into lower-level phases. The stance phase is divided into heel strike, foot flat, mid-stance, and toe off, whereas the swing phase is divided into acceleration, mid-swing, and deceleration.

The pelvis is a structure located between the hip joint and lumbosacral region. With the use of multiple muscles, the pelvis controls the movements of the hip joint and lumbosacral region. In this respect, the pelvic position is the most important factor for determining the body’s sagittal alignment and posture. With the pelvis in the neutral position, correct posture can be maintained, and movements occurring during activities of daily living and gait can be improved via proper control of the upper and lower extremities in dynamic postures. In addition, mechanical problems in the musculoskeletal system of the lumbar vertebrae can occur depending on the location of the pelvis. Moreover, forward and backward pelvic tilt exercises can influence spinal stability and physical alignment. Therefore, pelvic position is an important consideration during walking.

Several studies have been conducted on pelvic stability and postures required during walking. Lumbo-pelvic stabilization and posture have been shown to improve with bridge exercises and various mat exercises. In addition, some studies have examined postures or gait variables through pelvic adjustment. However, none of the studies have addressed the correlations among pelvic positions and differences in lower-extremity joint angles during walking. This basic data, which will be helpful for future studies on walking.

SUBJECTS AND METHODS

Thirty female students at the K University were selected as subjects. The average (mean±standard deviation) age, height, and weight of the subjects were 22.3±3.4 years,
were removed prior to filming of the respective motions. To lateral epicondyles, lateral malleolus, and medial malleolus, static postures, which had been attached to the medial and extremity joints during dynamic postures, the markers for heads. To track the three-dimensional motions of three lower to specific areas of the foot surface, which corresponded In the segments of the foot, reflective markers were attached a three-dimensional space. In addition, reflective markers were attached to each side of the thigh and shank in a square form to create iliac spine, thigh, and shank. Four markers were attached to were attached to each side of the sacrum, anterior superior pelvis, pelvic torsion (PPO), left and right inclination of the pelvis, pelvic torsion (PTO), degree of declination of the hip bone, and pelvic rotation (PRO). The Qualisys Track Manager (Qualisys AB, Sweden), a three-dimensional wireless motion analysis system with six cameras operating at 100 Hz per second, was used to analyze the kinematic motions of lower extremities in the subjects during walking. The L-frame was fixed on the starting point of walking to set the spatial coordinates. In terms of directions, the upper vertical axis was set as the \(+Z\)-axis, and the direction of motions and the horizontal axis were set as the \(+Y\)-axis and \(+X\)-axis, respectively. Based on the L-frame, the space within which movements would be performed was defined using the T-Wand to recognize markers clearly. Reflective markers for static postures to form basic frames were attached to each side of the sacrum, anterior superior iliac spine, thigh, and shank. Four markers were attached to each side of the thigh and shank in a square form to create a three-dimensional space. In addition, reflective markers were attached to the medial and lateral epicondyles, lateral malleolus, and medial malleolus on both sides of the body. In the segments of the foot, reflective markers were attached to specific areas of the foot surface, which corresponded with the calcaneal tuberosity and the first and fifth metatarsal heads. To track the three-dimensional motions of three lower extremity joints during dynamic postures, the markers for static postures, which had been attached to the medial and lateral epicondyles, lateral malleolus, and medial malleolus, were removed prior to filming of the respective motions. To reduce errors, a single well-trained person attached these reflective markers. Motion analysis was performed to derive differences between left and right flexion, abduction, and external rotation range of motion (ROM) of hip joints, flexion, abduction, and external rotation ROM of knee joints, and dorsiflexion, inversion, and abduction ROM of ankle joints, according to the X, Y, and Z-axes.

The measured data were analyzed using the SPSS 12.0 KO (SPSS, Chicago, IL, USA) software, and the collected data are presented in terms of means and standard deviations. Pearson’s correlation coefficient was used to observe correlations among the PPO, PTO, PRO, differences between left and right hip flexion (HDX), differences between left and right hip abduction (HYD), differences between left and right hip external rotation (HZD), differences between left and right knee flexion (KXD), differences between left and right knee abduction (KYD), differences between left and right knee external rotation (KXD), differences between left and right ankle dorsiflexion (AXD), differences between left and right ankle inversion (AYD), and differences between left and right ankle abduction (AZD). The statistical significance level was set at \(\alpha=0.05\).

### RESULTS

The PPO, PTO, PRO, HDX, HYD, HZD, KXD, KYD, KZD, AXD, AYD, and AZD measurements are presented as mean±standard deviation in Table 1. In terms of correlations among these variables, PPO showed positive correlations with HDX, HYD, KXD, KYD, and AYD. In other words, an increase in PPO resulted in corresponding increases in HDX \((r=0.51)\), HYD \((r=0.62)\), KXD \((r=0.45)\), KYD \((r=0.42)\), and AYD \((r=0.38)\). HDX exhibited a positive correlation with AXD, as an increase in HDX resulted in a corresponding increase in AXD \((r=0.64)\). KXD also showed positive correlations with KYD and AYD; an increase in KXD led to corresponding increases in KYD \((r=0.41)\) and AYD \((r=0.45)\), as shown in Table 2.

### DISCUSSION

Humans are exposed to gravity during upright walking. This causes them to experience pelvic and lower-extremity misalignment, which in turn influence posture, gait patterns, and balance. The pelvis supports the abdomen and connects the vertebrae and lower extremities. When an individual stands up from a seated position, the pelvis transfers the body weight from the vertebrae to the lower extremities and

| PPO  | PTO  | PRO  | HDX  | HYD  | HZD  | KXD  | KYD  | KZD  | AXD  | AYD  | AZD  |
|------|------|------|------|------|------|------|------|------|------|------|------|
| 2.7±0.9 | 3.6±1.7 | 2.2±1.5 | 5.2±1.8 | 3.5±1.7 | 5.1±1.4 | 6.3±1.6 | 6.4±1.6 | 6.2±1.4 | 5.8±1.5 | 5.5±1.0 | 5.8±1.4 |

Table 1. Mean±Standard deviation of PPO, PTO, PRO, HDX, HYD, HZD, KXD, KYD, KZD, AXD, AYD, and AZD (Unit-degree)
maintains correct posture, thereby enabling smooth movement of the upper extremities\(^1\)). With the pelvis positioned in neutral, correct posture can be maintained as well as appropriate motions can be performed during daily living activities; additionally, gait ability can be improved via proper control of the upper and lower extremities during dynamic postures\(^2\)).

In a similar study on the pelvis and walking, Cho and Jun selected 30 female university students and randomly divided them into a pelvic adjustment group (n=15) and a stretching group (n=15), which served as the control group, and analyzed their gait. They reported that differences in lower-extremity joint angles during walking. When these types of differences are present, pelvic adjustment is considered necessary for balanced walking. Additional studies should be carried out to implement pelvic adjustment or lumbo-pelvic stabilization exercises as interventions to reduce differences between the left and right lower extremity joint angles during walking.

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