Effect of Gender on Kinematics of the Ankle Joint During Walking

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Introduction
It is intuitive for some people that females and males walk differently. Further, an individual could accurately identify the correct gender based on joint motions, especially shoulder and hip, during walking (Barclay et al., 1978). Research reports from different groups of researchers have gradually added more detail to the differences between male and female walking characteristics. Morio et al., (1997) stated that gender-related gait differences were probably associated with the balance between step length, cadence and leg motions. Kerrigan et al., (1998) reported that there were differences in some sagittal plane kinetic and kinematic variables of lower extremities during walking between females and males. Nigg et al., (1992) concluded that in general the range of motion of the foot was greater for females than for males in the young adult (age 20-39 years). Foot function is associated with the motion of the lower limbs and possibly more proximal segments as well. Research focused on foot mechanics may elucidate the effect of gender on the foot motion during walking. This study compared three-dimensional (3D) kinematics of the patterns of ankle motion between the genders.

Methods
Twenty-three female and 20 male subjects (age: mean 31.65 (± 6.72), range 23-48 years) with normal arched feet participated in the study. Each subject had 6 retroreflective markers placed on the right rearfoot and leg (Figure 1). A four camera motion analysis system (Expert Vision advanced (EVa) Motion Analysis Corporation™ Santa Rosa, California) was used to record 3D movements of the segments and synchronise force platform variables at 60 Hz (Figure 2). Five trials of walking at a self selected speed were collected for each subject. Kinematic and force platform records were used to determine the events of the gait cycle. The 3D trajectories of the markers were measured and calculated by the EVa™ system. The position of markers and relative angles of ankle motion between the leg and rearfoot segments were then computed (raw data) and time-normalised (normalised data) using proprietary software (Kintrak™, Motion Analysis Corporation™ Santa Rosa, California). The temporo-spatial parameters, stride length and velocity, were calculated from the raw position data. The normalised angular displacement data was averaged for each subject. The mean and 95% Confidence Interval (CI) for each group were then calculated. Repeated measures ANOVAs and unpaired t-tests were used to analyse the maximum, minimum and range of the angles, and the temporo-spatial variables.

Results
The pattern of ankle motion in three different planes during walking was similar between females and males except for two periods during stance phase (Figure 3). Between heel-strike and foot-flat, males plantarflexed, everted and abducted the foot earlier than females. Females adducted the foot to a greater extent than males from mid stance to about toe-off to reach a greater (p=0.004) adduction/abduction range of motion. For the whole stride males produced greater (p=0.017) degree of dorsiflexion than the females. The ratio of stride length to height (SL:HT) was similar between the two groups (p=0.776). There was no significant difference in the walking velocity between the genders (p=0.327).

Discussion
The results demonstrate that there are significant gender differences in ankle motion during walking. Over stance phase, females had a significantly greater range of adduction/abduction. Adduction of the foot is equivalent to external rotation of the leg. Thus females externally rotate the leg to a greater extent than males. This could be due to the fact that females have a greater pelvic width than males (Williams et al., 1980) which may generally allow a greater range of rotation of the lower extremity. This rotation may contribute to the difference in perception of female and male walking patterns. The clinical implications of this finding need further study. The males had a greater degree of dorsiflexion. As the SL:HT was the same for women and men, this suggests that the men flexed more at the knee during stance phase (This finding has been confirmed in another study in preparation). Possible advantages or disadvantages associated with this difference could be investigated in further studies. These differences may be a reflection of more fundamental differences in control strategies between females and males for their ankle
joint motion during walking. Additionally, the combined effect of these different walking characteristics may also contribute to the reported differences in perception. When stride length is adjusted for height, there is no difference between females and males. As the walking velocity is similar, the observed differences in maxima and minima could not be attributed to either velocity or stride length differences. We conclude that the differences must be due to differences in the way females and males control their ankle joint motion during walking. The observed results from this study provide evidence for the presence of gender differences in the ankle joint motion during walking. Awareness of these gender effects may be helpful in interpreting differences between females and males in both foot research and the clinic.

**Figure 1.** Marker placement. **Figure 2.** The laboratory set up.

Female: Ankle Motion

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Heel strike

Male: Ankle Motion

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Heel strike

**Figure 3.** Female and male ankle motions

**References**