Gender Differences In Three-dimensional Ankle Kinematics During Walking

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Introduction: Walking is an important daily activity that habitually loads the joints of the lower extremities and likely contributes to the development and progression of joint degeneration such as osteoarthritis. The ankle joint, including the talocrural and subtalar joints acts as a shock attenuator at foot strike during walking, and bone motions within the ankle joint are the subject of research interest for their roles in lower extremity pathology. Gender differences in walking patterns among young and old adults have been studied; young healthy women tend to have shorter stride length and slower gait speed compared to healthy young men when walking at self-selected speeds [1], and the ankle range of motion in old women was greater than in men [2]. Although there is information about gender kinematic differences of gross motion during walking, it is unknown if gender differences exist in the talocrural and subtalar joint kinematics during walking. In recent years, radiographic shape matching techniques (3D-2D model image registration) have been used to evaluate joint kinematics [3] and more recently have been applied to foot and ankle motion analysis [4, 5]. The advantage of this method is high spatial accuracy for bony motion that is unaffected by the overlying soft tissues. The purpose of this study was to investigate gender differences in talocrural and subtalar joints kinematics during walking.

Methods: Seven healthy male subjects and six healthy female subjects participated in this IRB approved study. Informed written consent was obtained from all subjects. All subjects had normal type feet and were free from lower extremity pain, a history of serious injuries or any operative treatment. All subjects performed one gait-cycle task on their right foot in the test area. Each trial was recorded using lateral fluoroscopy. Images were obtained at a rate of 60 Hz using 1 msec x-ray pulses (200mA, 50kV, Infinix Celeve-i INFX-8000c, TOSHIBA medical systems). CT scans from 15 cm proximal to the lateral malleolus to the plantar surface were obtained for each foot/ankle with a slice thickness of 0.4 mm (IDT16, PHILIPS). 3D bone surface models of the tibia, talus and calcaneus were created from the CT images using open-source segmentation software (ITK-SNAP). Anatomical coordinate systems were embedded in each bone model following published methods [4]. Dorsi/plantar flexion was defined as rotation along the mediolateral axis, eversion/inversion was defined as rotation along the anteroposterior axis, and external/internal rotation was defined as rotation along the supero-inferior axis. (Figure 1) The motion at the talocrural joint was defined as the talus motion relative to the tibia, and the motion at the subtalar joint was defined as the calcaneus motion relative to the talus. In vivo three dimensional bone positions during landing were determined using 3D-2D model-image registration techniques with bone models and single-plane fluoroscopic images between the time of heel contact and toe off. All angles were referenced to zero at heel contact. An unpaired t-test was used to compare the values between males and females. The level of significance was set at p < 0.05.

Results: At the talocrural joint, the ranges of motion in males for dorsi/plantar flexion, eversion/inversion and external/internal rotation were 13º ± 4º dorsiflexion, 5º ± 1º eversion and 4º ± 1º internal rotation, respectively. The ranges of motion in females for dorsi/plantar flexion, eversion/inversion and external/internal rotation were 18º ± 4º dorsiflexion, 10º ± 2º eversion and 5º ± 3º internal rotation, respectively. The ranges of motion for dorsi/plantar flexion and eversion/inversion were significantly greater in females than in males. At the subtalar joint, the ranges of motion in males were 4º ± 1º dorsiflexion, 8º ± 3º eversion and 4º ± 1º external rotation, and in females 8º ± 2º dorsiflexion, 14º ± 2º eversion and 12º ± 4º external rotation, respectively. The ranges of motion for subtalar joint dorsi/plantar flexion, eversion/inversion and external/internal rotation were significantly greater in females than in males.

Discussion: Gender differences in talocrural and subtalar kinematics during walking were investigated using 3D-2D model-image registration techniques in healthy subjects. The most important finding of this study is the range of motion at the talocrural and subtalar joints during walking is significantly greater in females. These results suggest ankle joint mechanics during walking are different between males and females. These data contribute to the quantitative understanding of gender differences in normal ankle function and may be useful to better understand and treat ankle joint pathologies in a gender-specific manner. At the talocrural joint, the primary motion during stance phase was in the sagittal plane. All subjects showed talocrural plantar flexion from foot strike to approximately the first half of stance phase, while they experienced dorsiflexion during the last half of the stance phase. On the contrary, the subtalar joint motion was complex with calcaneal dorsiflexion, eversion and external rotation. Direct comparison with previous results is difficult because of differing experimental and reporting methods. Our measured motions and ranges of motion differed from previous work using fluoroscopy during quasi-static gait [6], but currently it is not possible to attribute these differences to methodologic, activity or subject variables.

Significance: These data contribute to the quantitative understanding of gender differences in normal ankle function and may be useful to better understand and treat ankle joint pathologies in a gender-specific manner.
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