Comparison of Hindfoot Kinematics between Normal and Flat Feet using 3D CT Reconstruction Images of Tarsal Bones

Presenting:
Kan Imai, MD
Kyoto, Japan

Additional Authors:
Kazuya Ikoma, MD, PhD
Daisaku Tokunaga, MD, PhD
Masahiro Maki, MD, PhD
Ryota Takatori, MD, PhD
Nozomu Inoue, MD, PhD
Toshikazu Kubo, MD, PhD

Background
In flat feet, hindfoot motions are limited in both plantar flexion and dorsi flexion by contracture of the Achilles tendon, joint instability, and bone construction. It is important to understand the motions of the foot bones in order to understand gait as well as flat foot pathologies; however, the three-dimensional (3D) motion of these bones is not yet completely understood. Herein, we report on a new method for studying tarsal bone kinematics by 3D reconstruction of computed tomography (CT) images using a custom-made device. The aim of this study was to use the new method to compare hindfoot bone kinematics in flat feet with those of normal feet in dorsi flexion and plantar flexion.

Materials and Methods
CT scans of 22 normal and 25 flat feet were used to construct a model of hindfoot bones (tibia, fibula, talus, navicular, and calcaneus). The scans were performed using a custom-made device that held the foot in neutral position, dorsi flexion, or plantar flexion, respectively. The hindfoot bones were segmented based on the threshold level. The volume merge method in three planes was used to calculate the rotation and translation of the talus relative to the tibia in the talocrural joint; the navicular bone relative to the talus in talonavicular joint; the calcaneus relative to the talus in the subtalar joint. For determining the Euler angles, three major axes of rotation - plantar flexion/dorsi flexion, abduction/adduction, and eversion/inversion - were examined for each bone. A Student’s t-test was used to compare the bone kinematics in flat feet with those in normal feet (p<0.05).

Results
With the foot held in maximal dorsi flexion, the talus in flat feet was less adducted relative to the tibia in the talocrural joint (normal foot: 5.0 ± 3.0 degrees, flat foot: 2.9 ± 3.7 degrees; p<0.05) than in normal feet. All other motion of the hindfoot bones was not significantly different between normal and flat feet in dorsi flexion. With the foot held in maximal plantar flexion, the talus in flat feet was significantly less dorsi flexed relative to the tibia (normal foot: -40.9 ± 5.4 degrees, flat foot: -29.3 ± 9.7 degrees; p<0.01) and less abducted (normal foot: -13.8 ± 5.4 degrees, flat foot: -8.4 ± 5.2 degrees; p<0.01) in the talocrural joint than in normal feet. Relative to the talus, the calcaneus in flat feet was significantly more dorsi flexed (normal foot: -0.5 ± 1.7, flat foot: -5.8 ± 5.2; p<0.01) and more abducted (normal foot: 0.2 ± 3.9 degrees, flat foot: -7.6 ± 5.4 degrees; p<0.01) in the subtalar joint than in normal feet. Relative to the talus, the navicular bone in flat feet was more dorsi flexed (normal foot: -6.5 ± 7.3 degrees, flat foot: -11.5 ± 7.6 degrees; p<0.05) and more abducted (normal foot: 1.2 ± 7.3 degrees, flat foot: -13.0 ± 10.2 degrees; p<0.01) in the talonavicular joint than in normal feet.

Conclusions:
In the present study, a new noninvasive method using 3D computer models from CT images was introduced to measure in vivo hindfoot kinematics. This method revealed that flat feet exhibit rigidity in the talocrural joint and instability in the subtalar and talonavicular joints.
Summary
We compared hindfoot bone kinematics in flat feet with those in normal feet on dorsi flexion and plantar flexion with 3D reconstruction of CT images using a new noninvasive technique (the volume merge method). In flat feet, there was rigidity in the talocrual joint and instability in the subtalar and talonavicular joints.