

THE RELATIONSHIP BETWEEN TIBIAL ROTATION AND REAR FOOT MOVEMENT

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INTRODUCTION

Rear foot movements are often observed in most footwear studies. However, with subjects wearing shoes, accurate measurement of the rear foot movement, such as the calcaneal inversion and eversion, may not be available. Studies have suggested that tibial rotation and rear foot movement are related in some way (Mann, 1978; Olerud and Rosendahl, 1987; Cornwall and McPoil, 1995). But, no clear relationship was established between these movements, and some of the methodologies used in these studies may be questionable. The object of this study is to examine and express the relationship between the tibial rotation and rear foot motion. In order to examine these movements, kinematic analyses of tibial rotation and rear foot motion were conducted with ten lower limb (below-knee) specimens obtained from cadavers. A nonlinear function could be expressed with the data collected. This would imply that by observing tibial rotation, rear foot movement can be ascertained indirectly. Therefore, interventions introduced in footwear such as orthotics or features in the insoles can be evaluated by observing tibial rotation for its effect on rear foot movement.

MATERIALS AND METHODS

Motion at the ankle joint complex was measured using the 'Flock of Birds' (FOB) electromagnetic tracking system (Ascension Technology Inc., Burlington, Vermont, USA). A non-metal experimental setup was fabricated to generate foot motion on the specimens (Fig. 1). The footplate was designed to rotate freely around a horizontal axis. In order to secure the specimen to the setup, a shank rod was designed such that one end of the rod was inserted into the medullary canal of the tibia bone of the specimen and the other end was threaded through an aperture in the upper part of the rig. This was deliberately designed so that the simulated inversion/eversion of the hind foot and associated internal-external rotation of the tibia were not impeded. Ten fresh frozen cadaveric specimens of the leg and foot, including the entire tibia were obtained. A 9-mm diameter hole was drilled into the tibial plateau, allowing the intramedullary shank rod to be threaded through it. Three of the motion-tracking receivers were attached to the tibia, talus, and calcaneum using a plastic screw. The specimen was then passively cycled through maximum inversion to maximum eversion, while the rotations of three segments—tibia, talus, and calcaneum—were simultaneously and continuously measured using the FOB. The process was repeated 5 times for each motion and the dual Euler angle parameter (Ying and Kim, 2002) for each specimen was calculated.

RESULTS AND DISCUSSION

The tibial torsion and the foot inversion/eversion movement were examined and their associations were explored. Eversion was regarded as negative as was the internal rotation of the tibia. The graphs plotted were non-linear, confirming the multi-axial nature of the two joints (Fig. 2). External rotation of the tibia occurred when the foot was rotated from inversion to eversion. The amount of this rotation varied nonlinearly with the extent of eversion. At 0° of dorsal extension, the average torsion was 1.3° per degree of inversion/eversion, with a standard deviation of 0.1. The angle of 4.9° to -15.1° of tibial external/internal rotation was recorded from a maximum range of -3.8° to 12.9° of eversion/inversion of the foot. Transmission of torsion occurs in the joint of the hind foot and ankle. The average torsion

per inversion/eversion observed in this study has a much higher value (1.3°) than the previous results of 0.42° by Olerud (1987). Wright et al. (1964) pointed out that the joints acting together as a universal joint is an oversimplified concept. Their argument was that the different axes of the joint complex are not perpendicular. This study also determined that the rate which torsion of the foot is transmitted to the leg is not constant, as would be expected from a true universal joint. There is a shift in the configuration of the subtalar joint over the range of motion, which affects the speed in transmission of torsion. The relationship between the torque applied to the foot and the torque at output, tibial torsion, yields a parameter of mechanical advantage (McCarthy, 2000), which relates the ratio of torque to the ratio of rotational velocities of the foot and tibia. This parameter can be expressed as:

$$\text{Mechanical_Advantage} = \frac{T_{tibia}}{T_{foot}} = \frac{\dot{\mathbf{q}}_{foot}}{\dot{\mathbf{j}}_{tibia}} \quad (1)$$

CONCLUSION

The relationship between torque applied to the foot and the torque generated at the tibia is easily determined by considering the equivalent mechanism and its mechanical advantage.

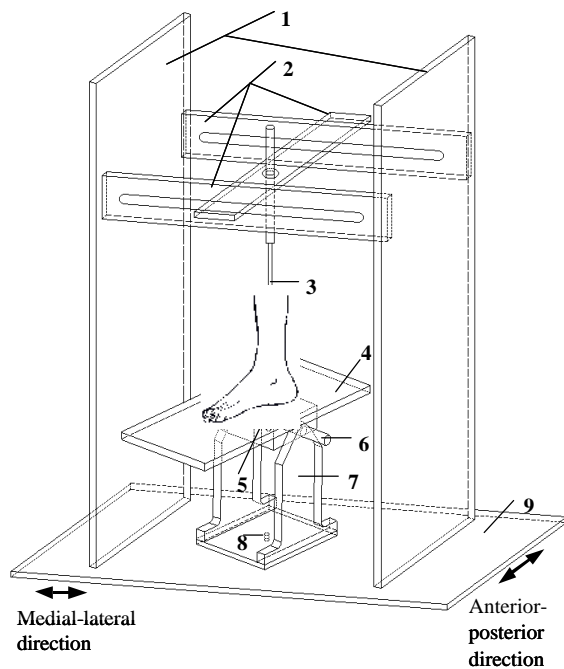


Fig.1 Experimental setup

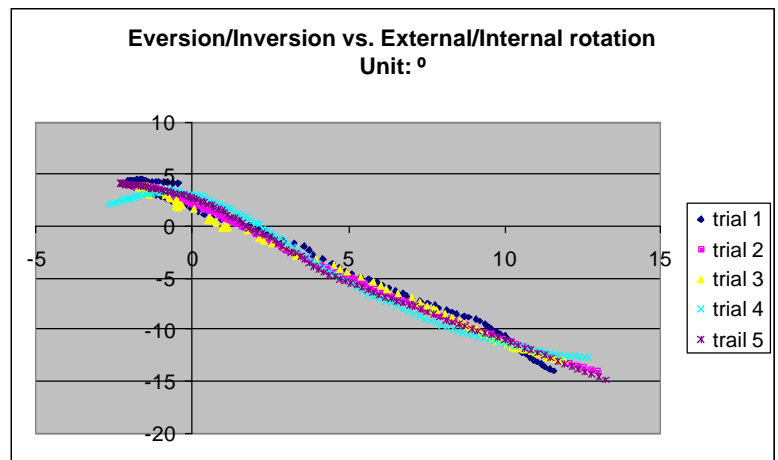


Fig. 2 The movement between tibia and calcareous

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