DO CALCANEAL MOTION AND TIBIAL TORSION INFLUENCE LEG AXIAL ROTATION DURING WEIGHT-BEARING DORSIFLEXION?

Michael G. Chizewski, Kaylynn S. Shewaga, Samantha N. Porter, and Loren Z. F. Chiu

University of Alberta, Edmonton, AB, Canada
web: www.ualberta.ca/~loren1/NMRP.htm

INTRODUCTION

The subtalar joint is often described as a mitered-hinge. In theory, calcaneal eversion, through the morphology of the talo-crural articulation, would result in internal rotation of the leg. However, our preliminary analyses of the 3D rotation of the leg during squatting and jumping tasks suggest two populations – one where the leg internally rotates and the other which externally rotates. From the mitered-hinge concept, it may be speculated that individuals whose leg externally rotates have calcaneal inversion occurring.

An alternate hypothesis that may explain the difference in leg rotation is tibial torsion angle. Tibial torsion describes the offset between the tibiofemoral and talo-crural joints’ flexion-extension axes in the transverse plane (Fig. 1). Differences in tibial torsion have been reported between men and women [1] and may influence gait mechanics [2]. Greater external tibial torsion could theoretically influence the transverse plane rotation of the leg segment.

The purpose of this research was twofold. First, the influence of calcaneal motion in three planes on leg rotation in the transverse plane during weight-bearing dorsiflexion was studied. Second, this research investigated whether differences between internally and externally rotating legs during weight-bearing dorsiflexion could be explained by tibial torsion angle.

METHODS

Healthy women (n=25; age=25.2±5.3 years) and men (n=23; age=25.1±5.4 years) volunteered to participate in this investigation. Retro-reflective markers in a 6-degree of freedom configuration were recorded by a 6-camera motion capture system (Qualisys) at 120 Hz sampling frequency.

Markers were placed on the medial and lateral tibial condylar prominences and the medial and lateral malleoli to define the leg segment. A four marker tracking cluster in a square configuration was fixed to the lateral side of the leg. Markers were placed on the medial, lateral, and posterior calcaneus, with additional markers on the distal great toe, the heads of metatarsals I and V, and the dorsum of the foot (at the joint between second and third cuneiforms).

Over a minimum of three trials, participants were asked to maintain a vertical trunk while flexing at the hip and knee, and dorsiflexing at the ankle to a position of maximum voluntary dorsiflexion. The distance between the greater trochanters of the femur was used to align the second toes of each foot in a standardized forward facing position.

Fig. 1: Tibial torsion angle (θ) (superior view) [1]. Markers/anatomic landmarks: A (medial malleolus); B (lateral malleolus); C (medial tibial condyle); D (lateral tibial condyle).
The leg (tibia and fibula) and calcaneus were modeled as rigid segments in Visual3D software. Rotations of the leg and calcaneus were determined relative to the laboratory using a ZYX Cardan sequence [3]. Mean calcaneal range of motion to maximum ankle dorsiflexion was calculated for three planes. Tibial torsion angle was calculated from measuring the offset in the transverse plane between the axis passing through the proximal tibial condyle markers and the axis passing through the distal markers on the malleoli (Fig. 1).

Participants were grouped by whether their leg internally or externally rotated. Participants were grouped for their left and right leg separately, as a small number of participants (n=6) had one leg internally rotated while the other externally rotated. Tibial torsion and calcaneal rotation in the sagittal, frontal, and transverse planes were compared between the internal and external leg rotators using unpaired two-tailed t tests.

RESULTS AND DISCUSSION

Anterior tilt of the calcaneus (sagittal plane) and external rotation of the calcaneus (transverse plane) were not significantly different between internal and external rotators (Table 1). Significant differences (p<0.01) were found for calcaneal eversion (frontal plane), with externally rotating legs demonstrating greater calcaneal eversion than those that internally rotated (6.60±2.47 versus 4.66±2.46). The motion of the calcaneus in the sagittal and transverse planes does not appear to influence axial rotation of the leg. In the frontal plane, calcaneal eversion appears to be a factor in whether the leg internally or externally rotates. However, the greater calcaneal eversion associated with externally rotating legs opposes the mitered-hinge theory.

For the legs that internally rotated during the weighted dorsiflexion task, tibial torsion angles were 11.56±6.24 and 11.65±5.56 in left and right limbs respectively. For legs that externally rotated, tibial torsion angles were 19.93±9.57 and 18.89±4.03° in left and right limbs respectively. Significant differences were noted for left (p<0.001) and right (p<0.0001) tibial torsion angles when comparing internal versus external leg rotators. This data indicates that tibial torsion angle plays a role in whether a leg internally or externally rotates during weighted dorsiflexion.

CONCLUSIONS

The direction of axial leg rotation will affect loading on the structures of the knee and potentially the hip [2]. Axial rotation of the tibia has been implicated as a factor in lower extremity injuries, for example, anterior cruciate ligament rupture. Research of injuries where tibial rotation is a factor should consider tibial torsion as a non-modifiable risk factor.

It is not known what causes differences in external tibial torsion. Further study must be devoted to identifying genetic or environmental conditions which may contribute to the magnitude of external tibial torsion. Additionally, it is unclear where in the leg segment the tibial torsion is created.

Our research demonstrates that an anatomical factor influences axial rotation of the leg. The task in this study required the foot to be in contact with the ground. However, it is important to study how tibial torsion influences leg and foot mechanics in non-weight-bearing situations, as well as during the transition from non-weight-bearing to weight-bearing tasks such as during gait.

REFERENCES


Table 1: Comparison of calcaneal rotation (in three planes) and tibial torsion angles of internally (IR) and externally (ER) rotating legs. For calcaneal rotation: positive = anterior tilt (X), inversion (Y), and internal rotation (Z). Tibial torsion angle: positive = increasing external tibial torsion.

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<th>Calcaneus-X (deg)</th>
<th>Calcaneus-Y (deg)</th>
<th>Calcaneus-Z (deg)</th>
<th>Tibial Torsion (deg)</th>
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