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Guest editorial

Tibial torsion: Significance and measurement

Following the acceptance for publication of the article by Hazlewood et al. in a recent issue of *Gait & Posture* we were invited by the Editor in Chief to comment on the challenging issue of measuring tibial torsion [1].

Tibial torsion describes the axial or transverse plane alignment of the shank segment of the lower extremity. In utero, lower extremity limb bud formation occurs during the 4th week of gestation [2,3]. During the 7th week there is medial rotation of the developing lower extremity, bringing the great toe to the midline. Lateral or external rotation then occurs slowly throughout the remainder of the growth and development years until skeletal maturity. Clinicians may describe tibial torsion based upon anatomical landmarks about the knee, ankle and foot [4–7]. At the knee, the long axis of the thigh, the patella, and the tibial tubercle have all been utilized to estimate the orientation of the flexion extension axis of the knee joint. At the ankle, the medial and lateral malleoli, the hindfoot, and the long axis of the foot have all been utilized to estimate the orientation of the plantar flexion-dorsiflexion axis of the ankle joint. The anatomical definition of tibial torsion is not precise, and there is poor consensus concerning the optimal technique for its clinical assessment [8,9].

Based upon assessment of the alignment of the bimalleolar axis relative to the longitudinal axis of the thigh, it has been determined that tibial torsion is approximately 5° external at birth, with progressive external rotation to 15° by skeletal maturity [4]. Utilizing the orientation of the bimalleolar axis relative to the flexion-extension axis of the knee, it has been determined that the tibia is 20° externally rotated when the knee is flexed to 90°, and rotates to 40° external as the knee is fully extended [10]. Dynamic internal rotation of the tibia relative to the femur as the knee flexes contributes to the femoral roll back mechanism [10]. Dynamic external rotation of the tibia relative to the femur as the knee extends contributes to joint stability [10]. At the ankle, dynamic external rotation of the tibia occurs during the loading response, which unlocks the hindfoot and midfoot joints, promoting shock absorption function [11–13]. Dynamic internal rotation of the tibia occurs during the remainder of the stance phase, which locks the hindfoot and midfoot joints, promoting stability in mid stance and optimizing the lever function of the foot relative to the ankle plantar flexor muscle group during terminal stance [11–13].

Transverse plane malalignment of the tibia is a common component of a variety of neurological and musculoskeletal disease processes in children and adults [7,9,14,15]. Excessive internal rotation of the tibia disrupts the shock absorption function of the foot during loading response and may compromise limb clearance in swing phase. Excessive internal tibial torsion may contribute to an internal foot progression angle and has been associated with medial compartment degenerative arthritis of the knee in adults [16,17]. Excessive external rotation of the tibia disrupts the stability and lever functions of the foot during mid and terminal stance [18]. Excessive external tibial torsion may contribute to an external foot progression angle and has been associated with progressive equinoplanovalgus foot segmental malalignment, hallux valgus malalignment, and midfoot degenerative arthritis in adults [16,19–21].

Given the importance of the transverse plane orientation of the distal ankle flexion-extension axis with respect to the biomechanical performance of the ankle and foot in gait, it is essential that measurements of transverse malalignment of the tibia are available for treatment decision-making. A number of methods to measure tibial torsion has been proposed with some adopted into clinical practice, including goniometry, ultrasound and computed tomography [4,22,23]. Of these, computed tomography is accepted as the most accurate, but it is not readily accessible for routine clinical use. More commonly in clinical practice, the method described by Staheli and Engel [4] is employed to evaluate tibial torsion where the patient is prone, the knee is flexed to 90°, the ankle is neutral, and a goniometer arms are aligned with the bimalleolar axis and the longitudinal axis of the thigh.

Measurement assumptions and challenges are associated with each of these strategies. Ultrasound and computed tomography examiners must select from several possible reference axes on the proximal tibia, although investigators have found that the differences introduced by choice of proximal axis are small [22,24]. In addition to requiring careful goniometer placement, the Staheli method is based

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on references that span the knee, thereby increasing the potential that artifact associated with through-knee transverse rotation may affect measured values of tibial torsion. It must be appreciated that a direct comparison of ultrasound and computed tomography methods with the Staheli method is difficult because of differences in the underlying anatomical references, i.e. these different methods measure different physical quantities.

Another technique for measuring tibial torsion was presented in the April 2007 issue of *Gait and Posture* [1] where the authors project the bimalleolar axis of the seated patient onto a reference surface in an approach that the authors termed the ''footprint method''. This technique demonstrates good repeatability when compared with the Staheli goniometric method described above and with measures obtained from a physical device fixed to the lower leg. The footprint approach is attractive with respect to potential clinical application because it is relative simple and straightforward. It does appear to require a certain level of experience to obtain reliable results, but then the other techniques carry this same requirement. This may be related to the fact that the proximal reference in this technique is the knee flexion-extension axis, thereby requiring the examiner to both estimate its orientation and avoid inadvertently introducing through-knee transverse rotation while positioning the partially weight-bearing lower leg.

All of these techniques, both direct (i.e. ultrasound and computed tomography) and indirect (e.g. footprint and Staheli) methods, provide measures of tibial torsion to varying degrees of accuracy and precision. Values of tibial torsion alone are not sufficient, however, for clinical decision-making. The consequences of pathological tibial torsion must also be assessed in the context of patient's gait. The clinician must appreciate whether measured torsional deformity adversely impacts ankle and knee biomechanics during gait. Torsional deformities that result in functional deficits during gait should be corrected by surgery designed to restore the normal anatomical alignment. Torsional deformities that are well compensated (i.e. are not associated with functional deficits during gait) do not require surgical correction.

Quantitative gait analysis techniques provide information on dynamic alignment and range of motion. Can this same technology be employed to also measure tibial torsion? Current gait analysis approaches can provide a measure of tibial torsion, i.e. knee rotation expressed as the transverse rotational displacement of the bimalleolar axis relative to the approximate knee flexion-extension axis. This again leaves open the prospect the distortion of the tibial torsion measure by through-knee motion. A more direct strategy would relate a proximal shank anatomical reference, such as the line connecting the tibial tuberosity and fibula head, to the already-instrumented distal bimalleolar axis. The clinical utility of this alternative torsional measure might then be enhanced by establishing its relationship with CT-based tibial torsion values. Reliability of this approach might be strengthened though the use of a pointer device to identify the anatomical landmarks as opposed to the usual retro-reflective markers [25].

The assessment of tibial torsion provides important information for the determination of the causes and possible treatments for a number of significant gait deviations in both children and adults. The authors of the study that appears in a recent issue of *Gait & Posture* are to be congratulated on their efforts to improve our ability to determine the transverse plane alignment of the tibia. Further work remains to be done to develop techniques that are accurate, reliable, and clinically practical.

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