Estimating fascial strain and elastic energy storage in the human iliotibial band

Carolyn M. Eng[1,2], Allison S. Arnold[1], Daniel E. Lieberman[2], and Andrew A. Biewener[1]
Departments of Organismic and Evolutionary Biology[1] and
Human Evolutionary Biology[2], Harvard University
Correspondence to: Carolyn M. Eng, Department of Ecology and Evolutionary Biology, Brown University, PO Box G-B204, Providence, RI 02912. E-mail: carolyn_eng@brown.edu

BACKGROUND
Fascia is hypothesized to have several functions during locomotion including distributing muscle forces, transferring loads among limb segments, and transmitting moments that stabilize joints. The functional hypothesis tested here is that the human iliotibial band (ITB), a complex thickening of the lateral fascia of the thigh, plays a role in elastic energy storage. The ITB receives muscle fibers anteriorly from tensor fascia lata and posteriorly from gluteus maximus (GMAX). As a tendinous structure, the ITB transmits forces from the muscles to the skeleton, generating moments about the hip and knee. However, whether the ITB stretches substantially, storing elastic energy, is not known, and how this structure's morphology contributes to locomotor function is not well understood. ITB syndrome (ITBS), a common overuse injury in runners, may be caused by excessive strain in the ITB. However, the biomechanical factors that contribute to this injury remain unclear because few studies have characterized the 3D geometry of the ITB or the strains that result from activity of the associated muscles.

METHODS
To estimate strains in the ITB and test the hypothesis that it stores elastic energy during running, we characterized the geometry of the ITB in five human cadaveric specimens, and estimated the forces generated by the surrounding muscles using a computer model. Because the posterior ITB (ITB_{post}) transmits larger forces and thus undergoes larger strains than the anterior ITB during locomotion, we focus on the ITB_{post} here. We measured moment arms of GMAX (i.e., the perpendicular distance from the muscle's line-of-action to the joint axis of rotation, which determines the length change of the muscle-ITB unit with joint motion) for hip flex/extension, hip ab/adduction, hip rotation, and knee flex/extension using the tendon excursion method. To estimate the muscle forces transmitted to the ITB_{post}, we weighed the portion of GMAX inserting on the ITB and characterized its force-generating capacity. We used these data to refine the geometry and muscle architecture of an existing human lower limb model to more accurately reflect the anatomy and material properties of the ITB and the moment-generating properties of GMAX. We used the model, in combination with measured joint kinematics and published electromyographic (EMG) recordings, to estimate the forces transmitted by ITB_{post} and the corresponding strains and energy storage in the ITB during running.

RESULTS
The ITB_{post} strains 4% during slow running and 7% during fast running in our model, storing as much as 17 J of energy per stride. The maximum strain occurs at the end of swing phase when the GMax is active, the knee is extended and the hip is flexed. Passive strains in the ITB are relatively small (~1%) when GMAX is not activated.

CONCLUSIONS
This work provides new insights into fascia function. The ITB's high compliance (i.e., its potential to transmit force while changing length) suggests a plausible, previously unrecognized mechanism for storing elastic energy in fascia during running. The model developed here provides a framework for further investigating how anatomy, joint kinematics, and muscle forces, influence ITB strain and potentially contribute to ITBS.