Beyond Ground Reaction Forces: Towards a Wearable Device for Monitoring Bone Stress, Preventing Stress Fractures

Research Objective: Long-term: develop a wearable device for monitoring tibia loading and preventing bone stress injuries in runners. Short-term: identify the minimal set of wearable sensors needed to estimate tibia bone loading across various running conditions. Here, we initially tested the ability to estimate tibia loading from ground reaction forces (GRFs).

Design: Criterion standard.

Setting: Motion analysis lab in the Center for Rehabilitation Engineering and Assistive Technology at Vanderbilt University.

Participants: Enrollment ongoing. Initially, three healthy individuals (2 male, 1 female, height 1.8 ± 0.1 m, weight 66.8 ± 7.0 kg, age 24.6 ± 1.5 years).

Interventions: Not applicable.

Main Outcome Measures: GRF vs. total tibia compression loading (sum of muscle contraction force and GRF acting axially along tibia).

Results: Tibia bone compression loading was estimated using comprehensive lab-based kinematics and GRF measurements to obtain the criterion standard. Bone loading varied with running speed, slope and step frequency. Peak tibia loading was 2-4 times larger than GRF. Increases in tibia loading did not consistently correspond to increases in GRF, or vice versa. For instance, when running at 6° incline vs. 6° decline, GRF impact peak decreased by 25% whereas estimated tibia load peak increased by 42%.

Conclusions: Preliminary results indicate that GRF alone is insufficient to estimate tibia loading, motivating the need to fuse data from multiple sensors. We are now exploring the placement (e.g., shank, foot) and type (e.g., inertial measurement unit, force-sensing insole) of sensors, as well as fusion algorithms that would enable wearable sensors to reliably estimate tibia loading. We envision a lightweight, low-profile wearable device that would allow users to track their day-to-day tibia bone loading, and notify users of potentially harmful loading patterns that may increase risk of stress fracture.

Author(s) Disclosures: N/a