Multi-sensor fusion algorithms offer a promising approach for monitoring tibia bone damage over multiple workouts

Emily S. Matijevich[1], Leon R. Scott[1], Peter Volgyesi[1], Kendall H. Derry[1] and Karl E. Zelik[1]

[1]Vanderbilt University, Nashville, TN, USA

Bone overuse injuries (e.g. tibial stress fractures) can result from an accumulation of microdamage to the bone [1]. Wearable sensors offer exciting opportunities for daily monitoring of loading, damage, or injury risk to the bone during activities like running. However, many commercial wearables utilize ground reaction force (GRF) impact metrics that are not indicative of the loading on structures inside the body. **PURPOSE**: Here we explore two new multi-sensor algorithms for more accurately monitoring tibial bone damage while running. **METHODS**: Bone damage was estimated using Miner's rule of cumulative fatigue over a series of loading cycles [2]. We simulated five-mile running workouts where each loading cycle (running stride) was a different speed-slope combination. Peak tibial load of each cycle was first estimated using lab-based equipment and a musculoskeletal model, our "ground truth" estimate. Then, peak tibial load was estimated using the GRF vertical averaged loading rate (VALR) and using our new multi-sensor algorithms (one physics-based and one machine learning). Finally, we compared trends in estimated bone damage across 25 independent running workouts of differing intensity. **RESULTS**: Using the VALR based estimates of bone damage would misguide runners about the damage their bone experiences, with some workouts being largely overestimated and some being largely underestimated. Alternatively, estimating bone damage with the physics-based or machine learning algorithm more accurately captures key trends in higher vs. lower damage workouts (**Fig. 1)**. **CONCLUSION**: Multi-sensor algorithms offer an exciting tool for capturing important trends in bone damage and potentially overuse injury risk while running.

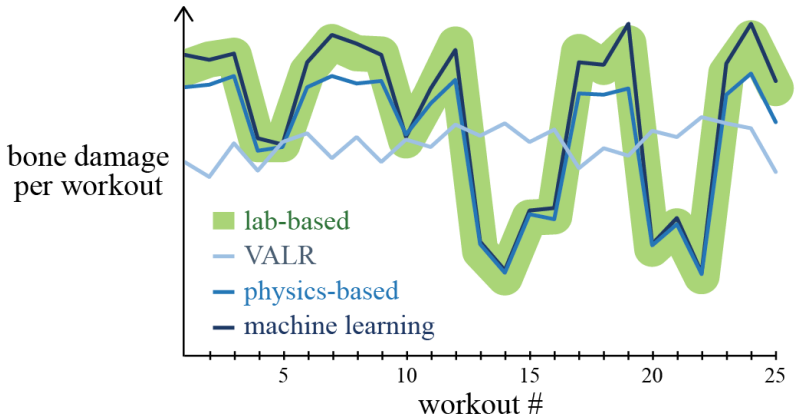

Figure 1. The green band represents lab-based estimates of bone damage over multiple workouts. This plot highlights how the physics-based and machine learning algorithms more accurately track trends in bone damage. Using VALR fails to provide the runner with accurate information about which workouts are more or less damaging to the bone.

References

1. Edwards, W. B. (2018). Modeling Overuse Injuries in Sport as a Mechanical Fatigue Phenomenon. Exercise and Sport Sciences Reviews. https://doi.org/10.1249/JES.0000000000000163.
2. Currey, J. D. (2013). Bones: Structure and Mechanics. Princeton University Press.