Motion Capture and Shear Wave Tensiometry Assessments of Achilles Tendon Load are Significantly Correlated

Zahra McKee[1,2]**,** Stephanie G. Cone[1,3], Karin Grävere Silbernagel[1,4] , Elisa S. Arch[1,2]
[1]Biomechanics and Movement Science, University of Delaware, [2]Kinesiology and Applied Physiology, University of Delaware, [3]Biomedical Engineering, University of Delaware, [4]Physical Therapy, University of Delaware
Email: mckeezn@udel.edu

Summary

Understanding the load in the Achilles tendon during dynamic tasks is important for injury rehabilitation. This study compared two methods of tendon loading assessment: shear wave speed proxy and motion capture plantarflexion moment estimation. Results showed that the peak, impulse, and peak rate of change of these two measures are significantly correlated across various activities.

Introduction

The Achilles tendon is prone to injuries like tendinopathy and tendon ruptures. For these injuries, managing the load experienced by the tendon is important for optimal recovery. Too little load results in insufficient stimulus required for proper tendon remodeling and repair, but too much load can induce pain and further injury [1, 2]. This load management is guided by pain and accomplished through a combination of physical therapy, orthotic devices, and activity limitation [2, 3]. Still, Achilles tendon injury rehabilitation can be lengthy, and some individuals never fully recover [2,3].

To most effectively design and prescribe load management protocols, we need to be able to directly assess the load in the tendon. Currently, estimates of tendon loading typically use motion capture (MC) [4]. However, MC methods make several assumptions to derive tendon load and do not capture the full picture of Achilles tendon loading for many activities. Shear wave tensiometry, an emerging technique, allows for direct measurement of the Achilles tendon [5]. SWT centers around the idea that tendon shear wave speed (SWS) varies in proportion to the square root of tendon axial stress and therefore SWS can be used as a proxy for tendon load [5]. Previous literature has found SWS and MC or torque-based estimates of Achilles tendon load to be in good agreement for walking, running, and isometric exertions [5, 6]. This study aimed to compare Achilles tendon loading assessed with MC and SWT during a variety of relevant dynamic exercises. We hypothesized that there will be significant correlations between the MC load estimate and SWS peaks, impulses, and peak rates of change.

Methods

3 healthy adults (1 M/2 F; 27.7± 2.08 yr) visited the lab so far, where they were outfitted with a six degree-of-freedom shank and foot MC marker set. Each participant was randomly assigned an evaluation leg and the shear-wave tensiometer was placed superficially to the Achilles tendon on this leg [7]. MC, force plate and SWT data were collected while participants performed several iterations each of 9 activities: single/double leg standing heel raises, squats, trailing/leading evaluation leg lunges, single leg countermovement and forward jumps, and running and walking at their self-selected speed on a treadmill.

MC kinematic and kinetic data was processed through Qualysis Track Manager, followed by analysis in Visual 3D to extract plantarflexion moments which were then transformed into load estimates. SWT data was processed in Matlab to extract SWS. Both MC and SWS data were then further processed to calculate the peak (maximum), impulse (area under the curve), and peak rate of change (maximal incremental slope over a 5% moving window) of the MC load estimate and SWS respectively [4]. A Spearman rank-order test was performed in RStudio to test for a correlation between the MC load estimate and SWS measures of the three metrics.

Results and Discussion

MC load estimate and SWS peaks ($p=0.013$, $\rho=0.48$), impulses ($p=0.008$, $\rho=0.51$), and peak rates of change ($p<0.001$, $\rho=0.78$) were significantly correlated (Figure 1).

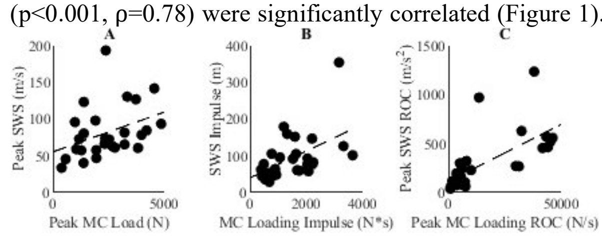

Figure 1: MC load estimate and SWS correlations for peaks (A), impulses (B) and peak rates of change (ROC) (C).

There are some expected differences between MC and SWT assessments of tendon loading. First, the MC load estimation relies on force plate contact, missing tendon load during periods like swing. Additionally, the MC method only measures overall ankle moment generation, combining the efforts of the plantarflexor and dorsiflexor muscles. In contrast, the SWT method can isolate the Achilles tendon, suggesting more accurate representation with SWS during periods of co-contraction. Despite this, the correlations between the two assessment methods for all three tendon loading metrics indicate that the methods similarly represent tendon loading.

Conclusions

The observed significant correlations between Achilles tendon SWS and MC load estimates indicate that trends in these three metrics can be compared between the two measurement methods. This provides context for future research and interpretation of SWT, paving the way for further use of SWT to evaluate tendon loading changes with different clinical populations and rehabilitation strategies.

References

[1] Kannus P et al. (1997). *Scan J Med Sci Spor,* **7**: 67-71
[2] Silbernagel KG et al. (2020). *J Athl Train,* **55**: 438-447
[3] Park SH et al. (2020). *Clin Orthop Surg,* **12**: 1-8
[4] Baxter J et al. (2021). *Med Sci Sport Exer,* **53**: 124-130
[5] Martin JA et al. (2018), *Nat Commun,* **9**: 1592.
[6] Keuler EM et al. (2019), *Sci Rep*, **9**: 13