Motion Capture and Shear Wave Tensiometry Measures of Achilles Tendon Peak Load, Loading Impulse, and Peak Loading Rate are Significantly Correlated in Healthy Adults

Zahra McKee[1,2], Stepha[illegible]Cone[1,3], Karin Gravere[illegible]ernagel[1,4] , Elisa S. Arch[1,2]
[1]Biomechanics and Movement Science, U[illegible]rsity 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 rehabilitation of Achilles tendon injuries. This study compared two methods of tendon load measurement; shear-wave tensiometry and motion capture plantarflexion mo[illegible] estimation. Results showed these two measurement methods are significantly correlated for the measures of peak load, loading impulse, and peak loading rate across various activities.

Introduction

The Achilles tendon is the strongest and largest tendon in the human body but 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 mechanical stimulus required for proper tendon remodeling and repair, but too much load can induce pain and possibly further injury [1, 2]. Currently, this load management is guided by pain levels and accomplished through a combination of physical therapy, orthotic devices, and limi[illegible]ctivities [2, 3]. Still, Achilles tendon injury rehabilitation can be lengthy and some individuals never fully recover [2,3].

In order to most effectively design and prescribe these load management protocols, we need to be able t[illegible]ess the load in the tendon. Currently, estimates of ten[illegible]loading have been made using motion capture-derived measures (MC) [4-6]. However, MC methods make several assumptions to derive these measures of tendon load, require expensive equipment, and do not capture the full picture of Achilles tendon loading for many activities. Shear-wave tensiometry (SWT), an emerging measurement technique, allows for direct measurement of the stress in the Achilles tendon, and may be a more accurate measurement tool [7]. This study aimed to compare SWT estimates of Achilles tendon loading to those obtained using MC during a variety of relevant exercises. We hypothesized that there will be significant correlations for MC and SWT measures of Achilles tendon peak load, loading impulse, and peak loading rate.

Methods

3 healthy adults (1 M/2 F; 27.7± 2.08 yr; body mass index = 27.9 ± 5.33 kg·m−2) visited the lab so far, where they were outfitted with a six degree-of-freedom shank and foot motion capture 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]. Participants performed several iterations each of nine activities; single/double leg standing heel raises, squats, trailing/leading evaluation leg lunges, single leg countermovement jump, single leg forward jumps, and running and walking at their self-selected speed on a treadmill. MC, force plate, and SWT data were collected during each of these activities.

Kinematic and kinetic data from MC was processed through Qualysis Track Manager, followed by analysis in Visual 3D to extract plantarflexion moment values. SWT data was processed in custom matlab scripts to extract shear-wave speed, which has been shown to be proportional with the square root of Achilles tendon axial stress [7]. Both MC and SWT measures of Achilles tendon load were then further processed to calculate the peak Achilles tendon load, loading im[illegible]e, and peak loading rate, all key aspects of the tendo[illegible]ding profile [4]. A Spearman rank-order test was performed in RStudio to test for a correlation between the three loading metrics for the MC and SWT approaches.

Results and Discussion

MC and SWT measures of peak load ($p<0.005$, $\rho=0.54$), loading impulse ($p<0.005$, $\rho=0.57$), and peak loading rate ($p<0.001$, $\rho=0.76$) were significantly correlated (Figure 1).

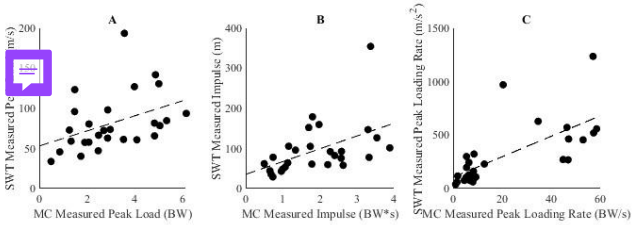

Figure 1: MC and SWT correlations for peak load (A), loading impulse (B) and peak loading rate (C)

MC and SWT measures of Achilles tendon load have also previously been found to be in good agreement for walking, running, and isometric exertions [7, 8]. There are some expected differences between MC and SWT measures of tendon load. Firstly, the MC plantarflexion moment estimation measure relies on force plate contact, missing tendon load during periods like swing. Additionally, the MC method only gets overall ankle moment generation, combining the efforts of the plantarflexor and dorsiflexor muscles. In contrast, the SWT method is able to isolate the Achilles tendon load, suggesting more accurate load representation during periods of co-contraction. Despite this, the correlations between the two measurement methods for all three tendon load metrics indicate that the methods similarly represent tendon loading, allowing for comparison.

Conclusions

The observed significant correlations between SWT and MC measures of Achilles tendon load indicate that trends in these three metrics can be compared between the two measurement methods. This paves the way for further use of tensiometry to evaluate tendon load changes with different clinical populations and rehabilitation strategies.

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