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TITLE: Objective Assessment of Functional Muscle-Tendon Behavior for Enhancing the Diagnosis and Treatment of Tendon Pathologies

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14. ABSTRACT The purpose of this study is to finalize development and field testing of a wearable kinetic system designed to objectively assess tendon health and function in individuals recovering from overuse tendon injuries. We will accomplish this by: (1) establishing baseline metrics of bilateral tendon kinetics during outdoor locomotor activities, (2) investigating functional adaptations in individuals exhibiting tendon pathology, and (3) evaluating the use of shear wave tensiometry to objectively identify tendon healing. To date, we have made substantial headway recruiting, hiring and training study team personnel. With the major technical development aspects of the wearable tensiometer system complete, we will begin testing both uninjured and injured participants. The overall timeline of the project remains unchanged.						
15. SUBJECT TERMS Tendon, tendinopathy, shear wave tensiometer, wearable devices, outdoor activity, rehabilitation, return-to-duty, symmetry, force, loading						
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TABLE OF CONTENTS

	<u>Page</u>
1. Introduction	1
2. Keywords	1
3. Accomplishments	1
4. Impact	7
5. Changes/Problems	8
6. Products	9
7. Participants & Other Collaborating Organizations	11
8. Special Reporting Requirements	14
9. Appendices	14

1. INTRODUCTION:

The purpose of this study is to finalize development and field testing of a wearable kinetic system designed to objectively assess tendon health and function in individuals recovering from overuse tendon injuries. We envision enabling clinicians the ability to precisely measure tendon behavior during operationally relevant activities such that they can monitor healing, guide rehabilitation, and quantitatively assess patients' capacity for safe return-to-duty. We will accomplish this by: (1) establishing baseline metrics of bilateral tendon kinetics during outdoor locomotor activities, (2) investigating functional adaptations in individuals exhibiting tendon pathology, and (3) evaluating the use of shear wave tensiometry to objectively identify tendon healing.

2. KEYWORDS:

Tendon, tendinopathy, shear wave tensiometer, wearable devices, outdoor activity, rehabilitation, return-to-duty, symmetry, force, loading

3. ACCOMPLISHMENTS:

What were the major goals of the project?

Specific Aim 1: Establish baseline metrics of bilateral tendon kinetics during outdoor locomotor activities in uninjured civilians.

Specific Aim 2: Investigate functional adaptations in active duty Service members exhibiting tendon pathology.

Specific Aim 3: Evaluate use of shear wave tensiometry to objectively identify tendon healing.

	Timeline	UW	NHRC	Progress (%)
Major Task 1: Prepare regulatory documents and research protocol				
	Months			
Write and submit CRADA	1-3	DT	AS/PS	100
Write and submit IRB protocol for civilian testing	1-2	DT/PA		100
Write and submit IRB protocol for injured/uninjured Active duty testing	1-2		AS/PS/J	100
Submit amendments, adverse events and protocol deviations as needed	As needed	DT	AS/PS	100
<i>Milestone Achieved: Local IRB approval at UW and NHRC</i>	3			100
<i>Milestone Achieved: CRADA approved</i>	6			100
Major Task 2: Hiring and training of study staff				
Hire graduate student	1	DT/PA		0
Advertise for and interview postdoctoral fellow	7-9	DT/PA	AS/PS/J	100
Advertise for and interview research engineer	7-9	DT/PA	AS/PS/J	100
Hire and onboard postdoctoral fellow	13	DT/PA		100
Hire and onboard research engineer	13		AS/PS/J	0
Train postdoctoral fellow	13-15	DT/PA		100
Train research engineer	13-15		AS/PS/J	0
<i>Milestone Achieved: Graduate student hired</i>	1			0
<i>Milestone Achieved: Postdoctoral fellow hired and trained</i>	15			100
<i>Milestone Achieved: Research engineer hired and trained</i>	15			0
Major Task 3: Aim 1 – Testing of uninjured participants				
Identify outdoor locomotor course	1-3	DT/PA		100
Recruit and test uninjured civilian participants	3-12	DT/PA		0
<i>Milestone Achieved: Validation testing complete</i>	12			0
Major Task 4: Aims 2 & 3 – Testing of participants with tendinopathy				
Subtask 1: Establish testing protocol and prepare for recruitment				80
Identify 0.5-mile outdoor testing course	13-15		AS/PS/J	100
Talk with local civilian and active duty physical therapists to aid in subject recruitment of injured participants	13-15		AS/JF	100
Subtask 2: Subject recruitment and testing				0
Recruit active duty participants with clinical tendinopathy diagnosis	16-39		AS/PS/J	0
Confirm tendinopathy with questionnaire, Doppler ultrasound, and medical chart review	16-39		JF	0

Test participants with tendon injury, before and after completion of rehabilitation	16-42		AS/PS	0
<i>Milestone Achieved: Testing protocol fully developed and implemented</i>	15			80
<i>Milestone Achieved: Partnering physical therapists identified</i>	15			0
<i>Milestone Achieved: Injured participant testing complete</i>	42			0
Major Task 5: Data analysis, dissemination and reporting of results				
Subtask 1: Disseminate results				0
<i>Milestone Achieved: Normative testing submitted for conference presentation</i>	12			0
<i>Milestone Achieved: Normative testing submitted for peer-reviewed publication</i>	18			0
<i>Milestone Achieved: Injured vs uninjured comparison submitted for conference presentation</i>	30			0
<i>Milestone Achieved: Injured vs uninjured comparison submitted for peer-reviewed publication</i>	42			0
<i>Milestone Achieved: Relationship between tendon structure and mechanical function submitted for conference presentation</i>	42			0
<i>Milestone Achieved: Relationship between tendon structure and mechanical function submitted for peer-reviewed presentation</i>	48			0
Subtask 2: Prepare and provide quarterly and annual reports to DoD	Quarterly	DT/AS	AS/PS	25

Projected Quarterly Enrollment

Target Enrollment Uninjured Normative Data (per quarter)	Year 1				Year 2				Year 3				Year 4				Total
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
UW (projected)	-	8	8	8	-	-	-	-	-	-	-	-	-	-	-	-	24
UW (actual)	-	0	0	0													0
NHRC (projected)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NHRC (actual)	-	-	-	-													-
Target Enrollment (cumulative-projected)	-	8	16	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Target Enrollment (cumulative-actual)	-	0	0	0													0

Target Enrollment Outdoor Injured Testing (per quarter)	Year 1				Year 2				Year 3				Year 4				Total
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
UW (projected)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
UW (actual)	-	-	-	-													-
NHRC (projected)	-	-	-	-	-	4	8	12	16	20	24	28	32	-	-	-	32
NHRC (actual)	-	-	-	-													0
Target Enrollment (cumulative-projected)	-	-	-	-	-	4	8	12	16	20	24	28	32	32	32	32	32
Target Enrollment (cumulative-actual)	-	-	-	-													0

What was accomplished under these goals?

1. Major Tasks 1: We have received regulatory approval with both research sites' IRB.
2. Major Tasks 2: We hired a full-time postdoctoral research associate at UW who has been fully trained and will be beginning testing of uninjured civilians participants. We were not able to recruit a graduate student this past year but will attempt again with the current incoming cohort of graduate students at UW this fall. We have advertised for and interviewed a research engineer at NHRC; this individual is currently in the process of being hired. There are also several other currently employed research assistants at NHRC who will be trained to work part time on the project and assist with subject recruitment and data collections.
3. Major Tasks 3: We have identified a suitable outdoor course at UW. Unfortunately, we were unable to recruit and test any uninjured civilian participants this past year as we worked diligently to overcome several technical challenges with the wearable tensiometer system. We redesigned the wearable system and both the Achilles and patellar tensiometers to improve their reliability during testing. We also made a mobile calibration device that will enable testing to take place completely outdoors without the need for lab-based force plates other calibration equipment. We incorporated GPS into the wearable device so that we can track location along the outdoor course so experimental data can be matched to overground conditions (e.g., slopes, grass, pavement). As part of a separate study, preliminary bilateral testing in healthy, young adults was conducted to check for data repeatability and validity of assumptions (i.e., healthy adults have a symmetric loading pattern). Overall, we found that our tensiometry metrics are similar to other metrics as determined from traditional inverse dynamics methods. We submitted two abstracts related to these data to the North American Congress on Biomechanics and the Military Health Systems Research Symposium.
4. Major Task 4: We have identified a suitable outdoor course at NHRC. We have also engaged with the local medical leadership and community to aid in subject recruitment of injured participants. Testing of injured participants should begin as planned during this upcoming second year. NHRC personnel visited UW in July 2022 to received initial training on the tensiometer system. UW personnel will travel to NHRC in August 2022 to deliver all the necessary equipment to perform testing and assist with final training on the wearable tensiometer system.
5. Major Task 5: Nothing to report.

What opportunities for training and professional development has the project provided?

Alex Reiter, the hired postdoctoral research associate at UW, has received extensive training and professional development as a result of working on this project. Under the guidance and mentorship of the key personnel on this project as well as working with other members of the lab, Alex gained experience in human subject research, tensiometry, motion capture, wearable technology.

Yiteng Ma, an undergraduate student at UW, has subsequently been mentored by Alex Reiter. Through his work in the lab at UW, Yiteng has gained proficiency in computer programming.

How were the results disseminated to communities of interest?

Nothing to report.

What do you plan to do during the next reporting period to accomplish the goals?

1. Major Tasks 1: Nothing to report.
2. Major Tasks 2: We will attempt to recruit and train a graduate student at UW during the next academic year. We will train the newly hired research engineer as well as some of the currently employed researchers at NHRC to work on the project.
3. Major Tasks 3: We plan to test most, if not all, of our uninjured civilian participants during September and October this year. We will resume outdoor testing in the spring of 2023 for any remaining participants.
4. Major Task 4: After training is complete with NHRC in August, we will begin recruitment of injured participants. We expect the timeline for this to follow the approved SOW.
5. Major Task 5: We will submit conference abstracts for the normative uninjured participants this coming winter. Peer-reviewed publications will be submitted next spring, if not sooner, once all participants have been collected. We plan to submit conference abstracts for the injured versus uninjured comparison based on the progress of Major Task 4.

4. IMPACT:

What was the impact on the development of the principal discipline(s) of the project?

Nothing to report.

What was the impact on other disciplines?

Nothing to report.

What was the impact on technology transfer?

Nothing to report.

What was the impact on society beyond science and technology?

Nothing to report.

5. CHANGES/PROBLEMS:

Changes in approach and reasons for change

Nothing to report.

Actual or anticipated problems or delays and actions or plans to resolve them

We are delayed in hiring a graduate student at UW. We will continue to advertise and recruit for a graduate student this fall. We will train current research staff at NHRC to lead data collections and they will, in turn, train the newly hired research engineer once that individual is onboarded. At this, we do not expect these delays in personnel hiring to affect the overall timeline of the project.

We were unable to collect on uninjured participants this past year as we overcame several technical challenges with the wearable tensiometer system. We will be testing these participants during this next year.

Changes that had a significant impact on expenditures

Nothing to report.

Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Not applicable.

Significant changes in use of biohazards and/or select agents

Not applicable.

6. PRODUCTS:

- **Publications, conference papers, and presentations**

Journal publications.

Nothing to report.

Books or other non-periodical, one-time publications.

Nothing to report.

Other publications, conference papers and presentations.

1. Reiter, AJ, Martin, JA, Knurr, KA, Thelen, DG: Shear wave tensiometry predictions of Achilles tendon force during running. North American Congress on Biomechanics, Ottawa, ON, Canada, 2022.
2. Reiter, AJ, Martin, JA, Knurr, KA, Adamczyk, PG, Thelen, DG: Evaluating Tendon Loading Asymmetry During Walking and Running via Shear Wave Tensiometry with Applications to Rehabilitation. Military Health System Research Symposium, Orlando, FL, 2022.

- **Website(s) or other Internet site(s)**

Nothing to report.

- **Technologies or techniques**

Nothing to report.

- **Inventions, patent applications, and/or licenses**

Nothing to report.

- **Other Products**

Nothing to report.

7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

What individuals have worked on the project?

Name: Darryl Thelen
Project Role: PD/PI
Nearest person month worked: 1
Contribution to Project: Dr. Thelen oversaw the scientific and administrative direction of the overall project, and day-to-day oversight of the portions of the project at UW.

Name: Pinata Sessoms
Project Role: Co-PD/PI
Nearest person month worked: 1
Contribution to Project: Dr. Sessoms oversaw the scientific and administrative direction of the overall project, and day-to-day oversight of the portions of the project at NHRC.

Name: Amy Silder
Project Role: Co-PI
Nearest person month worked: 3
Contribution to Project: Dr. Silder completed the NHRC regulatory documents and began preparatory work for testing.

Name: John Fraser
Project Role: Co-I
Nearest person month worked: 1
Contribution to Project: Dr. Fraser has participated in group meetings.

Name: Peter Adamczyk
Project Role: Co-I
Nearest person month worked: 1
Contribution to Project: Dr. Adamczyk directed the development and deployment of the wearable systems.

Name: Alex Reiter
Project Role: Postdoctoral Research Associate
Nearest person month worked: 12
Contribution to Project: Dr. Reiter completed the UW regulatory documents, redesigns of the wearable systems, and testing.

Name:	Yiteng Ma
Project Role:	Undergraduate student
Nearest person month worked:	1
Contribution to Project:	Yiteng assisted in computer programming on the wearable system.
Funding Support:	NIH STTR

Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

Nothing to report.

What other organizations were involved as partners?

Nothing to report.

8. SPECIAL REPORTING REQUIREMENTS

COLLABORATIVE AWARDS:

QUAD CHARTS:

9. APPENDICES:

Appendix-1: Abstract submitted to the North American Congress on Biomechanics

SHEAR WAVE TENSIOLOGY PREDICTIONS OF ACHILLES TENDON FORCE DURING RUNNING

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Introduction

Shear wave tensiometry [1] has been introduced as a non-invasive technique for directly assessing muscle-tendon loading during movement. Prior studies have used tensiometry to assess Achilles tendon (AT) loading during walking [2] and quiet standing [3]. Recent work has introduced a wearable tensiometer that was used to evaluate AT loads while walking outdoors on varying terrain [4]. The wearable tensiometer could enable a vast array of sports medicine opportunities by evaluating muscle-tendon tissue loading in the field. This study was undertaken to assess the capacity for shear wave tensiometry to produce a valid measure of tendon loading during running. We measured AT forces during running across a range of speeds, and then assess validity by comparing our loading metrics to that reported previously via motion analysis techniques.

Methods

Shear wave tensiometers were secured bilaterally to the AT of 10 healthy adults (5M/5F, 25.8±4.4 years). Shear wave speeds were collected while individuals walked (1.34 m/s) and ran (2.68, 3.35, and 4.47 m/s) for 20 seconds on a treadmill. Wave speeds were calibrated to AT force using simultaneous measures of ground reaction force during a lateral sway task. Linear least squares estimation was used to calculate subject-specific AT force normalized to body weight (bw) from wave speeds collected during walking and running. Wave speed and normalized force were ensemble averaged across strides for each leg ($n=20$). Differences in peak force between speeds were analyzed using a Friedman test with Dunn's multiple comparison ($p<0.05$).

Results and Discussion

Qualitatively, AT wave speed over a gait cycle increased from walking to running and modulated with increasing running speed (Fig. 1A). Force linearly increased with squared wave speed during the calibration task (Fig. 1B) allowing for predictions of force during walking and running (Fig. 1C). Peak force during walking (1.34 m/s: 4.3(3.7-5.1) bw (median with IQR)) was significantly lower than peak force during running (2.68 m/s: 7.4(5.8-8.9) bw, $p=0.042$; 3.35 m/s: 7.9 (6.7-9.2) bw, $p<0.001$; 4.47 m/s: 9.2(7.3-10.3) bw, $p<0.001$). Peak force increased with faster running speed; force at 4.47 m/s was significantly higher than at 2.68 m/s ($p<0.001$).

This study demonstrates the potential for measuring AT force during running via shear wave tensiometry. Predicted peak forces were similar to reported values in literature [5-7]. In contrast to these prior studies using inverse dynamics, this study predicted forces using a non-invasive device secured superficially to the AT. These results set the stage for using wearable versions of tensiometry to evaluate muscle-tendon loading during unobstructed athletic movements performed in the field.

Significance

Shear wave tensiometry was previously limited to assessing AT loading during walking [2] or static tasks [3]. Here, we demonstrated its potential to predict AT force during running. This opens the possibility of using tensiometry for evaluating AT

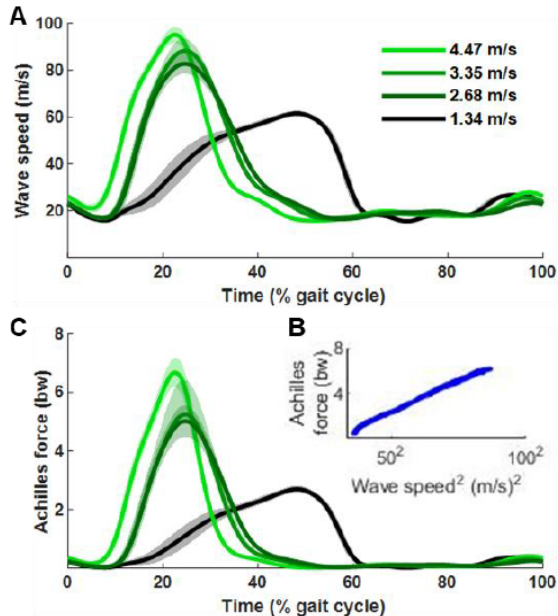
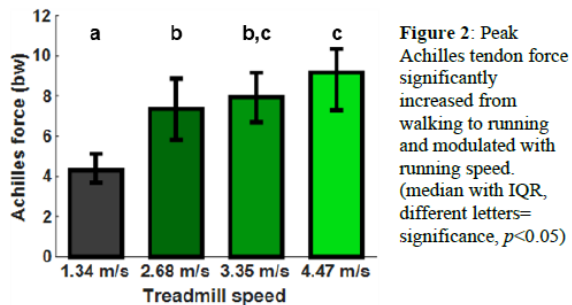


Figure 1: Representative data for a single subject. (A) Ensemble average wave speed over a gait cycle during walking (1.34 m/s) and running (2.68, 3.35, and 4.47 m/s). (B) Squared wave speed was calibrated to Achilles tendon force with linear least squares estimation. (C) Force was predicted from calibrated wave speed. (mean±SD)



kinetics in the context of athletic performance, injury prevention, or rehabilitation where running or a similarly high-dynamic task is of interest.

Acknowledgments

NIH (TL1TR002375, R42AR074897), DOD CDMRP (129866603), and Wisconsin Alumni Research Foundation.

References

- [1] Martin+, 2018. *Nat Comm.* 9(1).
- [2] Keuler+, 2019. *Sci Rep.* 9.
- [3] Acuna+, 2019. *Phys Rep.* 7(23).
- [4] Harper+, 2020. *Sensors.* 20(17).
- [5] Scott+, 1990. *Med Sci Sport Ex.* 22(3).
- [6] Giddings+, 2000. *Med Sci Sport Ex.* 32(3).
- [7] Werkhausen+, 2019. *JAP.* 127(1).

Appendix-2: Abstract submitted to the Military Health System Research Symposium

Title: Evaluating tendon loading asymmetry during walking and running via shear wave tensiometry with applications to rehabilitation.

Authors: Alex J. Reiter¹, Jack A. Martin^{1,2}, Keith A. Knurr², Peter G. Adamczyk¹, and Darryl G. Thelen¹
¹Department of Mechanical Engineering, ²Department of Orthopedics and Rehabilitation, University of Wisconsin-Madison, Madison, WI

Introduction

Musculoskeletal injuries (MSKIs) in training and deployed environments are one of the leading health problems in the military resulting in detrimental effects to both individual and unit readiness. Nearly 800,000 injuries are reported annually representing an injury rate of 628 per 1000 person-years [1-2]. Among these reported injuries, 12% were classified as overuse injuries of the foot and ankle [1]. Rehabilitation of service members following these injuries needs to balance an expedited return-to-duty while minimizing the risk of future re-injury to optimize retention on duty over the long term. Following MSKIs, assessments of lower limb asymmetries (e.g., strength, joint kinematics, or ground reaction forces) can be used as rehabilitation criteria for determining recovery and the ability to return-to-duty. However, traditional clinical measures used to quantify asymmetry are either subjective or surrogate evaluations of the injured tissue of interest. For example, qualitative gait analysis and heel raise tests do not provide a clinician information about the actual loading experienced by a chronically injured Achilles tendon (AT).

Shear wave tensiometry [3] has been introduced as a non-invasive technique for directly assessing muscle-tendon loading during movement. Prior studies have used tensiometry to assess AT loading during walking [4] and quiet standing [5]. Recent work has introduced a wearable tensiometer that evaluated AT loads while walking outdoors on varying terrain [6]. These studies investigated only unilateral tendon loading, whereas bilateral may be more helpful in assessing MSK health. Thus, this study was undertaken to assess the capacity for shear wave tensiometry to produce valid measures of tendon loading asymmetry. We measured AT shear wave speed bilaterally to quantify asymmetry during walking and running across a range of speeds, and then assessed validity by comparing our asymmetry metric to those reported previously for related metrics.

Materials and Methods

Shear wave tensiometers were secured bilaterally to the AT of 10 healthy adults (5M/5F, 25.8±4.4 years). The tensiometers consisted of an electrodynamic tapper device to induce shear waves and two miniature accelerometers placed in series over the tendon to record the propagating shear wave. The shear wave speed was calculated by finding the time shift that maximized the normalized cross-correlation of the two accelerometer signals. Bilateral AT shear wave speeds were collected while individuals walked (1.34 m/s) and ran (2.68, 3.35, and 4.47 m/s) for 20 seconds on an instrumented treadmill with ground reaction forces (GRFs) simultaneously recorded. Gait data were ensemble averaged across strides for each leg, and peak wave speed, vertical GRF, and anterior-posterior (AP) GRF were determined. Asymmetry of peak values was calculated for each participant ($|\text{left} - \text{right}| / ((\text{left} + \text{right})/2)$) [7]. Differences in asymmetry across gait speeds were analyzed using a Friedman test ($p < 0.05$).

Results

Peak AT wave speed asymmetry was similar across walking and running speeds, ranging from 8.1% to 14.7% (1.34 m/s: 12.2(5.3-17.8)%; 2.68 m/s: 8.1(5.2-20.1)%; 3.35 m/s: 14.7(4.7-18.6)%; 4.47 m/s: 11.9(6.9-16.6)%, $p=0.95$, median with IQR). GRF asymmetries were also similar between locomotion speeds, with vertical GRF asymmetry ranging from 0.8% to 2.7%, and AP GRF asymmetry

ranging from 6.3% to 9.3% (vertical GRF [1.34 m/s: 2.7(0.6-3.8)%; 2.68 m/s: 0.9(0.6-1.5)%; 3.35 m/s: 0.8(0.5-2.4)%; 4.47 m/s: 1.4(1.3-1.8)%, $p=0.16$]; AP GRF [1.34 m/s: 6.6(5.4-7.4)%; 2.68 m/s: 9.3(6.5-12.5)%; 3.35 m/s: 9.0(4.8-10.6)%; 4.47 m/s: 6.3(3.2-9.8)%, $p=0.34$], median with IQR).

Conclusions

This study demonstrates the potential for measuring AT loading asymmetry during walking and running via shear wave tensiometry. For reference, asymmetry values for vertical GRF reported here were similar to previously reported values in athletes while running ($2.8\pm 0.2\%$) [7]. At the joint level, asymmetries of $11.2\pm 0.9\%$ for ankle positive work, $14.5\pm 1.0\%$ for ankle negative work, and peak ankle plantarflexor moment of $5.5\pm 0.4\%$ [7] have previously been observed. AT shear wave speed asymmetry measured in the present study were of similar magnitude to ankle work and moment measures. Uniquely, this study assessed asymmetry via a shear wave tensiometer secured superficially to the AT, a novel sensor which can be deployed as a wearable [6].

These results set the stage for using wearable versions of tensiometry to evaluate muscle-tendon loading asymmetry outside of a military treatment facility or laboratory setting. This would enable objective assessments of cumulative loading and recovery following injury during realistic training environments (e.g., load carriage on uneven terrain), ultimately aiding in return-to-duty decision making. While the focus of this work was on the AT, this technology has the potential to be extended to other commonly injured tissues including the patellar and hamstring tendons.

As this technology matures, there are several potential applications relevant to medical readiness: (1) In a training or garrison environment, tendon loading asymmetry via tensiometry could provide an objective, quantitative, and non-invasive metric for assessing recovery and return-to-duty status. (2) In a deployed or forward environment where communication with medical teams is limited, asymmetry metrics could provide service members the ability to self-monitor recovery when MSKIs do occur. As mission requirements allow, metrics could be digitally communicated back to medical teams to facilitate “telehealth” care. (3) Tensiometry has the potential to be implemented for large-scale collections across specific military populations (e.g., basic trainees or special operation units) to build normative databases of asymmetry in a healthy population for a range of military-relevant tasks to use as rehabilitation targets.

Disclaimers

Funding from the DOD CDMRP (129866603), NIH (TL1TR002375, R42AR074897), and Wisconsin Alumni Research Foundation.

References

[1] Hauret+, *Am J Pred Med*, 38(1S), 2010. [2] Grimm+, *Sports Med Arth Rev*, 27(3), 2019. [3] Martin+, *Nat Comm*, 9(1), 2018. [4] Keuler+, *Sci Rep*, 9, 2019. [5] Acuna+, *Phys Rep*, 7(23), 2019. [6] Harper+, *Sensors*, 20(17), 2020. [7] Stiffler-Joachim+, *Med Sci Sport Ex*, 53(5), 2021.

Learning Objectives:

1. Describe how shear wave tensiometry can be implemented to assess asymmetry in Achilles tendon loading.
2. Determine Achilles tendon shear wave speed asymmetry during walking and running.
3. Discuss potential applications of shear wave tensiometry to assess MSKI rehabilitation.