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A Comparison of Achilles Tendon Morphological Characteristics Based Upon VISA-A Score in Active Adults Over Age 50

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ABSTRACT

International Journal of Exercise Science 17(3): 1517-1529, 2024. Morphologic Achilles tendon properties obtained via diagnostic ultrasound imaging are valuable in understanding Achilles tendon health and injury. Currently, limited information exists regarding Achilles tendon morphological properties amongst active aging adults based upon Victorian Institute of Sport Assessment (VISA-A) scores. Achilles tendon morphologic properties defined by VISA-A score groupings allow clinicians and researchers to compare data values amongst current patients. Purpose: Comparison of physically active aging adults Achilles tendon morphological properties with various VISA-A scores or a previous Achilles tendon rupture. A convenience sample of 121 participants (71 females, 50 males) at least moderately active and 50 years old, were recruited. Participants completed a VISA-A survey, and assigned groups by scores (Group 1: 90-100, Group 2: 70-89, Group 3: 45-69, Group 4: Previous Achilles tendon tear). Achilles tendon ultrasound imaging occurred at the malleolar line (The apex of the medial and lateral malleolus). Following imaging Achilles tendon cross-sectional area (CSA), thickness, and elastography were measured and analyzed. Participants with a previous Achilles tendon rupture displayed significantly larger tendon CSA and thickness compared with other groups ($p<0.05$). Individuals with VISA-A scores from 45-69 displayed significantly larger tendon CSA and thickness than participants with scores greater than 90 ($p<0.03$). No significant differences were noted for elastography between groups ($p>0.05$). Achilles tendon morphological differences exist based upon pain level in physically active aging adults. Diagnostic ultrasound may be used during assessment and rehabilitation of injured tendon tissue to inform about current tendon tissue properties.

KEY WORDS: Diagnostic ultrasound, Achilles tendinopathy, imaging evaluation

INTRODUCTION

Numerous adults over age 50 are choosing to participate in recreational exercise for leisure time enjoyment and beneficial health outcomes (12). While recreational exercise is associated with numerous health related benefits, it also increases the risk of musculoskeletal injuries such as Achilles tendinopathy (42).

Due to aging the Achilles tendon experiences numerous degenerative tissue adaptations including changes in tendon structure, composition (15, 40), and physiologic processes such as tenocyte activity (19, 40). These degenerative processes have been hypothesized as contributors to the development of Achilles tendinopathy and Achilles tendon ruptures that occur with increasing frequency as people age (23, 45). As individuals age, participation in athletics may place appropriate loading forces on a tendon that are required for maintenance of healthy tissue (21). However, overloading the Achilles tendon during sports participation may disrupt tendon collagen fibrils, resulting in dysfunction and pain (30). Identifying Achilles tendon morphological properties amongst various Victorian Institute of Sport Assessment – Achilles (VISA-A) score groupings may allow clinicians and researchers to better prevent, diagnose, and rehabilitate aging individuals with Achilles tendinopathy (10).

Maintaining Achilles tendon function in aging adults is vital to maintain or increase activities of daily living and quality of life (41). The Victorian Institute of Sports Assessment – Achilles Questionnaire (VISA-A) is a valid and reliable self-assessment tool to understand clinical Achilles tendon health (33). The VISA-A questionnaire is based on self-response scored questions giving each participant a score on a scale of 0-100 with 100 being a perfectly healthy tendon and a score of 0 indicating extreme limitations (33). A score greater than 90 can be equated to "excellent" tendon health (20). A VISA-A score less than 60 is likely attributed to a person experiencing Achilles tendinopathy (20). The VISA-A is a valuable clinical tool to understand subjective Achilles tendon health, although further understanding of tendon health is attainable if used in conjunction with other objective clinical tests such as musculoskeletal imaging using diagnostic ultrasound (10, 13).

Diagnostic ultrasound imaging is a reliable, valid, and repeatable tool that can be used for a more complete understanding Achilles tendon health (27, 28). Diagnostic ultrasound imaging provides information about the morphological properties of an Achilles tendon which aid in predicting (25), diagnosing, and rehabilitating (2, 31) injured tendon tissue. Diagnostic ultrasound may be particularly valuable for individuals who are at risk for developing Achilles tendinopathy as structural deficits seen via ultrasound are associated with a four-fold increased risk of pathology(25). Morphological information obtained during ultrasound imaging may include Achilles tendon cross-sectional area (CSA) (39), thickness (9), and elastography (9). These Achilles tendon characteristics have been associated with the diagnosis, and the future development of Achilles tendinopathy (9, 34, 37). Despite beneficial knowledge provided by ultrasound imaging, this modality is seldom used to evaluate Achilles tendon properties due to patient concerns and lack of impact on treatment decisions, including in adults over age 50 (3). There is currently a tremendous dearth of knowledge regarding Achilles tendon morphological properties by VISA-A score groupings (table 1) in this age group. Further establishment of normative values in these areas will aid clinicians and researchers as they attempt to predict, and diagnose, Achilles tendon pathology in active individuals over age 50.

The purpose of this study is to compare Achilles tendon cross-sectional area, thickness, and elastography as measured via diagnostic ultrasound amongst active adults over age 50 with varying VISA-A scores or a previous Achilles tendon rupture. We hypothesize that adults over age 50 with lower VISA-A scores will display increased Achilles tendon CSA, and thickness with a corresponding decrease in Achilles tendon elastography when compared with individuals with high VISA-A scores.

METHODS

Participants

One hundred twenty-one volunteers were recruited for this study from a convenience population (71 females, age = 64.44 ± 6.57 years, height = 165.27 ± 9.00 cm, weight = 66.92 ± 12.80 kg, 50 males, age = 68.75 ± 8.36 years, height = 178.32 ± 9.19 cm, weight = 82.04 ± 11.02 kg) (Table 1). The inclusion criteria for this study consisted of: 1) participants must be at least 50 years old, 2) participating in the Huntsman world senior games, 3) receive at least a moderate activity score on the international physical activity questionnaire (IPAQ). Exclusion criteria for the study were any individuals who were under 50 years old, and/or a calculated score less than moderate on the IPAQ. Every participant read and signed an informed consent approved by a university institutional review board (study protocol, IRB X2020-201). All study procedures adhered to the ethical policies of the *International Journal of Exercise Science* (26). All participant data was collected in a single visit at the Huntsman World Senior games. Power Analysis indicated detection of a 4% change in Achilles tendon CSA using a standard deviation of 0.025 (28), required 6.25 participants per VISA-A/previous Achilles tear group. Due to the nature of the Huntsman World Senior Games data collection and high demand for Achilles tendon imaging among participants, data was continuously collected during the duration of the event resulting in many more participants recruited than the power analysis indicated. All imaged participants were included in this data set.

Table 1. Participant demographic data by group reported in Mean (SD).

Participant Demographics by Group				
VISA-A Groups	*90-100*	*70-89*	*45-69*	*Previous Tear*
Males	31	5	6	8
Females	52	10	7	2
Age (years)	66.56 (8.00)	68.47 (8.53)	63.69 (6.79)	65.70 (4.69)
Height (cm)	169.84 (10.05)	167.56 (13.88)	173.89 (11.48)	177.17 (10.63)
Weight (kg)	72.03 (14.38)	69.73 (11.62)	79.13 (13.58)	78.23 (12.13)
VISA-A score	99.17 (1.83)	81.53 (5.21)	56.42 (7.14)	91.7 (12.09)

Protocol

Questionnaire - Prior to ultrasound imaging, all participants completed a Qualtrics survey that contained the International Physical Activity Questionnaire (IPAQ) survey and the VISA-A survey as well as a series of demographic and health history questions. The IPAQ is a 12-question assessment that is used to understand self-reported measures of weekly physical activity. IPAQ data was scored based upon calculated metabolic equivalent (MET) minutes and corresponding activity categories were assigned (17). VISA-A surveys were scored and calculated according to previously published standard practice (33). Participants were split into three groups based upon VISA-A scoring. Group one consisted of participants who scored between 90 – 100 or excellent tendon health, group two participants scored between 70 – 89 or a fair to good tendon health, group three participants scored 45 – 69 or poor tendon health. A fourth group consisted of individuals who had previously experienced a partial or complete Achilles tendon rupture regardless of VISA-A score. The participants reported a previous tear between 8-20 years prior to imaging. Nine of the participants in the tear group had a VISA-A score greater than 90, and one participant had a VISA-A score of 82.

Figure 1. Malleolar line imaging location and foot and ankle positioning during ultrasound imaging.

Ultrasound Imaging Sessions - Following completion of the surveys, all participants completed an ultrasound imaging session. Ultrasound imaging was performed by two individuals that were trained to perform Achilles tendon ultrasound evaluations. All imaging was overseen by authors (J.S. and W.J.) whose experience collectively amounts to over 27 years of imaging experience. Training included a minimum of five practice imaging sessions prior to data collection. During Achilles tendon ultrasound imaging, the participant laid prone on a treatment table with their ankle resting in a comfortable position with their feet hanging off the table and positioned for marking that was used during imaging. A mark was placed in a straight line between the apex of the medial and lateral malleolus for use during ultrasound imaging as seen in previous studies (27, 38). Study participants were positioned with their feet fixed in a strap attached to the table. The feet were fixed by adjusting patient position so the feet were firmly resting against the strap. The strap was positioned at their forefoot and used to maintain a 90-degree ankle position during imaging as seen in figure 1. Ensuring ankle position ensured no participant movement during ultrasound imaging. Ultrasound images were taken of the participants left then right Achilles tendons using a GE logiq Fortis, or S8 machine (GE Logic E, GE Healthcare, Little Chalfont, United Kingdom). Achilles tendon CSA, thickness and elastography images were taken at the mark made between the level of the medial and lateral malleolus (figure 1). CSA and thickness ultrasound images were taken using a li8 -18 "hockey stick" probe, while stiffness images were acquired using a 9L probe with capability for elastography. Cine-loop images consisting of multiple frames were taken for use in tendon CSA, thickness, and elastography calculations. A continuous cine loop image consisting of at least three separate frames was collected of elastography data for use in determining Achilles tendon stiffness. While obtaining elastography images care was taken to ensure that the ultrasound probe was placed perpendicular to the Achilles tendon. Additionally, image quality was ensured by viewing the contrast between the Achilles tendon and Kager's fat pad directly deep to the Achilles tendon.

Imaging Data Analysis - Achilles tendon CSA, thickness, and elastography were analyzed using internal software on the ultrasound machine. The ultrasound machines include capability using a measure button to trace the Achilles tendon on screen. To analyze CSA the Achilles tendon border was outlined manually for both the left and the right leg (Figure 2). The tendon was outlined twice (once on each cine loop) for each the right and the left leg by the same individual. Intra-rater reliability ICC values for Achilles tendon CSA were 0.99 with a confidence interval between 0.99 and 0.99. When performing analysis for Achilles tendon thickness the tendon was measured from the superficial to the deep border of the tendon on two different cine-loop frames. The measurement occurred at the midpoint of the ultrasound screen, as the midpoint of the ultrasound screen corresponded to the malleolar line. Achilles tendon thickness measurements were all performed by the same individual. Intra-rater reliability ICC values for Achilles tendon thickness were 0.99 with a confidence interval between 0.99 and 1.00. Achilles tendon elastography was analyzed across two different cine-loop frames by the same individual using the measure area function (Figure 2). The average of the two cine-loop frames was used for statistical analysis. The measured area spanned the superficial side of the tendon to the deep side of the tendon. During statistical analysis only one tendon was used. There were no significant differences between left and right side for participants who scored >90 on the VISA-A, thus the authors chose to use the right Achilles tendon. For individuals with no pain the right tendon was used. For those participants who had Achilles tendon pain or previous rupture the injured tendon was used.

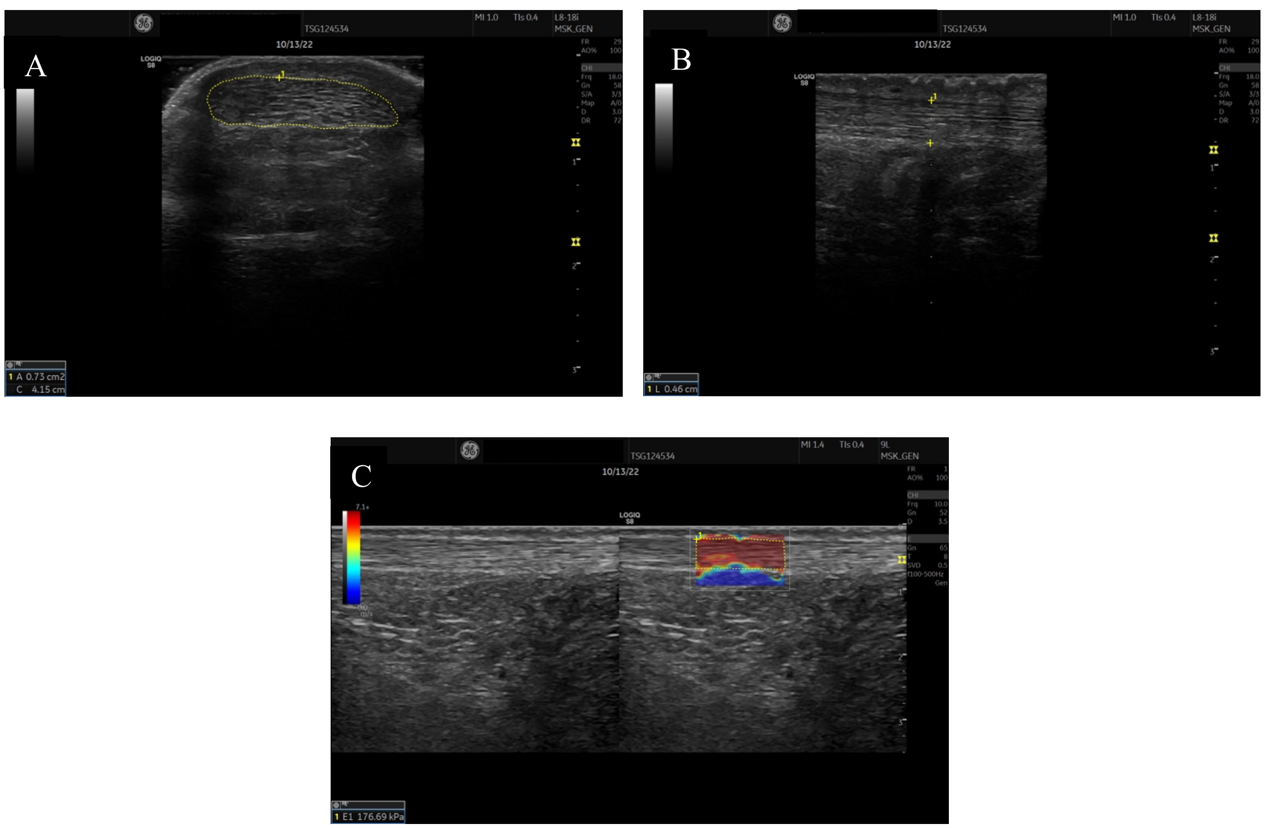

Figure 2. Examples of Achilles tendon measurement. Panels indicate measurements performed for A) CSA B) Thickness C) Elastography.

Statistical Analysis
A log transformation was performed on Achilles tendon CSA and thickness variables as data was not normally distributed. Following the log transformation an analysis of variance was utilized to determine differences in VISA-A score groups for Achilles tendon CSA, thickness, and elastography. Where applicable a Tukey post hoc test was used to determine specific group differences. Age, weight, height, and sex were all included as fixed effects in the model. If the fixed effects were found to be statistically non-significant they were removed from the model using a backwards stepwise regression. Alpha was set at $p<0.05$. Statistical analysis was completed using Statistical Analysis Software (JMP pro Version 16.0, SAS institute, Inc. Cary, NC, USA). Cohen's D effect sizes were calculated using Cohen's D = $\frac{\bar{X}_1-\bar{X}_2}{SD_{pooled}}$. Cohen's D effect size was used to describe the strength of relationships between our groups, and evaluate the practical significance of our findings (24). Cohen's D effect size was interpreted using the following values: 0 – 0.19 = no effect size, 0.20 - 0.40 = small effect size, 0.41 - 0.80 = medium effect size, 0.81 – 1.30 = large effect size, greater than 1.30 = very large effect size.

RESULTS

Individuals who experienced a previous partial or complete Achilles tendon rupture displayed significantly larger Achilles tendon CSA and thickness when compared with all other groups as seen in figure 3 ($p<0.05$). Very large Cohen's D effect size differences were noted when comparing CSA and thickness differences between participants in the tear group and healthy participants (1.54, 1.59). Participants with VISA-A scores from 45 – 69 had significantly larger tendon CSA and thickness than participants with VISA-A scores greater than 90 ($p<0.03$). These differences resulted in medium Cohen's D effect size differences. No statistically significant differences and small to no Cohen's D effect were noted between the groups with VISA-A scores from 70 - 89 and 90 – 100 ($p>0.05$). During both analyses of Achilles tendon CSA and thickness height was a significant fixed effect ($p<0.01$). No statistically significant differences and small to no Cohen's D effect sizes were seen between any groups when comparing Achilles tendon elastography scores as seen in figure 3 ($p>0.05$).

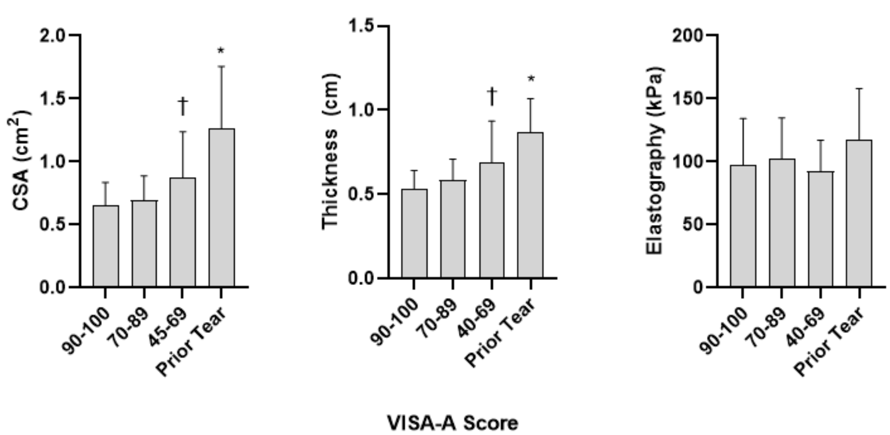

Figure 3. Participant Achilles tendon morphological properties by VISA-A score groups. * indicate statistically significant size difference from all other groups. † Indicates significant difference from group participants with a VISA-A score greater than 90.

Table 2. Effect size calculations comparing limited, severely limited and tear groups to the healthy group.

	CSA	Thickness	Elastography
Healthy	No Effect	No Effect	No Effect
Limited	0.17	0.35	0.22
Severely Limited	0.66	0.63	0.15
Tear	1.54	1.59	0.16

DISCUSSION

The aim of this study was to compare Achilles tendon morphological properties using VISA-A score groupings in physically active adults over age 50. The groups in our study displayed similar levels of physical activity based upon results from the IPAQ survey. Despite similar physical activity levels study participants with a previous Achilles tendon partial or complete Achilles tendon rupture displayed significantly larger Achilles tendon CSA and thickness when compared with all other groups. Additionally, participants who had VISA-A scores between 45 - 69 exhibited a significantly thicker Achilles tendon than participants with VISA-A scores greater than 90. No statistically significant Achilles tendon elastography differences were seen between any groups.

Study participants with a previous history of partial or complete Achilles tendon rupture displayed significantly larger Achilles tendon CSA and thickness from all other participants regardless of VISA-A score. Noted differences resulted in very large Cohen's D effect size differences. This study agrees with previous literature which has shown increased Achilles tendon CSA and thickness following Achilles tendon rupture (16, 29). However, this study is the first to show that morphological differences are still present 8-20 years following the complete or partial rupture. Achilles tendon CSA and thickness are a possible morphological measure to diagnose, track, and predict Achilles tendon health (13, 31). Increased Achilles tendon CSA has been hypothesized as one way to increase the safety margin of an Achilles tendon preventing Achilles tendon rupture (22). Achilles tendon CSA has been shown to be an important predictive measure of Achilles tendon health following surgery (35, 36). However, no study has indicated Achilles tendon CSA in the time frame seen in this study. Potentially the increased Achilles CSA seen in this study is a protective measure of the Achilles tendon to prevent further rupture even years following the injury. Further investigation concerning the breaking stress of the Achilles tendon following rupture are needed.

Individuals with a VISA-A score less than 69 displayed a significantly thicker Achilles tendon than individuals with a VISA-A score >90. These differences were of medium Cohen's D effect. Although no significant differences were noted between the >90 group, and the group with VISA-A scores from 70-89, there is a noticeable pattern of increasing tendon thickness and lower VISA-A scores. Although in an older population this study agrees with previous literature showing increased Achilles tendon thickness and corresponding lower VISA-A scores in young adults (7). Agreement between thickness measures and decreased VISA-A scores in this population and a younger population indicate thickness may be a sensitive indicator of Achilles tendon health for clinicians to use regardless of age.

Morphologic characteristics of an Achilles tendon are often used during diagnosis of Achilles tendinopathy and can be used to monitor recovery of the tendon and predict a patient's outcomes (14, 25). In particular heavy slow resistance training has a positive correlation between resolution of tendinopathic symptoms structural morphology of a tendon (14). This study contributes valuable information to the literature that Achilles tendon morphologic differences exist in physically active older adults with varying VISA-A scores. The highest VISA-A score group had the smallest tendon CSA and thickness. During rehabilitation Achilles tendon CSA or thickness may be monitored in conjunction with a VISA-A score as additional evidence of resolution of tendinopathy. Additional longitudinal research during rehabilitation could further document structural changes as VISA-A scores change.

Achilles tendon elastography changes throughout the healing process following an Achilles tendon rupture (18). Achilles tendon shear wave elastography has previously been shown to be highly reproducible, and display fair to excellent reliability (8, 32). Previous literature has shown that the Achilles tendon continues to increase stiffness following Achilles tendon rupture (18, 44). This study found that participants with a previous Achilles tendon rupture had no significant difference in elastography values as those with no history of rupture. Achilles tendon stiffness is a result of collagen cross linking (11). Frankewycz demonstrated that Achilles tendon stiffness reaches a high elastographic value 6-8 weeks following injury and that incremental increases in stiffness occur thereafter (18). This study contributes to the literature that in a long term follow up when compared with healthy individuals with no Achilles tendon rupture history, Achilles tendon elastography is not significantly different in those with a history of rupture.

This study found no statistically significant difference in Achilles tendon elastography between various VISA-A score groupings. Aubry et al. showed that shear wave elastography was highly specific for quantification of Achilles tendons who had previously been diagnosed with Achilles tendinopathy (1). Participants in Aubry's study were examined with the ankle in maximal plantarflexion, and with the ankle in a neutral position. The individuals with diagnosed Achilles tendinopathy displayed significant decreases in elastography values (1). This was the first investigation to our knowledge of Achilles tendon elastography differences based on VISA-A scores amongst physically active adults aged 50 and older. While VISA-A scores are a representation of Achilles tendon health, none of the participants in this study were diagnosed with Achilles tendinopathy. This could account for the Achilles tendon elastography differences between the Aubry (1) study and the current investigation. Each of the adults in this study were still actively participating in the Huntsman World Senior Games, and thus tendon tissue health may not have degenerated enough to display Achilles tendon elastography differences.

Achilles tendon CSA, thickness, and elastography were not different between men and women for any of the groups utilized in this study. Achilles tendon CSA and thickness differences between males and pre-menopausal females has previously been demonstrated (38, 43). Cycling of estrogen and progesterone, related to a females menstrual cycle, has been hypothesized as a likely contributor to a lack of Achilles tendon hypertrophy seen in these women despite high physical activity levels (4). Additional literature has supported this idea by finding hormone replacement therapy in post-menopausal women decreases tendon diameter in comparison with similarly aged women not on hormone replacement therapy (5). The average age of women in this study population is above the average age of menopause of 52 (6). Although this study did not aim to describe differences in Achilles tendon morphological properties amongst men and post-menopausal women, it adds additional evidence of the potential effect of estrogen and progesterone on Achilles tendon properties. Future studies may aim to understand the effects of estrogen and progesterone on tendon morphological properties. Knowledge of Achilles tendon baseline morphologic properties in this population is vital as diagnostic ultrasounds use continues to expand in evaluating Achilles tendon properties.

This study is limited in various ways. One limitation is ultrasound imaging variability. To attempt to limit this variability we assessed our reliability of the ultrasound measurements. Our measured reliability was excellent. Another limitation is potential confounding variables for Achilles tendon size. We chose in this study not to exclude individuals based upon current or past medical conditions. Medical treatments or conditions may impact Achilles tendon CSA, thickness, or elastography. For example as previously mentioned hormone replacement therapy may impact these characteristics. In this initial study we chose to have a larger population base.

An additional limitation is participant honesty during completion of the VISA-A and IPAQ surveys. In an attempt to eliminate confusion and ensure participants understood each questionnaire a research associate with knowledge of the questionnaires assisted participants. Participants were able to ask questions for further understanding.

In summary Achilles tendon morphological differences were exhibited in aging study participants who were physically active. Achilles tendons of individuals with a previous partial or complete Achilles tendon rupture had a significantly larger CSA and thickness. Individuals who had VISA-A scores less than 69 had significantly larger CSA and thicker tendons than their counterparts who scored higher than 90 on the VISA-A. These Achilles tendon morphological values may be used to help clinicians and researchers diagnose, and monitor tissue health in conjunction with additional assessments. Older men and women have comparable tendon morphologic tendon characteristics than has previously been published in younger men and women.

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