Sonoelastographic Assessment of the Gender Related Changes of Achilles the Tendon

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ABSTRACT

Objective: The objective of this study is to assess the gender related differences in the elasticity and thickness of the Achilles among healthy young participants.

Methods: Forty-eight volunteers, which were healthy adults between the ages of 20 and 25 years, included the study. Metabolic equivalents (MET) scores, tendon thickness and shear wave velocities (SWVs) were compared between males and females.

Results: The median age of males was 24.00 and of females was 23.00 years. The mean BMI score was 22.22±1.92 kg/m^2 among males, and 21.84±2.29 kg/m^2 among females. The median MET score of both males and females was 4.00. The median SWVs was found 4.76 m/s in males, and 4.77 m/s in females. There was no statistically significant difference in age, BMI, MET scores and SWV values between males and females (p=0.349, p=0.537, p=0.923 and p=0.578, respectively). The mean thickness of Achilles tendon was found statistically significantly higher in males than females (4.47±0.41 mm and 4.03±0.44 mm, respectively) (p=0.001).

Conclusion: The effect of gender on Achilles tendon elastic property is not a significant covariate in the young, healthy population. Muscle strength might play a more important role in Achilles tendon injury rather than tendon elasticity.

Keywords: Achilles elastography, gender

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INTRODUCTION

The Achilles tendon is the thickest and most robust tendon in the body. Additionally the Achilles tendon is also the tendon that ruptures most commonly. During a run, nearly 12.5 times body weight is loaded on the Achilles tendon, which explains the high rate of injury to the tendon (1, 2). Tendon injury may be linked to multifactorial factors, but frequently occurs due to excessive load on the tendon during activity. Both external (training conditions and equipment) and internal (anatomical conditions or systemic diseases) affecting factors have been described (3, 4).

One of the anatomical conditions is tendon elasticity. Elasticity of Achilles tendon arranges the elastic strain energy storage and release (5). As a result of this mechanism, the economy and performance of motion are ensured (5, 6). Previous studies show that tendon elasticity decreases with age (7, 8). A decrease of tendon elasticity is related to increased tendon injury (6, 9). Additionally it is known that tendon injury is higher in males compared to females (6, 10). It is also not clear whether tendon damage in males is due to differences in muscle strength or tendon elasticity.

Currently tendon elasticity can be measured ultrasonographically with different methods like “real time elastography and shear wave elastography”. Shear wave is a new elastography technique which does not require manual compression reducing dependence on the user and allowing quantitative evaluation. There are a number of studies which have shown that mechanical properties and metabolism in tendon are different in men and women. In these human studies variable methods such as the tendon biopsy investigation and ultrasonography (US) were used (6, 10-12). To the best of our knowledge, there is only two studies on elastography comparing the Achilles tendon elasticity according to sex in adults with a wide age range (8, 13).

In our study to examine the effect of gender on Achilles tendon elasticity, Achilles tendon was evaluated sonoelastographically in healthy individuals from 20-25 years of age with similar levels of physical activity.

METHODS

Setting and study population

This observational study was performed at the ultrasonography unit, which has been in service for 23 years, and serves approximately 25,000 patients annually, at the department of radiology at a university hospital. The study was approved by our institution's human research ethics committee. Informed consent was obtained from all individuals. The minimum required sample size found 42 (21 male, 21 female) for Student-t test and Mann-Whitney U test with a 0.05 of α error, a 0.80 of power (1-β error), and a 0.80 of effect size. Volunteers were recruited from the medical students as healthy adults between the ages of 20 and 25 years. The levels of physical activity were calculated with MET scores according to the American College of Sports Medicine (ASCM) (14). Individuals with chronic disease, trauma, previous orthopedic surgery, history of peripheral artery disease, body mass index (BMI) outside of normal limits (lower than 18.5kg/m2, greater than 24.9 kg/m2) and MET scores > 6 and < 3 were excluded from the study. A total of 48 volunteers (24 males, 24 females) was included in the study (Figure 1).

Ultrasound technique

All volunteers US examination were performed with a Siemens Acuson S3000 ultrasound system equipped with the Virtual Touch Tissue Imaging Quantification (VTIQ) software (Siemens Medical Solutions, Mountain View, CA, USA). Examinations were performed in a relaxed position of the right Achilles tendon while the volunteer was lying prone with his/her feet hanging freely down the side of the table (Figure 2). A 9 MHz transducer was equipped for B-mode ultrasound and elastography examinations. The probe was moved gently with no downward pressure and was held vertical to the tendon while performing the examination to avoid anisotropy. Achilles tendons were divided into three parts during examination; proximal third (musculotendinous junction), the middle third (2-6 cm above the insertion) and distal third

(15). The middle third of the Achilles tendon, which is a more hypo-vascular part of the tendon, was used for measurements (16, 17). To standardize shear wave velocities (SWVs) measurements, sites that were approximately 4 cm above the insertion on the calcaneus were selected as regions of interest (ROI) (Figure 3). Anterioposterior dimension of tendon in B-mode was measured as tendon thickness. The size of the VTIQ measuring box was adjusted to include the tendon and surrounding tissue. The size of ROI was 1.5x1.5 mm which is specified by the manufacturer. For each tendon, six ROI were identified and the mean shear wave velocities (SWVs) of ROI were taken. B mode estimations included tendon thickness, homogeneity and structural abnormalities. The size of the VTIQ measuring box and the location of ROIs were adjusted by consensus of two radiologists who had more than 5 years of experience.

Statistical Analysis

G*Power 3 (Erdfelder, Faul, & Buchner, 1996) was used for determining sample size (18). For the statistical analyses SPSS for Windows version 19 software package (SPSS Inc, Chicago, IL, USA) was used. Descriptive statistics of continuous variables are given with mean and standard deviation, or with median and interquartile range (IQR). Shapiro-Wilk test was used to test the normality of the data. The student t test was used for 2 group comparisons of normal distributed variables, and Mann Whitney U test was used for non-normal distributed variables**.**

RESULTS

Baseline characteristics and the B-mode findings of the volunteers were presented in Table 1. The median age of males was 24.00 years (IQR: 27.75-23.00) and of females was 23.00 years (IQR: 24.75-22.25). The mean BMI score was 22.22±1.92 kg/m^2 among males, and 21.84±2.29 kg/m^2 among females. The MET score of males was 4.00 (IQR: 5.00-3.25) and of females was also 4.00 (IQR: 5.00-3.25). There was no statistically significant difference in age, BMI and MET scores between males and females (p=0.349, p=0.537 and p=0.923, respectively) (Table 1).

On B-mode examination, the mean thickness of Achilles tendon was found statistically significantly higher in males than females (4.47±0.41 mm and 4.03±0.44 mm, respectively) (p=0.001). The median SWVs was found 4.76 m/s (IQR: 5.61-4.47) in males, and 4.77 m/s (IQR: 5.26-4.41) in females. The SWVs scores were found statistically similar between males and females (p=0.578) (Table 1).

DISCUSSION

Epidemiologic studies have shown that men have a higher risk than woman of getting lower limb tendon pathologies and Achilles tendon rupture (19, 20). Differences in muscle strength and sex hormone effects on tendon elasticity have both been shown the reason of gender differences in Achilles tendon pathology (6, 10, 21-24).

It is known that by the alteration of gene expression sex hormone effects on soft tissues (25, 26). Some studies have identified estrogen receptors in the tibial and flexor digitorum longus tendons (25). On the other hand, sex hormone receptor expression has not been directly studied in Achilles tendons and the effect of sex hormones on Achilles tendon is still controversial. Wojtys et al. showed that during the ovulatory phase when estrogen levels are most elevated the incidence of ACL rupture increases and also further they added that using oral contraceptives decreases the injury incidence peak observed during the ovulatory phase (27, 28). Additionally, another study by Lee et al. revealed evidence that estrogen reduced fibroblast synthesis (29). This may indirectly reduce collagen density in tissue and resistance to tissue injury. Despite the fact that tendons differ from ligaments in terminology, both of them have similar hierarchical structure and mechanical function. However, Burgess et al. reported that there is no difference in the mechanical properties of medial gastrocnemius and the patellar tendon with acute fluctuations in either progesterone or estrogen (30, 31). Likewise Bryant et al. showed that acute fluctuations in plasma estrogen during the menstrual period did not change the Achilles tendon strain management (32).

In our study, our results showed that with homogeneous age distribution and physical activity, the Achilles tendon elasticity of young volunteers did not vary linked to gender. This shows sex hormones effect on Achilles tendon elastic property is not a significant covariate in the young healthy population. The effect of external and internal risk factors on_muscle strength might play a more important role in tendon elasticity and biomechanics rather than hormonal effects. Further work to resolve tendon injury risk factors may provide greater insight into why these injuries occur less frequently in women.

Similar to our results, Muraoka et al. found that there is no gender related difference in the mechanical properties of the Achilles tendon (6). They indicated that the difference in Achilles tendon mechanical properties between men and women was correlated to the difference in muscle strength not to gender. Morrison et al. compared 10 male and 10 female cyclists which had overlapping ranges for mass and height, and they reported that Achilles tendon stiffness varies with muscle strength and not sex (24).

In a recent study primarily investigated the age related alterations in the Achilles tendon using sonoelastography, with a study group consisted of both women and men, it was found that there was a significant positive correlation between age and Achilles tendon thickness (7). However, the authors did not evaluate the association between sex and tendon thickness. Ruan et al. used the virtual tissue quantification (VTQ) sonoelastography technique to evaluate the gender and age related changes in the Achilles tendon (8). They reported that, there were significant differences between different age groups, but there were no significant differences between men and women in any age group. VTQ provides a single point SWV measurement, whereas VTIQ displays a color coded two dimensional SWV map, allowing measurement of SWV in multiple locations. VTQ is used with 5x5 mm ROI so that neighboring soft tissue enters the measurement field of the evaluated tendon. The entry into the measurement field of surrounding soft tissue causes serious variation in mean velocity values linked to tendon thickness. With the VTIQ method, a 1.5 x1.5 mm ROI is used, so optimal measurements can be made within the area of interest of the user. In a more recent study by Fu et al. with 326 healthy volunteers older than 18 years, Achilles tendon thickness was found positively correlated with age in men and women, and it was larger in men than in women in all age group (13). The authors also reported that, the SWV of the tendon in the sagittal section decreased slightly with age, but no significant differences between men and women in any group.

Kubo et al. studied the viscoelastic properties of the tendon of the medial gastrocnemius muscle among men and women, and they found that the maximum strain was significantly greater, the stiffness and Young’s modulus were significantly lower in women than in men (10). They conclude that there are gender differences in the viscoelastic properties of tendon structures which might explain performance differences between males and females. In a recent mice study, while the Achilles tendons were found 6% larger in male than in female mice, and the cell density of female mice was 19% greater than males, tendons have very similar mechanical properties and biochemical composition in male and females, with small increases in some ECM proteins and proteoglycans evident in female tendons (33).

This study has several limitations. It was a single-center, prospective analysis with a relatively small population. This may affect the external validity of the results. Instead of laboratory tests, oral interview was used to rule out concomitant diseases and metabolic disorders of volunteers. This method is a limited source of information in terms of diseases in which people have not yet been diagnosed or known. All elastography techniques including VTIQ are US-based techniques; hence they have the all limitations of US such as operator dependency. To avoid operator dependency, two radiologists, who are highly experienced in the field of musculoskletal imaging, performed the sonoelastography. Also the ultrasonographers were blinded to each other’s results. To assess the interobserver agreement, 20 randomly selected volunteers were re-examined, and it was found excellent with a K index of 0.90.

CONCLUSION

The effect of gender on Achilles tendon elastic property is not a significant covariate in the young, healthy population. Muscle strength might play a more important role in Achilles tendon injury rather than tendon elasticity. To investigate the gender effect on Achilles tendon stiffness by VTIQ further studies with larger sample sizes are needed.

ACKNOWLEDGEMENTS

Author Contributions

E Caglar conceived paper, oversaw data collection, conducted data analysis, wrote the manuscript and approved the final version. II Oz participated in study design, data analysis and interpretation, critically revised manuscript and approved the final version. The authors declare that they have no conflicts of interest.

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Table 1. Baseline characteristics and the B-mode findings of the participants.

	Male (n=24)	**Female (n=24)**	***p***
Age (years), median (IQR)	24.00 (27.75-23.00)	23.00 (24.75-22.25)	0.349*
BMI (kg/m2), mean±sd	22.22±1.92	21.84±2.29	0.537**
MET score, median (IQR)	4.00 (5.00-3.25)	4.00 (5.00-3.25)	0.923*
Tendon thickness (mm), mean±sd	4.47±0.41	4.03±0.44	0.001**
SWVs (m/s), median (IQR)	4.76 (5.61-4.47)	4.77 (5.26-4.41)	0.578*

* Mann-Whitney U test was used for comparison; ** Student-t test was used for comparison. sd=standard deviation; SWVs=Shear wave velocities; MET=Metabolic equivalents; BMI=Body mass index.

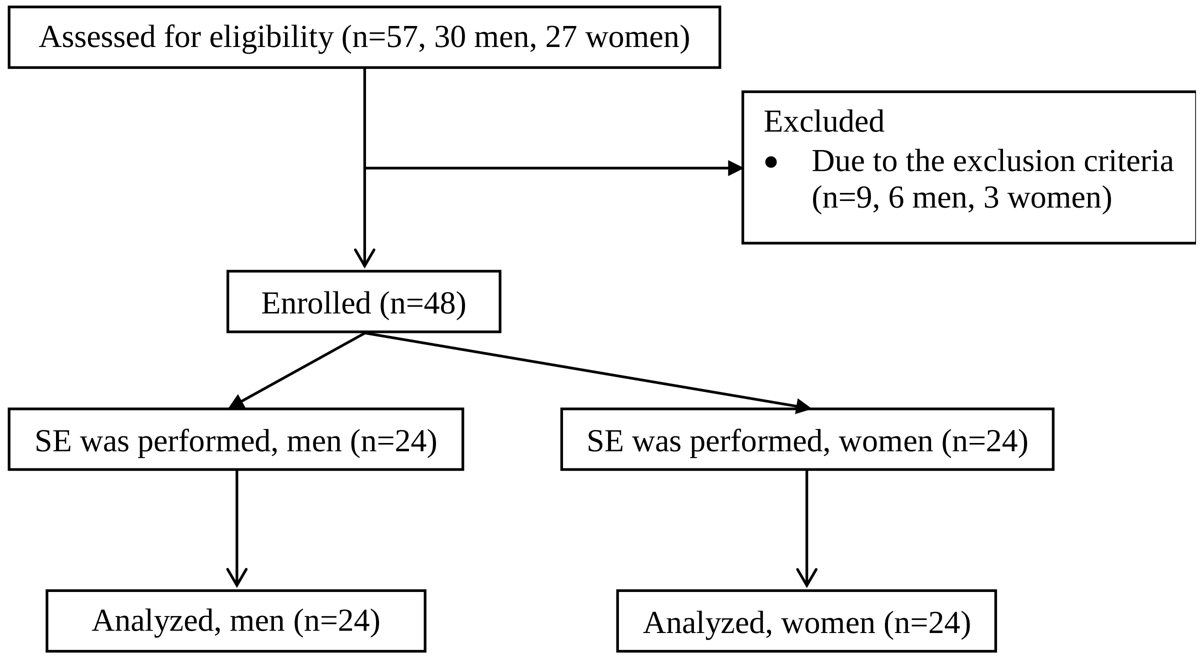

Fig. 1: Flow diagram of the study

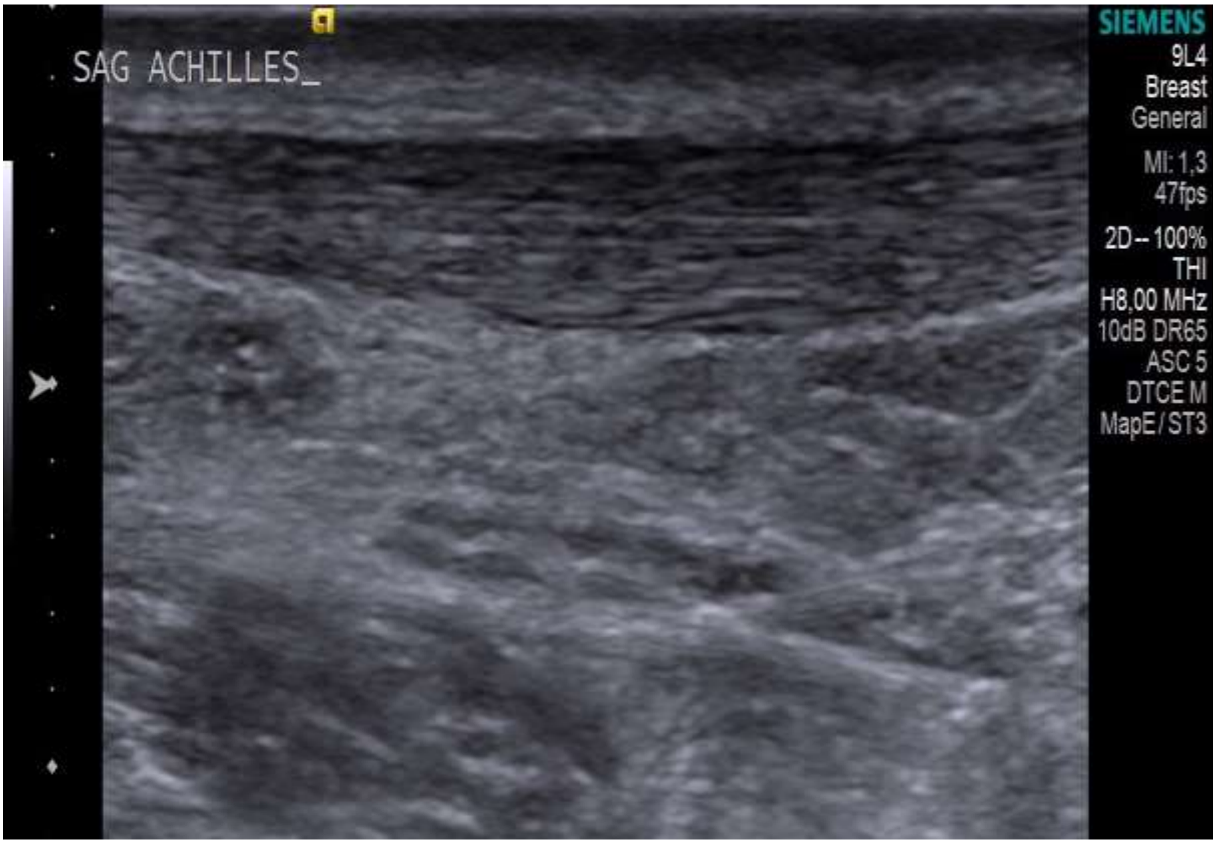

Fig. 2: B-mode imaging of the right Achilles tendon in a state of relaxation in a healthy 24 years-old men.

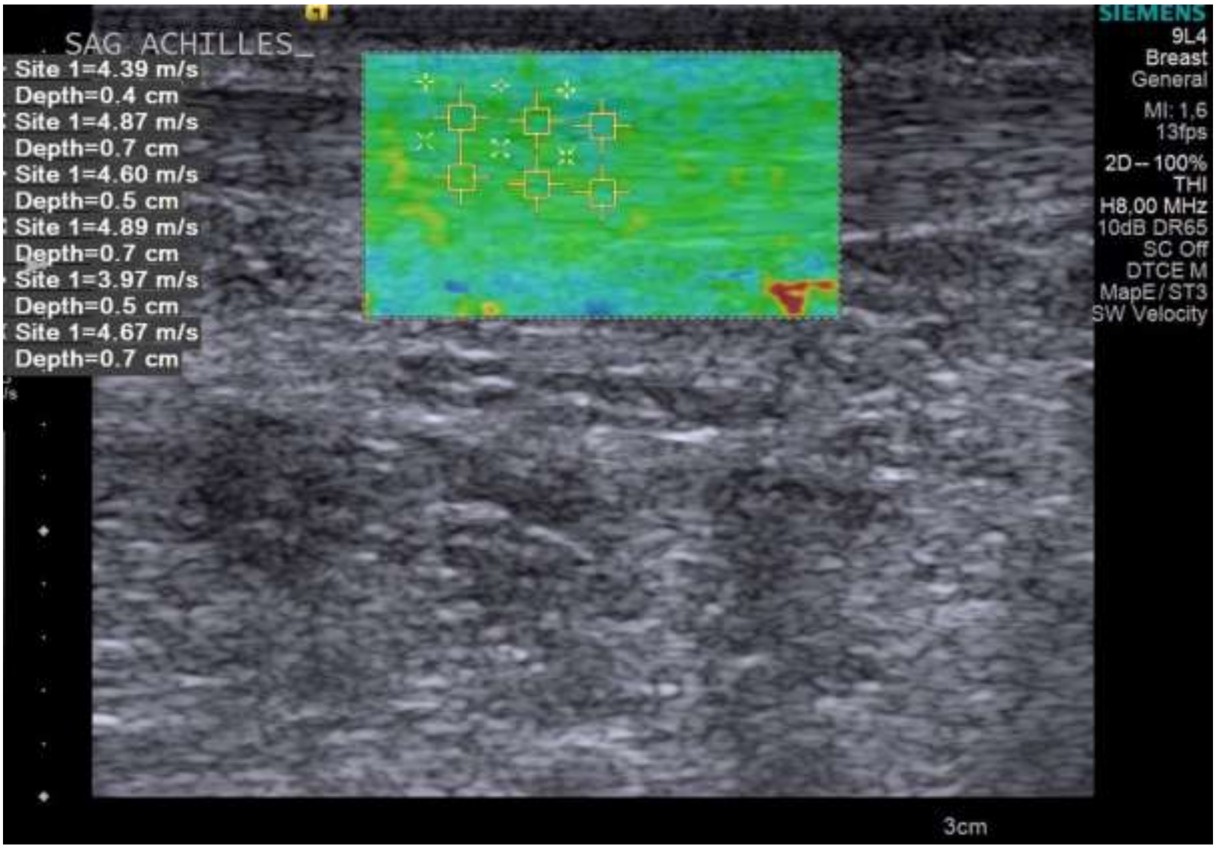

Fig. 3: The shear wave velocities (SWVs) measurement of the right Achilles tendon in a state of relaxation with VTIQ.