ORIGINAL ARTICLE

Achilles Tendon Measurements in Asymptomatic Saudi Adults Using High-frequency Ultrasound

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ABSTRACT

Objective: *To measure the Achilles tendon length, thickness and cross-sectional area in asymptomatic adult Saudi participants and to investigate the possible changes in these measurements based on their different ages and body height.*

Methods: *The prospective cohort study was done between January 2014 and March 2015. A total of 200 asymptomatic participants with 175 males (87.5%) and 25 females (12.5%) between the ages of 14 and 65 years, with the mean age of 25 ± 1.5 years, were scanned at two radiology departments. Ultrasound (US) scans for the Achilles tendons were performed using a Hitachi (EZU-MT30-S1 HI Vision Avius, Hitachi, Japan) US machine. Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA) was used to analyse the results.*

Results: *There was no significant difference in the length, cross-sectional area and thickness of the Achilles tendons among the participants of different ages; however, the cross-sectional area of Achilles tendons of the older participants (≥ 47 years) was higher than that of the participants of the younger age groups. Moreover, there was no correlation between the length, cross-sectional area, and thickness of the Achilles tendons and their body heights; however, the participants of ≥ 153 cm in height showed an increase in their Achilles tendon cross-sectional areas.*

Conclusion: *Ultrasound is a useful imaging tool in the assessment of the Achilles tendons. The normal variations of the tendon morphological characteristics should be considered in the clinical diagnosis. Additional studies on the correlations among the Achilles tendon length, thickness and cross-sectional areas of ethnicity of the participants in Saudi Arabia are suggested.*

Keywords: Achilles tendons, age ranges, body height, morphometry, prospective cohort study, ultrasound.

INTRODUCTION

Achilles tendons are the single, largest, thickest, strongest, greatest, and the more resistant tendons in the human body that transmit the force of powerful calf muscles to the feet, facilitating walking and running; however, they are also one of the most common sites of injuries (1–5). Achilles tendons have long been known as the sites that are susceptible to disabling injuries. Achilles tendon injuries are usually related to poor ankle flexibility and strength and to overuse. Elderly people are also subject to tendon rupture, which may be due to the degeneration of the tendon structures (6–8). In addition, chronic renal failure, rheumatoid arthritis and thyroid disorders may also be correlated with tendon degeneration and rupture (9–11). Forces up to 12 times the body weight may arise during sporting activities (12). Achilles tendon disorders

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are among the most frequent maladies encountered in sports medicine (13).

Until a few years ago, the radiological assessment of the tendons was essentially based on low kilovoltage radiography that provided very few information (14, 15). In the great majority of the cases, it can only indicate the site where there is an increase in the soft tissues, irregularities in the tendon contour or the presence of calcifications (16, 17). Radiography had been reported in the past to provide valuable information about diseased Achilles tendons, but is no longer considered to be the modality of choice for detecting tendon disorders (18).

Currently, magnetic resonance imaging (MRI) and ultrasound (US) are the modalities of choice that best reveal the abnormalities within the Achilles tendons (19–21). Magnetic resonance imaging can show the tendon pathology in detail (22). However, the therapeutic guidelines based on the MRI are missing, and their importance in clinical decision making has not been established (18). Lin *et al* (23) asserted that US generated a better spatial resolution than MRI, when the studies done with the most modern devices were compared. This was due to the fact that the tissues with few mobile protons emitted little or no signal; therefore, the tendon internal architecture was not well displayed by MRI (16). Ultrasound facilitated the study of tendons in a real-time dynamic mode (24, 25), whereas low cost, easy availability and the fact that, usually, during the examination, the comparison with the opposite side would be available were considered as the other US advantages (26, 27). Moreover, US is non-invasive and is easily available. It had been reported that US had high reliability in the measurements of the Achilles tendons (1).

It had been reported that the length of the Achilles tendons would be changed in patients with long-term diabetes mellitus or other diseases (8, 28, 29). Some previous studies found that the thickness of the Achilles tendons was correlated with the rupture and the abnormalities of the tendons, whereas the age-related changes in the thickness of the Achilles tendon were seldom reported (7, 30, 31). The measurement of the cross-sectional area had been used in the assessment of the Achilles tendons; however, the possible age-related changes in the cross-sectional area of the tendons had not been documented (1). It is necessary, therefore, to understand the thickness, cross-sectional area and the length of the normal Achilles tendons for accurate diagnosis.

This study was designed to evaluate the thickness, cross-sectional area and the length of the Achilles tendons using US in asymptomatic adult Saudi participants and to investigate the possible changes in these measurements based on their age and body heights. Furthermore, the information from this study will establish the normal Achilles tendon measurement referential values in the asymptomatic adult Saudi sample, which will provide a better understanding of the tendon morphological characteristics, which may help the sonologist in making a more accurate diagnosis.

MATERIALS AND METHODS

Selection and description of the participants

After receiving the approval from the local ethics committee, a total of 200 healthy participants with no history of Achilles tendon injuries or abnormalities were recruited between January 2014 and March 2015 in this prospective study. The male participants were scanned at the Radiology and Medical Imaging Department of Prince Sattam bin Abdulaziz University, Saudi Arabia, whereas the females were examined at the US Clinic of the University Hospital of Prince Sattam bin Abdulaziz. All the participants were provided written informed consents before their participation in accordance with the institutional guidelines.

The exclusion criteria were the participants who had been treated with corticosteroids because they had implications in the aetiology of the tendon rupture and could affect the size of the Achilles tendons (32, 33). Also, the participants with a history of inflammatory and metabolic diseases (*eg*, gout, rheumatoid arthritis, ankylosing spondylitis), which might affect the size of Achilles tendons (34). The sampled subjects were selected based on their Saudi nationality, area of location in Saudi Arabia, gender difference either males or females, ages and ethnicities.

Ultrasound equipment

Ultrasound examinations were conducted using two Hitachi (EZU-MT30-S1 HI Vision Avius, Hitachi, Japan) US units, equipped with a linear probe of a frequency 10 MHz (Figure). The printing facility was provided through the US digital graphic printer, 100 V, 1.5 A and 50/60 Hz, with the serial number of 3-619-GBI-01 and made by Sony Corporation, Japan.

Technique

In both areas of this study, the same sonologist conducted US scan for each participant to minimize the Achilles tendon measurement biases. The US scanning was done bilaterally on the right and the left Achilles tendons. The participants were lying in the prone position with their ankles extended beyond the examination bed. Each ankle was held at an angle of 90º, whereas the feet were rested against the wall to maintain a constant angle. This position was chosen to facilitate the contact between the probe and the tendons and to avoid the anisotropy effect which could occur if the tendons were not taut (35).

The distances were measured by built-in calipers at the level where the tendons separates from the calcanei (36). The length of the Achilles tendons was measured with the extended field-of-view sonography in the longitudinal planes from the calcaneal tendon insertion to the calf tendon–muscle interface. The thickness and cross-sectional area of the tendons were measured at the level of the medial malleolus for the standardization of the measurements (1).

Figure: Hitachi (EZU-MT30-SI HI Vision Avius, Hitachi, Japan) US units equipped with a linear probe of a frequency 10 MHz.

The thickness of the Achilles tendons was measured by the maximum anteroposterior diameter of the Achilles tendons, whereas the cross-sectional area of the tendons was measured by using the continuous trace method to outline the boundaries of the tendons. The body heights of the participants were also measured, using a plastic tape meter to measure the lengths.

Statistics

The data were initially summarized as means ± standard deviation (SD) in the form of tables and graphs. The statistical analyses were done using standard Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL, USA) version 15 for Windows. The *t*-test was applied for the comparison between the Achilles tendon measurements and the participants' ages, ethnicities and heights. The p-value ≤ 0.05 was considered to be significant.

RESULTS

The study's sample comprised 200 healthy participants with 175 males (87.5%) and 25 females (12.5%). Their ages ranged from 18 to 65 years, with a mean age and SD of 21 ± 1.5 years. The participants were divided into five ethnic groups: n = 100 (50%), n = 40 (20%), n = 17 (8.5%), n = 32 (16%), and n = 11 (5.5%) from the Centre, North, South, West, East of Saudi Arabia, respectively.

The participants were classified into five age groups: 14–24 years, 25–35 years, 36–46 years, 47–57 years, and 58–68 years. Among the sample of the study, 120 participants were in the age group 14–24 years, representing 60% of the sample. The age group of 58–68 years or older was the smallest (1.5%) of the sample (Table 1). The highest mean ± SD of the Achilles tendon length was 12.3 ± 1.8 cm found in the age group 14–24 years, whereas the lowest mean ± SD of the Achilles tendon length was 11.1 ± 1.9 cm found in the age group 25–35 years (Table 1). The results showed that there were no significant difference in the length of the Achilles tendons between the participants of the different age groups ($p > 0.05$), where $p \leq 0.05$ for the results was considered to be significant (Table 1).

Table 1: Achilles tendon mean length ± SD (cm) in participants of different age groups

Age ranges (years)	n; %	Mean age ± SD (years)	Achilles tendons; mean length ± SD (cm)	*p*-value
14–24	120; 60%	21 ± 1.2	12.3 ± 1.8	> 0.05
25–35	58; 29%	32 ± 1.8	11.1 ± 1.9	> 0.05
36–46	15; 7.5%	40 ± 1.9	11.8 ± 2.7	> 0.05
47–57	4; 2%	48 ± 1.3	12.1 ± 2.1	> 0.05
58–68	3; 1.5%	62 ± 1.7	11.9 ± 1.9	> 0.05

The results showed that there were no significant differences in the thickness of the Achilles tendons between the participants of the different age groups ($p > 0.05$) (Table 2). The highest mean ± SD of the Achilles tendon thickness was 5.5 ± 0.9 cm found in the age group 25–35 years, whereas the lowest mean ± SD of the Achilles tendon thickness was 4.9 ± 1.7 cm found in the age group 47–57 years (Table 2).

In all the Achilles tendons examined, the highest mean ± SD of the Achilles tendon cross-sectional area was 8.6 ± 1.5 cm^2 found in the age group 58–68 years, whereas the lowest mean ± SD of the Achilles tendon cross-sectional area was 5.4 ± 1.7 cm^2 found in the age group 25–35 years (Table 3). The cross-sectional area of the Achilles tendons of the participants 47 years or older was higher than that of the participants in the other age groups (Table 3).

Table 2: Achilles tendon mean thickness ± SD (cm) in participants of different age groups

Age ranges (years)	n; %	Mean age ± SD (years)	Achilles tendons; mean thickness ± SD (cm)	*p*-value
14–24	120; 60%	21 ± 1.2	5.1 ± 1.7	> 0.05
25–35	58; 29%	32 ± 1.8	5.5 ± 0.9	> 0.05
36–46	15; 7.5%	40 ± 1.9	5.1 ± 1.5	> 0.05
47–57	4; 2%	48 ± 1.3	4.9 ± 1.7	> 0.05
58–68	3; 1.5%	62 ± 1.7	5.2 ± 0.8	> 0.05

Table 3: Achilles tendon mean cross-sectional area ± SD (cm^2) in participants of different age groups

Age ranges (years)	n; %	Mean age ± SD (years)	Achilles tendons; mean cross-sectional area ± SD (cm^2)	*p*-value
14–24	120; 60%	21 ± 1.2	5.7 ± 1.2	> 0.05
25–35	58; 29%	32 ± 1.8	5.4 ± 1.2	> 0.05
36–46	15; 7.5%	40 ± 1.9	5.8 ± 1.5	> 0.05
47–57	4; 2%	48 ± 1.3	7.9 ± 1.8	> 0.05
58–68	3; 1.5%	62 ± 1.7	8.6 ± 1.5	> 0.05

The highest mean ± SD of the participants' height was 173 ± 0.9 cm found in 19% of the participants, whereas the lowest mean ± SD of their height was 128 ± 1.5 cm found in 1% of the participants (Table 4). There were no significant differences among the participants' height and the length of their Achilles tendons ($p > 0.05$ and $p < 0.05$), where $p \geq 0.05$ for the results was considered to be significant (Table 4).

Table 4: Achilles tendon mean length ± SD (cm) in participants of different heights (cm)

Height ranges (cm)	n; %	Mean height ± SD (cm)	Achilles tendons; mean length ± SD (cm)	*p*-value
120–130	2; 1%	128 ± 1.5	12.3 ± 1.8	> 0.05
131–141	9; 4.5%	137 ± 1.8	11.1 ± 1.9	> 0.05
142–152	21; 10.5%	150 ± 1.7	11.8 ± 2.7	> 0.05
153–163	130; 65%	157 ± 1.8	12.1 ± 2.1	> 0.05
164–174	38; 19%	173 ± 0.9	11.9 ± 1.9	> 0.05

The results displayed in Table 5 suggest that there were no significant relationships between the participants' heights and their Achilles tendon mean thickness ($p > 0.05$). The same findings are confirmed in Table 6 between the participants' heights and their Achilles tendon cross-sectional areas ($p > 0.05$ and $p > 0.05$).

Table 5: Achilles tendon mean thickness ± SD (cm) in participants of different heights (cm)

Height ranges (cm)	n; %	Mean height ± SD (cm)	Achilles tendons; mean thickness ± SD (cm)	*p*-value
120–130	2; 1%	128 ± 1.5	5.1 ± 1.7	> 0.05
131–141	9; 4.5%	137 ± 1.8	5.5 ± 0.9	> 0.05
142–152	21; 10.5%	150 ± 1.7	5.1 ± 1.5	> 0.05
153–163	130; 65%	157 ± 1.8	4.9 ± 1.7	> 0.05
164–174	38; 19%	173 ± 0.9	5.2 ± 0.8	> 0.05

Table 6: Achilles tendon mean cross-sectional area ± SD (cm^2) in participants of different heights (cm)

Height ranges (cm)	n; %	Mean height ± SD (cm)	Achilles tendons; mean cross-sectional area ± SD (cm^2)	*p*-value
120–130	2; 1%	128 ± 1.5	5.7 ± 1.2	> 0.05
131–141	9; 4.5%	137 ± 1.8	5.4 ± 1.2	> 0.05
142–152	21; 10.5%	150 ± 1.7	5.8 ± 1.5	> 0.05
153–163	130; 65%	157 ± 1.8	7.9 ± 1.8	> 0.05
164–174	38; 19%	173 ± 0.9	8.6 ± 1.5	> 0.05

DISCUSSION

High-resolution US has been shown to be a non-invasive, simple and easy method with its lower cost and greater availability in the assessment of the morphometry of the Achilles tendons (1, 5). However, to establish its usefulness as a tool of measurement, it is important to have the baseline information of the tendons.

The findings of this study (Table 1) revealed that age was not a factor in the variation of the Achilles tendon among the participants of the different age groups ($p < 0.05$). Therefore, age was not a factor in the variation of the Achilles tendon length. Pang and Ying confirmed the findings that there was no significant difference in the length of the Achilles tendons between the subjects of the different age groups ($p > 0.05$) or between the dominant and nondominant ankles ($p > 0.05$) (37). Also, it had been reported that ankle equinus is a common foot deformity associated with the shortening of the Achilles tendons due to different diseases such as Achilles tendonitis and diabetes mellitus (38, 39). This study provided the baseline information about the length of the Achilles tendons for sonographic examinations, and substantial shortening of the tendon abnormalities.

The results in Table 2 also show that there is a significant difference in the thickness of Achilles tendons between participants of different ages ($p > 0.05$); however, the cross-sectional area of the Achilles tendons of the participants 47 years or older was higher than that of the participants of the younger age groups (Table 3). Many recent studies had reported that advancing age is associated with the degeneration of the Achilles tendon structures (1, 3, 6, 40). Strocchi *et al* reported that in advancing age groups, the Achilles tendons tend to have a decrease in the density and the size of collagen fibrils but there is an increase in the fibril concentration of the tendons (41). Gibbon *et al* demonstrated that such reduction of the collagen fibril density and size might cause the tendons to have a lower mechanical strength, and with this change, the tendons were more likely to have repetitive microtears and microtrauma. The tendons are constantly remodelling themselves by a repetitive process of minor injuries and repairs, resulting in tendon hypertrophy (42); thus, the cross-sectional area of the Achilles tendons in the older subjects was relatively greater as compared to the younger age groups' tenons. In addition, the difference in tendon thickness among the different age groups was not statistically significant. These might be due to the fact that tendon hypertrophy caused the enlargement of the whole tendon, and there was relatively only a small increase in the tendon thickness, which might not be statistically significant (42).

Pang and Ying (37) confirmed that there was no significant correlation between the body height and Achilles tendon length ($r = 0.26$; $p < 0.05$), whereas similar results showed that there was no significant difference between the participants' height and the length of the Achilles tendons ($p = 0.0002$ and $p < 0.05$), where $p \geq 0.05$ for the results was considered to be significant (Table 4). In contrast to this result, Rosso *et al* found a highly significant correlation ($r = 0.62$) between body height and Achilles tendon length in a study done on the physiological relationship between the Achilles tendon length and tibia length (43).

It had been previously shown that the width, but not the cross-sectional area, of the Achilles tendon was greater in the elderly (> 70 years) endurance and power sport athletes compared with that of the age-matched controls (24). Furthermore, it was recently shown that endurance-trained young subjects had a greater Achilles tendon cross-sectional area than that of the untrained subjects (44). Increased tendon cross-sectional area in response to physical activity is in accordance with the metabolic studies of the human peritendinous tissue, in vivo (45, 46). Together, these studies suggested that physical activity likely resulted in a net collagen synthesis. The participants in the present study were sedentary, and our findings (Table 5) showed that there was no significant relation noted between the participants' height and their Achilles tendon mean thickness ($p = 0.0002$ and $p < 0.05$). The same findings were confirmed between the participants' height and Achilles tendon cross-sectional area ($p = 0.05$ and $p < 0.05$) where no significant correlation was noted, although there was an increase in the Achilles tendon cross-sectional area in the participants whose heights were 153 cm and more (Table 6).

A limitation of this study, however, was the small sample size (n = 200). Further studies with larger sample sizes are suggested for more accurate results. Another limitation of this study was that the Achilles tendon length was defined as the distance between the proximal defined point and the distal insertion without taking the three dimensionalities of the tendon into account. The tendon could travel in an oblique way through this field of interest making the Achilles tendon slightly longer.

In conclusion, sonography is a useful imaging tool in the assessment of Achilles tendons. The normal variations of the tendon morphological characteristics should be considered in the clinical diagnosis. There was no significant difference in the length, cross-sectional area and thickness of Achilles tendons between the participants of different ages; however, the cross-sectional area of the Achilles tendons of the older participants (≥ 47 years) was higher than that of the participants of the younger age groups. Moreover, there was no correlation between the length, cross sectional-area, and thickness of the Achilles tendons and the body height; however, the participants of ≥ 153 cm in height had an increase in the Achilles tendon cross-sectional area. Additional studies on the correlations among the Achilles tendon length, thickness and the tendon cross-sectional area of participants in Saudi Arabia are suggested.

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