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Influence of BMI on Elastographic Strain Ratios of Achilles Tendon

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ABSTRACT

The Achilles tendon have two major problems due to injury; one being a chronic injury called Achilles tendinopathy and the second being acute injury which are more commonly known as Achilles tendon rupture. Changes in stiffness of Achilles tendon is alarming and can cause deleterious effects on quality of life in an individual. Achilles tendon is reported to be affected significantly due to the weight of an individual. The effect of Body Mass Index (BMI) on stiffness of Achilles tendon was evaluated in the current study. Elastography was performed on individuals ranging from 19 to 23 years for detecting the stiffness of the Achilles tendon. Individuals were grouped according to their BMI in 3 categories (underweight, normal and overweight) and their strain ratios were measured. The strain ratio results for all volunteers were ranging from 1.03 to 6 (1.03 for underweight and 6 for overweight). Difference in weight of individuals effect the Achilles tendon stiffness. The overweight individuals had the highest stiffness while the underweight individuals had the lowest. It is concluded that higher stiffness may likely lead to Achilles tendon injury.

Keywords: Elastography, Body Mass Index, Ultrasound, Achilles tendon, stiffness.

1 Introduction

The Achilles tendon joins two heads of the gastrocnemius muscle with soleus muscle. In the human body Achilles tendon is the strongest and the largest tendon. It bears forces up to 12.5 times of the actual weight of the body while sprinting [1]. Because the size of Achilles tendon and its demand it is injured easily [2].

Achilles tendon is a tough band tissue that connect the muscle with bone, it is the largest tendon in human body, it supports the activity of human body like walking, running and jumping [3].

Achilles tendon can get injured and the most common problem in Achilles tendon due to stiffness is Achilles tendinitis [4]. Overweight/ Obese people (high BMI, more then 25) are more prone to get Achilles tendonitis[5, 6].

Achilles tendinitis is Inflammation of the Achilles tendon [7]. During Achilles tendinitis the tendon tends to be stiffer than normal that decreases the movement and increases the pain [4].

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Achilles tendinitis occurs due to increase in physical activity, like walking extensively or running for a long time. Another reason for Achilles tendinosis is increased activity levels after a long periods or intervals of inactivity. Furthermore, weakness in the calf muscle is also related to Achilles tendinosis. Bearing significantly higher weight than normal also gives rise to Achilles tendinitis [8].

Prior to the use of ultrasound to determine stiffness in Achilles tendon, palpation was widely adopted. Palpation is the process of examining the features physically. However, this greatly depends upon the experience of the observer and it had various limitations like repeatability and reproducibility of the results. It's limited to accessible organ and not accurate.

Various studies have shown successful use of ultrasound for the detection of Achilles Tendinosis. However, ultrasound diagnosis for Achilles tendinosis has demonstrated some limitations in terms of determining the stiffness of the tendon.

Elastography is new technique that detects Achilles tendon; it's an enhanced form of ultrasound. It's better than palpation and ultrasound because it detect mechanical properties like stiffness/strain ratio. The Ultrasound Elastography has various types; most commonly used technique are Strain Elastography (SE) and Shear Wave Elasticity Imaging (SWEI) [9].

This study aims to determine the effect of Body Mass Index (BMI) on stiffness of Achilles tendon among young Saudi population. Furthermore, the objective of this study is to provide first-hand information to the clinicians on current health status of young Saudi population.

2 Materials and Methods

Fifteen healthy individuals were invited and divided into 3 groups with reference to BMI (underweight, normal weight and overweight).The BMI of each individual was calculated using formula stated in equation 1.

$$BMI = \frac{Weight}{Height^2} \tag{1}$$

- Where:
  a. Weight is in Kg
  b. height is in meters

All the volunteers were divided according to their BMI in 3 groups as mentioned earlier. All volunteers had sedentary life style. Average age for the volunteers was 21.8 years while they ranged from 19 to 23 years. Average weight for the volunteers was 74.5 Kg, while minimum weight was 42.8 Kg and maximum weight was recorded to be 140.9 Kg. Volunteers had an average height of 1.729m while their height varied from 1.64 to 1.84 m.

In order to determine the proximal and distal ends of the Achilles tendon, B-Mode ultrasound examination was performed at a gain of 50% and a frequency of 10 MHz with a linear probe (L14-5/38) on only right leg of individuals in prone position via SonixTouch Q+ from BK Ultrasound, Analogic Corporation, 8 Centennial Drive, Peabody, MA, USA. Throughout the examination the right leg of the individuals was left hanging from the distal edge of the examination couch as shown in figure 1.

Figure 1. Examination of central part of Achilles tendon as marked by the box. The green line shows the length of Achilles tendon determined via B-mode ultrasound.

After determining the length of Achilles tendon a marker was used to mark the length of Achilles tendon and calculate the central region. Elastography was performed in the central region only with linear probe in longitudinal direction.

From a cine loop of 99 images, 5 best images were selected that were in range of strain sensor. Out of the 5 images selected, 3 random region of interest (ROI) were selected from Achilles tendon and surrounding tissue respectively to determine the strain ratios.

The current study was conducted at department of biomedical technology, college of applied medical sciences, King Saud University. All the examination was performed at room temperature. Previously described protocol for Achilles tendon ultrasound was used [10] and all parameters of the ultrasound elastography machine were kept constant throughout the study.

2.1 Elastographic Strain ratio

After examining the B-mode image, elastographic mode was selected to measure the strain ratios of the tumor. To determine strain ratios at 3 different locations; one area within the tumor while other area outside the tumor but within the thyroid gland was selected as shown in figure 2.

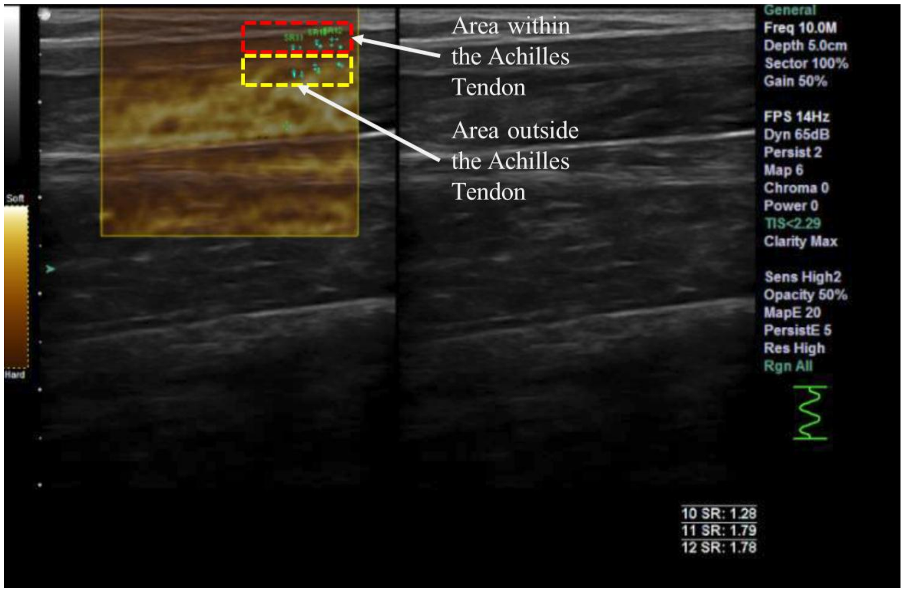

Figure 2. Elastographic and B-mode image for Achilles tendon. Red and Yellow dashed box indicated random location selected to determine strain ratio.

3 Results

The BMI results of the underweight volunteers were observed to be from 15.53 to 18.36, with an average BMI of 17.18 ± 1.21. Volunteers with normal BMI initiated with a BMI of 18.96 until 23.88, while the average recorded was 21.232 ± 1.74. Overweight volunteers demonstrated highest BMI ranging from 26.65 to 44.47, while their average was 35.836 with standard deviation of 7.68.

Length of Achilles tendon did not played any role in the stiffness as it can be observed from table 4.1. No significant difference was observed among the length of Achilles tendon between the groups.

Table 1. Length of Achilles tendon among different groups

Length	Lowest Reading	Highest Reading	Average ± STD DEV
Underweight	21	25	**22.5**
Normal weight	21	24	**22.1**
Overweight	20.5	26	**22.7**

The Strain Ratio results (figure 1) of the Underweight Volunteers demonstrated lowest values among all the group ranging from 1.03 to 2.52, with an Average of 1.627 having standard Deviation of 0.069. Normal weight volunteers had strain ratios of 1.65 to 4.12, with average of 2.617 and a standard deviation of 0.133. Moreover, overweight volunteers had the highest strain ratios, with a minimum of 2.31 while going up to 6, the average strain ratio in this category was recorded to be 4.294 with a standard deviation of 1.125. Significant differences can be observed between all the groups.

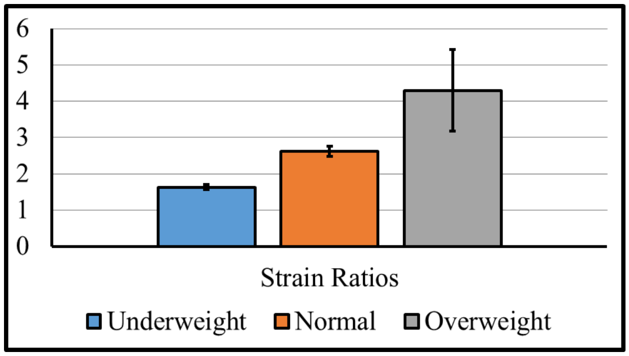

Figure 3 Strain ratios of Achilles tendon among different groups.

Elastographic images for different BMI group demonstrates that in case of underweight volunteer the Achilles tendon have bright color and the strain ratio have a low reading that's mean Achilles tendon not very stiff.

As shown in Figure 3, the Achilles tendon surrounding by muscle and skin, the Achilles tendon has unidirectional muscle fibers, while surrounding muscle has randomly arranged fibers.

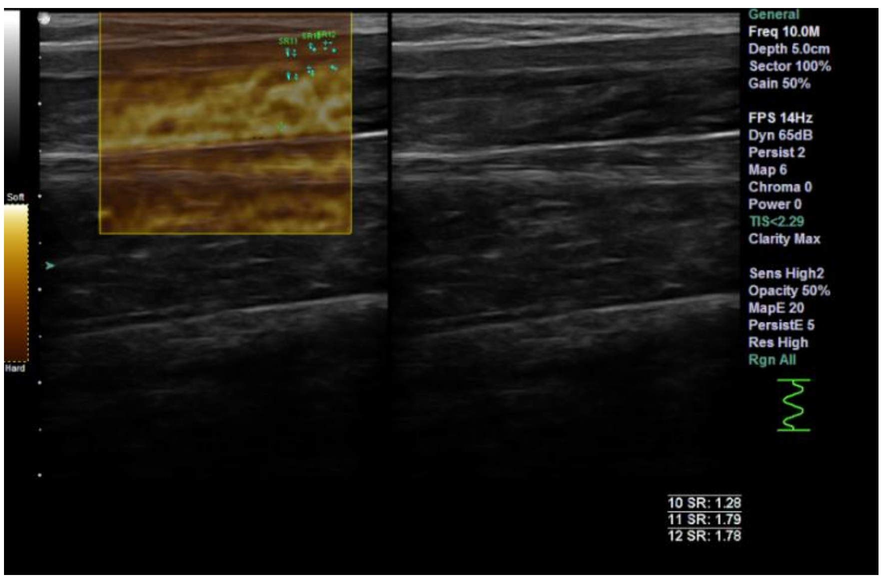

Figure 4 Elastographic and B-mode image for Achilles tendon of underweight individual.

Figure 4 shows Achilles tendon of volunteers having normal weight. It was observed that B-mode ultrasound image for Achilles tendon is not very bright color and the strain ratio have a normal reading that's mean Achilles tendon stiffer when compared to their underweight counterparts.

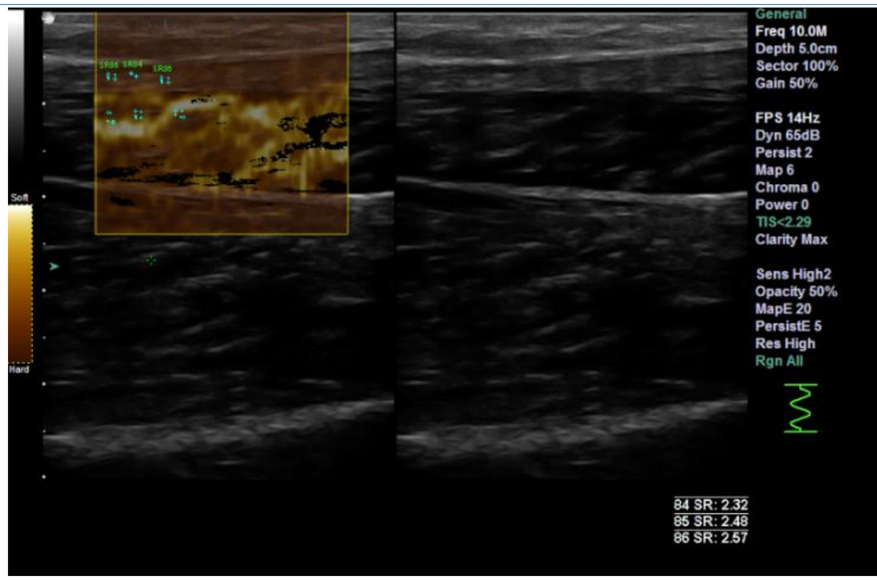

Figure 5 Elastographic and B-mode image for Achilles tendon of normal weight individual.

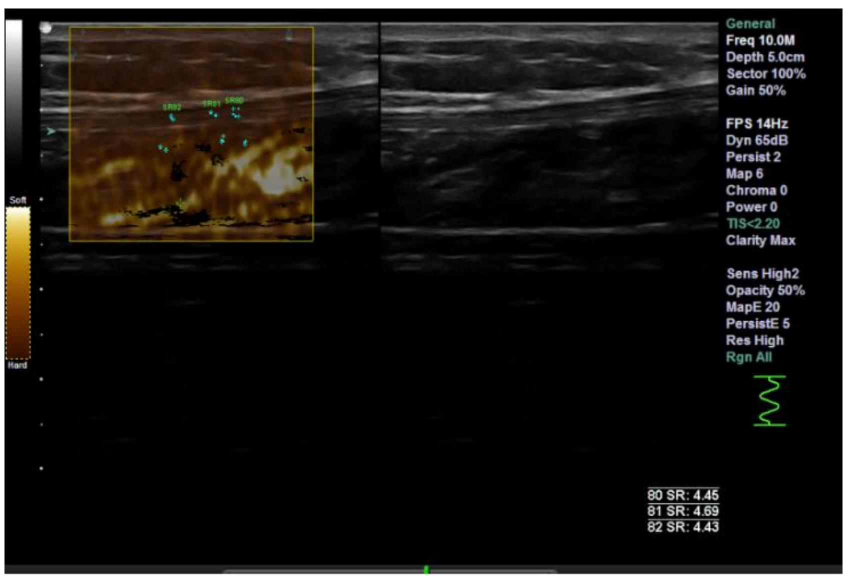

Figure 6 Elastographic and B-mode image for Achilles tendon of overweight individual.

For overweight volunteer B-mode image in figure 6 displays the Achilles tendon to have very dark grey scale and the strain ratio have a high reading meaning that stiffness of Achilles tendon is significantly different than its surrounding tissue.

4 Discussion

It was observed that strain ratios were directly proportional to the BMI of an individual, irrespective of their Achilles tendon length.

Other researchers have reported that elastography compares well with ultrasound for Achilles tendon. They found that Achilles tendon among normal individuals is hard when compared to surrounding tissues [11]. Similar results were observed in our study, where all the volunteers demonstrated their Achilles tendon to be stiffer than surrounding tissue irrespective of their BMI.

Elastographic images for different BMI groups demonstrated a clear visual difference among the Achilles tendon. The Achilles tendon for underweight individuals was much clear when compared to normal and overweigh individuals. Furthermore, it was observed through the elastographic images that the individuals that fall in the category of overweight had a significantly higher amount of fat deposition around the Achilles tendon.

Moreover, Elastographic pattern for images with respect to BMI demonstrated that higher the BMI the greater is the tissue stiffness variation between Achilles tendon and surrounding tissue.

5 Conclusion

It was concluded that difference in weight (refer to BMI) effect the Achilles tendon stiffness, the overweight people (refer to BMI) they have highest stiffness, when compared to the normal weight and for underweight people. The stiffness in Achilles is likely to increase the possibility of Achilles tendon injury. Young people must be advised to perform regular exercise to maintain a balance in their BMI. Moreover, further studies are required to ascertain the findings.

Current study only comprise of male volunteers who had sedentary activity throughout the day. Results presented in this report are for an age group of 19 to 23.

It is recommended that future studies must also be carried on females and on a larger population with diverse ages. Secondly, strain ratios must be obtained at different settings of the ultrasound machine to make sure the repeatability of results. We suggest that in future the research should be directed towards comparison of strain elastography with other types of elastography techniques in order to ascertain the repeatability of results from different techniques.

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