

# MORPHOMETRIC ANALYSIS OF TENDOACHILLES TENDON WITH ITS CLINICAL IMPLICATIONS

Manju Singhal <sup>\*1</sup>, Nisha Parmar <sup>2</sup>, Deepak Singhal <sup>3</sup>.

<sup>\*1</sup> Associate professor, Department of Anatomy, Surat Municipal Institute of Medical Education and Research (SMIMER), Surat, Gujarat, India.

<sup>2</sup> Tutor, Department of Anatomy, Surat Municipal Institute of Medical Education and Research (SMIMER), Surat, Gujarat, India.

<sup>3</sup> Tutor, Department of FMT, Surat Municipal Institute of Medical Education and Research (SMIMER), Surat, Gujarat, India.

## ABSTRACT

**Background:** Tendoachilles tendon, the strongest and thickest tendon of the body, is formed by tendons of soleus and gastrocnemius begins near the middle of the back of leg and is inserted to the midpoint of the posterior surface of the calcaneum. Normal morphometric measurements of Achilles tendon serve as an important landmark in its anthropometric evaluation and biomechanical attribute. The morphological changes in the tendon size provide important health information for the management of various clinical conditions related to Achilles tendons like simple tendinopathy or acute ruptures of it etc.

**Aim:** The current study aimed at finding out the detailed morphometric measurements of the Achilles tendon which can be of substantial use to clinicians for determining any pathological conditions associated with tendoachilles.

**Materials and Methods:** Total 108 lower limbs from 54 donated embalmed cadavers (31 males & 23 females) of age between 55 to 85 years were procured for dissection. The study was carried out in the department of Anatomy SMIMER Surat.



**Results:** Present cadaveric study found that the length of tendoachilles was significantly high in male than in female and no statistically significant difference in length of tendoachilles between right and left side were noted. The width of the tendoachilles at origin between the right and left side tendons was statistically significant.

**Discussion:** We found that the length of Tendoachilles was significantly high in male than in female and also width of the tendoachilles at origin was more on right side. Being a frequent site for rupture, degenerative change and inflammation, knowledge pertaining to normal morphometric measurements of Achilles tendon is imperative before determining any pathological variations associated with the tendon and opens the management options to orthopedic surgeons, podiatrist, sports physicians and physiotherapists.

**KEY WORDS:** Tendoachilles tendon, Tendocalcaneus, Morphometric analysis, Tendinopathy.

**Address for Correspondence:** Dr. Manju Singhal, MBBS, MD (Anatomy), 48, Sumangal Prabhat society, opposite Kapadia health club, Bhatar Road, Surat-395001, Gujarat, India.

Mobile: 9427544466 E-Mail: [manjudeepaksinghal@gmail.com](mailto:manjudeepaksinghal@gmail.com)

Access this Article online	Journal Information
<b>Quick Response code</b>  DOI: 10.16965/ijar.2019.165	<b>International Journal of Anatomy and Research</b> ICV for 2016 90.30 ISSN (E) 2321-4287   ISSN (P) 2321-8967 <a href="https://www.ijmhr.org/ijar.htm">https://www.ijmhr.org/ijar.htm</a> DOI-Prefix: <a href="https://dx.doi.org/10.16965/ijar">https://dx.doi.org/10.16965/ijar</a> 
Article Information	
Received: 05 Mar 2019 Peer Review: 06 Mar 2019 Revised: None	Accepted: 07 Apr 2019 Published (O): 05 May 2019 Published (P): 05 May 2019

## INTRODUCTION

The Achilles tendon, named after the seemingly

indestructible mythological Greek warrior. The Achilles tendon is the strongest and thickest and

more resistant tendon of the human body. It is also one of the most common sites of overuse injuries among athletes [1]. This tendon in the body begins near the middle of the back of leg and made up of the tendons of the soleus and two heads of the gastrocnemius muscles and is attached to the midpoint of the posterior surface of the calcaneum [2].

The Achilles is directly related to the upright stance and bipedal locomotion of the human providing unique characteristic features to the human[3]. The Achilles with its muscles soleus and two heads of the gastrocnemius and other antigravity muscles of lower limb are much better developed in bipeds in comparison to quadrupeds helping them to lift the whole body up during attaining the erect posture and also in walking up a staircase [4]. The Achilles tendon has been a key player in natural selection process. It was absent from Australopithecus and originated in hominids since more than three million years ago [5].

During development of limbs, rotation of the limb bud occurs i.e. Achilles tendon is twisted and therefore the fibers from the gastrocnemius get arranged on lateral side and those from the soleus get arranged on medial side and are inserted accordingly on calcaneum [ 6, 7]. Part of the Tendo-achilles which is derived from gastrocnemius can be twisted variably relative to soleus because gastrocnemius crosses the knee joint. Because of this twisting, when the Achilles tendon is under load, it is subject to wringing action [8].

The human has largest angle between the long axis of tibia and calcaneum as compared to any mammal. Due to upright posture of the human, the foot is at right angle to the leg and the Achilles tendon approaches the back of the foot tangentially which generates heavy torque [9].

The Achilles tendon is one of the strong plantar flexor of ankle joint. It transmits approximately seven times force of the body weight during running while in standing it transmits only half of the body weight [8].

The Achilles tendon is more vulnerable to injury because of its limited blood supply and combination of forces to which it is subjected [2, 10]. The Achilles tendon consists of collagen type 1

fiber [11]. However, resynthesized collagen becomes type III after the injury [12]. The human Achilles tendon reflects age related changes in its cellular and fibrous components. These changes are often manifested with flattening of the cells along with their decreased quantity [13]. The Achilles tendon is a frequent site to degenerative changes, inflammation and rupture. Pathology of the tendon results in imbalance between mobility and stability. The morphological and morphometric analysis of the Achilles tendon is related to functional necessity and its knowledge provide important health information about tendon such as its undue thickening which could be a precursor for tendon rupture [14]. Therefore, normal morphometric measurements of Achilles tendon serve as an important landmark in its anthropometric evaluation and biomechanical attribute. The normal morphometric measurements of the Achilles tendon Knowledge is imperative before determining any pathological variations associated with it.

## MATERIALS AND METHODS

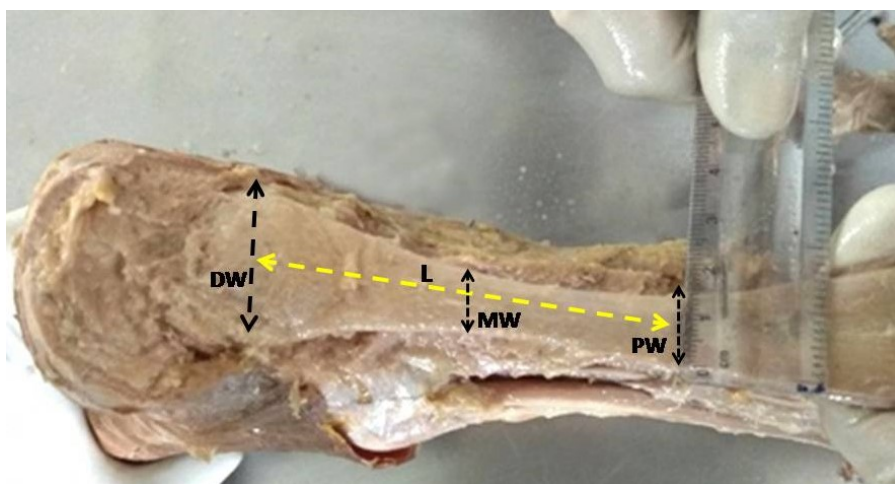
The current study aimed at finding out the detailed morphometric measurements of the Achilles tendons. For this study 108 lower limbs, 54 right and 54 left lower limbs of 54 donated embalmed cadavers (31 males & 23 females) of age group ranging from 55 to 85 years were procured for dissection. The study was conducted in the department of Anatomy SMIMER, Surat. All the lower limbs of cadavers were thoroughly and meticulously dissected. The soleus and gastrocnemius muscles were dissected from their origins. The measurements of Tendoachilles tendons were taken with the help of measuring scale (figure- 1).

Following parameters were considered for study:

1. Length of tendoachilles tendon (from its formation/origin to insertion)
2. Proximal width of the tendon (near its origin),
3. Middle width of the tendon (midway between origin and insertion)
4. Distal width of the tendon (near its insertion). The distal width of the tendon was measured at the closest point of insertion to the calcaneal tuberosity.

**Fig. 1:** shows the measurements of Tendoachilles:

DW- Distal width,  
L- Length,  
PW- Proximal Width,  
MW- Middle width.



## OBSERVATIONS

The following findings were observed in our study.

**Table 1:** Various morphometric measurements of tendoachilles tendons.

Side of Tendoachilles	Length of tendoachilles tendon in centimeters	Width of Tendoachilles tendon in centimeters		
		At origin/Proximal width	At middle	At insertion/Distal width
Right Tendoachilles (54)	7.24 ± 2.57	1.45 ± 0.18	1.23 ± 0.30	2.33 ± 0.52
Left Tendoachilles (54)	7.06 ± 2.16	1.35 ± 0.25	1.25 ± 0.28	2.25 ± 0.46
P value	0.07	0.02	0.65	0.79

Note: P value <0.05 is significant

**Table 2:** Showing morphometric measurements of tendoachilles tendons in male and female.

Gender	Length of tendoachilles tendon in centimeters	Width of Tendoachilles tendon in centimeters		
		At origin/Proximal	At middle	At insertion/Distal
Male	7.93 ± 2.66	1.23 ± 0.33	1.25 ± 0.45	2.13 ± 0.63
Female	6.34 ± 1.61	1.40 ± 0.22	1.23 ± 0.45	2.18 ± 0.62
P value	0.003	0.41	0.94	0.91

The length of tendoachilles tendon varies from individual to individual. In our study, average length of all 108 cadaveric lower limbs was 7.15 ± 2.37 cm and mean length of right tendoachilles tendon was 7.24 ± 2.57 cm and that of left was 7.06 ± 2.16 cm. Tendoachilles length showed no statistically significant differences between the right and left side. The mean width of right tendoachilles tendon at its origin was 1.45 ± 0.18cm, at middle it was 1.23 ± 0.30cm and at insertion it was 2.33 ± 0.52 cm. The mean width of left tendoachilles tendon at origin was 1.35 ± 0.25cm, at middle it was 1.25 ± 0.28cm and at insertion it was 2.25 ± 0.46 cm. The right and left tendoachilles showed statistically significant difference in width at its origin. (p value is 0.02) (Table –1).

The mean length of tendoachilles tendon in male was 7.93 ± 2.66 cm and in female it was 6.34 ± 1.61cm. Tendoachilles length between the male and female tendons was statistically significant. (p value is 0.003). The mean width of tendoachilles tendon in male at origin was 1.23 ± 0.33 cm, at middle it was 1.25 ± 0.45 cm and at insertion it was 2.13 ± 0.63cm. The mean width of tendoachilles tendon in female at origin was 1.40 ± 0.22 cm, at middle it was 1.23 ± 0.45 cm and at insertion it was 2.18 ± 0.62cm. (Table–2). But the width of Tendoachilles did not show statistically significant difference.

## DISCUSSION

Tendocalcaneus or human Achilles tendon is the most easily accessible, superficial tendon of

human body that transfers the force of muscles to the bones [15,16]. The Tendoachilles is a conjoined tendon made up of Gastrocnemius and Soleus muscles. The soleus plantar flexes the ankle joint and it act as postural muscle because it contains a high proportion of slow-twitch fibers preventing the body from falling forward when standing. However the gastrocnemius also flexes the knee joint and promotes the vigorous propulsive movements because contains a greater number of fast twitch fibers.

Different opinions regarding morphometric changes of tendoachilles have been laid down among various races and social groups. Some studies reported that tendoachilles morphometry vary considerably in different races and social groups while few studies documented that no such differences exist between various races. In our study, we found that average length of tendoachilles in all 108 cadaveric lower limbs was  $7.15 \pm 2.37$  cm. This finding similar with the study of Naveen Ku et al which showed average length of Tendoachilles 7 cm.[17] A study of Apaydin N et al stated that the average length of the tendoachilles is 15 cm, ranging from 11 to 26 cm. This variation can be due to different racial population used in their study as weight and body mass index has also a good correlation with tendon size [18,19].

The mean length of right tendoachilles tendon was  $7.24 \pm 2.57$  cm and that of left tendoachilles tendon was  $7.06 \pm 2.16$  cm. Tendoachilles length showed no statistically significant differences between the right and left side tendons. This is similar to study of Naveen Ku et al. and study by Canbolat M, et al which also showed no significant difference in length of right and left tendoachilles. Canbolat M. et al also found that Achilles tendon width, thickness and area showed no significant differences between the right and left side tendons. This study also confirmed the changes in various morphometric measurements among the individuals who are active in sports and sedentary life style [19]. Bailus et al confirmed the differences in the length of the tendon between dominant and non-dominant side in cadaveric study [20]. Egwu OA et al in Nigerian population documented that significant change in the thickness

of tendoachilles between dominant and non-dominant feet and also in right and left side Tendoachilles [21].

In present study, width of Tendoachilles range was from 1.20 to 1.70 cm at origin, 1.00 to 1.90 cm at middle and 1.50 to 3.00 cm at insertion showing the width of tendon was gradually decreasing from its origin to midsection then broadens at its insertion site. These findings are similar to Apaydin N et al study which showed that the mean width of tendoachilles gradually decreases at the midsection from at its origin. He also documented that tendoachilles becomes more rounded at an average of 4 cm above the calcaneus, of about width of 3.4 cm (2.0–4.8 cm) at its insertion site over the posterior surface of the calcaneus [18]. Knobloch et al. found that the width of the tendon ranged was from 2 to 6 cm [22]. De Mallo et al. stated that the tendoachilles width would be higher in the overweight body mass index individuals as compared to normal individuals [23].

During comparison of various parameters between right and left limbs, we found that mean width of right tendoachilles tendon at origin was  $1.45 \pm 0.18$  cm,  $1.23 \pm 0.30$  cm at middle and  $2.33 \pm 0.52$  cm at insertion. The mean width of left tendoachilles tendon at origin was  $1.35 \pm 0.25$ , at middle it was  $1.25 \pm 0.28$ , at insertion it was  $2.25 \pm 0.46$ . We found that width of the tendoachilles between the right and left side tendons at origin was statistically significant (p value is 0.02).

In this study, Tendoachilles length between the male and female tendons was statistically significant. (p value is 0.003) which is similar to study of Canbolat M et al who suggested that males have higher length and width than female and concluded that this can be due to differences in muscle strength and mechanical property.[ 19,24].

In our study, mean width of tendoachilles tendon in male at origin was  $1.23 \pm 0.33$  cm, at middle it was  $1.25 \pm 0.45$  cm and at insertion it was  $2.13 \pm 0.63$ cm. The mean width of tendoachilles tendon in female at origin was  $1.40 \pm 0.22$  cm, at middle it was  $1.23 \pm 0.45$  c and at insertion it was  $2.18 \pm 0.62$ cm. (Table-2).

Munteanu SE et al said that the thinner tendons



are more prone to the risk of tendinopathy and tendency to rupture in comparison to thicker tendon [25]. Koivunen-Niemela & Parkkola opined that the flat arched foot type is often associated with a thinner tendoachilles tendon. They also believe that the variation in the shape of the tendon caused up to 25% variation in its width and that differences in population height could also be related to the tendon thickness [26].

During our literature review we came across that various studies of morphometric evaluation of tendoachilles were done ultrasonographically while cadaveric studies related to Tendoachilles were very less. Studies have shown that ultrasound image measurements of the tendo-calcaneus had exact correlation with the measurements on cadavers. This indicates that morphometric evaluation of tendoachilles in cadavers is a valid and reliable factor which is considered as a gold standard for measurement [27].

As morphological and morphometric variation of Tendoachilles are related to functional requirements, they can be an important landmark for anthropometric evaluation and biomechanical characteristics. The achilles tendon provides a learned practical well-referenced approach to the various manifestations of achilles tendinopathies, acute rupture of the achilles tendon, chronic heel ulcer. The knowledge regarding the normal morphometric measurements of Achilles tendon is imperative before determining any pathological variations associated with the tendon and allows exploring newer options for specific management.

Achilles tendinopathy numbers has been increased in recent years amongst athletes due to overuse of Achilles tendon. Our study presenting normal values of tendoachilles would be very helpful to sport medicine physicians for diagnosis and treatment of Achilles tendon overuse injuries and explain the pathology associated to tendinopathy.

## CONCLUSION

Present cadaveric study found that the length of Tendoachilles was significantly high in male than in female and also found that width of the tendoachilles at origin was more on right side. The knowledge regarding the normal

morphometric measurements of Achilles tendon may provide new insights in the management of Achilles tendinopathy to orthopedic surgeons, podiatrist, sports physicians and physiotherapists and it can be useful as a tool for diagnosis of achilles tendon medicine.

**Conflicts of Interests: None**

## REFERENCES

- [1]. Reinherz RP, Zawada SJ, Sheldon DP. Recognizing unusual tendon pathology at the ankle. *J Foot Surg* 1986;25:278-283.
- [2]. Standring S, editor. *Gray's Anatomy*. 40th ed. Edinburgh: Churchill Livingstone; 2010. pp. 1451.
- [3]. Standring S, editor. *Gray's Anatomy*. 40th ed. Edinburgh: Churchill Livingstone; 2010. pp. 1420.
- [4]. Chaurasia B.D, *Human Anatomy, Lower limb and Abdomen*. 1st ed. CBS Publisher; 1988. pp.1.
- [5]. Bramble DM, Lieberman DE. Endurance running and the evolution of Homo. *Nature* 2004;432:345-352
- [6]. White JW. Torsion of the Achilles tendon: Its surgical significance. *Arch Surg* 1943; 46:784-787.
- [7]. Cummins EJ, Anson BJ, Carr BW, Wright RR, Hauser EDW. The structure of calcaneal tendon ( of Achilles) in relation to orthopedic surgery. *Surg. Gynecol Obstet* 1946; 83:107-116.
- [8]. Maffulli, Nicola, Michael Benjamin, P. Theobald, D. Suzuki, and H. Toumi. *The Anatomy of the Achilles Tendon - The Achilles Tendon*. 1<sup>st</sup> edn. 2007; 5-15.
- [9]. Ker RF, Bennett MB, Bibby SR, Kester RC, Alexander RM. The spring in the arch of the human foot. *Nature* 1987;325:147-149.
- [10]. Mazzone, M.E. and T. Mccue. Common conditions of the Achilles Tendon: American family physician, 2002;65:1908-1910.
- [11]. Maffulli N, Ewen SW, Waterston SW, Reaper J, Barrass V. Tenocytes from ruptured and tendinopathic achilles tendons produce greater quantities of type III collagen than tenocytes from normal Achilles tendons. An in vitro model of human tendon healing. *Am J Sports Med*. 2000;28:499-505.
- [12]. Whittaker P, Canham PB. Demonstration of quantitative fabric analysis of tendon collagen using two-dimensional polarized light microscopy. *Matrix*. 1991;11:56-62.
- [13]. Strocchi R, De Pasquale V, Guizzardi S, Govoni P, Alberto Facchini, Mario Raspanti, Mauro Girolami, Sandro Giannini. Human Achilles tendon: Morphological and Morphometric Variations as a Function of Age. *Foot & Ankle International*. 1991;12(2);100-104.
- [14]. Jarvinen TA, Jarvinen TL, Kannus P, Jozsa L, Jarvinen M. Collagen fibers of the spontaneously ruptured human tendons display decreased thickness and crimp angle. *J Orthop Res*. 2004;22:1303-1309.
- [15]. Koivunen-Niemela T, Parkkola K. Anatomy of the Achilles tendon (tendo calcaneus) with respect to tendon thickness measurements. *Surg Radiol Anat*. 1995;17:263-268.

- [16]. Levangie P, Norkin C. Joint structure and function: a comprehensive analysis. The ankle and foot complex. 5th ed. New Delhi; Jaypee Brothers. 2011;440-482.
- [17]. Naveen Kumar, Ashwini P Aithal, Satheesha B Nayak, Jyothsna Patil, Abhinitha Padavinangadi, Biswa Bina Ray. Morphometric evaluation of human tendocalcaneus: a cadaveric study of south indian male population. Muscles Ligaments Tendons J. 2017 Jan-Mar; 7(1): 62–68.
- [18]. Apaydin N, Bozkurt M, Loukas M, Vefali H, Tubbs RS, Esmer AF. Relationships of the sural nerve with the calcaneal tendon: an anatomical study with surgical and clinical implications. Surg Radiol Anat. 2009;31(10):775–780.
- [19]. Canbolat M, Ozba D, Ozdemir Z, Demirtafl G, fiahin Kafkas A. Effects of physical characteristics, exercise and smoking on morphometry of human Achilles tendon: an ultrasound study. Anatomy. 2015;9(3):128–134.
- [20]. Balias R, Alomar X, Rodas G, et al. The soleus muscle: MRI, anatomic and histologic findings in cadavers with clinical correlation of strain injury distribution. Skeletal Radiol. 2013;42:521–530.
- [21]. Egbu OA, Ogbonna CO, Salami E, Eni OE, Besong E, Onwe CC. Normal thickness of the tendo calcaneus (TCT) in an adult Nigerian population: an imaging based normographic study. Br J Med Med Res. 2014;4:2100–2111.
- [22]. Knobloch K, Kraemer R, Lichtenberg A, et al. Achilles tendon and paratendon microcirculation in midportion and insertional tendinopathy in athletes. Am J Sports Med. 2006;34(1):92–97.
- [23]. DeMello RAF, Marchiori E, dos Santos AASMD, Torres Neto G. Morphometric evaluation of Achilles tendon by ultrasound. Radiol Bras. 2006;39(3):161-165.
- [24]. Muraoka T, Muramatsu T, Fukunaga T, Kaneehisa H. Elastic properties of human Achilles tendon are correlated to muscle strength. J Appl Physiol. 2005;99:665-9.
- [25]. Munteanu SE, Barton CJ. Lower limb biomechanics during running in individuals with Achilles tendinopathy: a systematic review. J Foot Ankle Res. 2011;4(1):1–15.
- [26]. Koivunen-Niemelä T, Parkkola K. Anatomy of the Achilles tendon (tendo calcaneus) with respect to tendon thickness measurements. Surg Radiol Anat. 1995;17:263–268.
- [27]. Silbernagel KG, Shelley K, Powell S, Varrecchia S. Extended field of view ultrasound imaging to evaluate Achilles tendon length and thickness: a reliability and validity study. Muscles, Ligaments and Tendons Journal. 2016;6(1):104-110.

**How to cite this article:**

Manju Singhal, Nisha Parmar, Deepak Singhal. MORPHOMETRIC ANALYSIS OF TENDOACHILLES TENDON WITH ITS CLINICAL IMPLICATIONS. Int J Anat Res 2019;7(2.2):6550-6555. DOI: 10.16965/ijar.2019.165