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Morphometric Study of Tendon of Achilles in Correlation With Height in the Cadavers of Nepalese Origin

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ABSTRACT

Background

Tendon of Achilles (TA) plays an important role in maintaining the normal gait of an individual. It can receive a stress of 3.9 times body weight during walking and 7.7 times body weight during running. The objective of the study was to determine the morphometry of TA and its length in correlation with the height of cadavers of Nepalese origin.

Methods

This cross-sectional study was conducted at the department of Anatomy of Nobel Medical College Teaching Hospital during the time frame of Sep 2024 to Feb 2025. A total of 35 cadavers (25 M & 10 F) with 70 limbs were dissected to study their morphometry. The mean values were compared between the right and left sides in both males and females using an unpaired t-test. The proximal, middle, and distal mean values were compared using one way-ANOVA test.

Results

The mean length of tendon of Achilles and the various parameters were higher in male compared to female. The morphometry of the right limb was higher than the left limb in both male and female. The average height of the cadavers were 9.81 times in male and 10.16 times in female the length of TA.

Conclusions

The better understanding of the morphometry of tendon of Achilles will be helpful during the diagnosis and surgical repair of tendon of Achilles as it is one of the important tendons that keeps one in position.

Keywords: Achilles tendon; Cadavers; Morphometry; Tendinopathy.

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INTRODUCTION

The common tendon of the triceps surae, which is made up of the two heads of the gastrocnemius and soleus, forms the tendon of Achilles (TA), the largest tendon in the human body.[1] The term tendon of Achilles was originally used in 1693 in Verheyen's book 'Corporis Humani Anatomiae.[2] The tendon, which has an average length of 8 to 17 centimeters, is implanted on the posterior medial surface of the calcaneus bone.[3] Aging and being overweight put too much strain on the Achilles tendon (TA), changing its cellular and molecular makeup.

The goal of the current study was to determine the morphometry of the TA in male and female cadavers of Nepalese origin and to compare the findings with those of previous studies. The results of this study will provide population specific data of TA in correlation with height to the orthopaedic surgeons, sports medicine, podiatrists, radiologists, and physiotherapists, especially in the surgical and non-surgical treatment of Achilles tendon diseases.

METHODS

Study Area

This study was conducted during the normal practical routine dissection of lower limbs on the cadaver for MBBS 1st year students at the Department of Anatomy of Nobel Medical College Teaching Hospital.

Study Design

This was a cross-sectional study.

Sample size and sampling

35 well embalmed cadavers (no. of limbs n=70) of known sex (10 female and 25 males) average age of 55 years of Nepalese origin without any gross damage to the lower limbs were considered for the study. The exact cause of death of the cadavers were unknown. All the cadavers were embalmed using formalin as per standard methods.

Was done by using Cochran's formula.

The base formula is: $N=Z^2XpX(1-p)/d^2$

Where,

N= Desired sample size.

Z= standard normal deviate (usually 1.96 for a 95% confidence level.

p= expected proportion of the population being studied.

d= margin of error/ precision (0.05 as decimal).

Inclusion criteria: Well embalmbed cadavers, intact lower limbs, known sex.

Exclusion criteria: Dry cadavers, difficult to dissect, cadavers with trauma or surgery to the lower limb, unknown sex.

Data Collection

The study was conducted from September 2024 to February 2025. All the experimental procedures in the study were preceded after obtaining the proper ethical clearance from the Institutional Review Committee of Nobel Medical College, Biratnagar (Ref. No.: 61/2024). The clearance applies to cadaveric study involving animals, human volunteers, or living patients.

Bilateral exposure of the Tendon of Achilles (TA) of the cadavers was performed according to the standard procedures of Cunningham's Manual of Dissection Volume I. All the dissection procedures were done by keeping the cadavers in a prone position on the dissecting table. Bilateral exposure of the leg was done to expose the tendon of Achilles. The back of the leg was finely dissected to trace the tendon from its point of formation to its point of insertion. Two pins were marked on the site of formation and insertion. The morphometry of the tendon was obtained with the help of measuring scale, thread, and digital Vernier Calliper. All measurements were taken on the left and the right lower limbs for comparison within the same cadaver using a digital caliper (accuracy ±0.01 mm) and repeated three times.

The following parameters were included in the study:

Length of Tendon of Achilles (formation to its insertion) (LAT)

Proximal width of Tendon of Achilles (PWAT)

Width of Tendon of Achilles at the middle (MCAT)

Distal width (DWAT) and circumference of the Tendon of Achilles at its insertion (DCAT)

Length of Tendon of Achilles in correlation with

height of cadavers.

Data Analysis

The results were calculated as Mean ± Standard Deviation. The data were analyzed using BM SPSS Statistics for Windows, Version 20.0. Armonk, NY; IBM Corp., and $p \leq 0.05$ are considered as the level of significance. The mean values were compared between the right and left sides in both males and females using an unpaired t-test. And the mean values between males and females were compared using an independent t-test. The proximal, middle, and distal mean values were compared using one way-ANOVA test.

RESULTS

In this study we dissected and exposed the tendon of Achilles in 35 cadavers (10 female and 25 male). The average morphometric values of the various parameters of the Tendon of Achilles for both the right and left legs in male and female are presented in the table 1, table 2, and table 3. The correlations between the height of cadavers and the length of tendon of Achilles is shown in the table 4 below. All the measurements did not show a statistically significant difference between the right and left limb and in between male and female cadavers (T-test, $p < 0.05$). In addition, the width and circumferences did not showed any significant differences. A statistically significant positive linear correlations was observed between the length of tendon of Achilles and the height of cadavers ($p = 0.008$ and $r = +0.440$). While correlating the height with length of TA, it was found that the average height of the cadavers were 9.81 times the length of TA in male and 10.16 times the length of TA in female, and it's the novel part of the present study. The morphometric values of right limb was higher than the left limb in both male and female. The average value of TA and height of cadavers of male was higher than that of the female. There was significant difference in the height of cadavers between male and female ($p < 0.05$). The Table 1 shows the descriptive analysis of parameters of TA in both limbs in male, where the length of TA in right limb is greater than the left limb, it is because of dominant right limb.

Table 1: Comparison of descriptive analysis of parameters of Tendon of Achilles between right and left limb in male (n=50).

Parameters of TA (in cm)	Right limb (Mean ± SD)	Left limb (Mean ± SD)
Length of TA	16.56±2.21	16.23±1.97
Proximal width of TA(PWAT)	6.80±1.08	6.50±1.32
Width of TA at middle(MCAT)	4.79±0.85	4.44±0.86
Width at distal end(DWAT)	3.86±0.70	3.54±0.74
Height of cadavers	157.28±2.42	

The table 2 shows the descriptive analysis of parameters of TA in both limbs in female, where the length of TA in right limb is greater than the left limb, it is because of dominant right limb.

Table 2: Comparison of descriptive analysis of parameters of Tendon of Achilles between right and left limb in Female cadavers (n=20).

Parameters of TA (in cm)	Right limb (Mean ± SD)	Left limb (Mean ± SD)
Length of TA	15.10±1.37	14.40±1.50
Proximal width of TA(PWAT)	6.80±1.03	6.40±0.96
Width of TA at middle(MCAT)	3.60±0.65	3.45±0.92
Width at distal end(DWAT)	3.20±0.63	3.50±0.85
Height of cadavers	150.10±4.40	

The table 3 shows the descriptive analysis of parameters of TA in male and female , where the length of TA in right limb is greater in male than in female, it may be because of more height of male cadavers compared to female.

Table 3: Comparison of descriptive analysis of parameters of tendon of Achilles between male and female (n=70).

Parameters of TA (in cm)	Male right & left limb (Mean ± SD)	Female right & left limbs (Mean ± SD)	P value
Length of TA	16.22±2.09	14.75±1.40	0.253
Proximal width of TA(PWAT)	6.65±1.19	6.60 ± 0.99	1
Width of TA at middle(MCAT)	4.61±0.85	3.52±0.78	0.61
Width at distal end(DWAT)	3.70±0.72	3.35±0.74	0.51
Height of cadavers	157.28±2.42	150.10±4.40	0.002

The table 4 shows the correlation between the height of cadavers and length of TA.

Table 4: Correlation between length of tendon of Achilles and height of cadavers (n=35).

Parameters	Length of Tendon of Achilles	Height of Cadavers
Length of tendon of Achilles		
Pearson Correlation	1	.440**
Sig. (2-tailed)		0.008
N	35	35
Height of Cadavers		
Pearson Correlation	.440**	1
Sig. (2-tailed)	0.008	
N	35	35

***. Correlation is significant at the 0.01 level (2-tailed).*

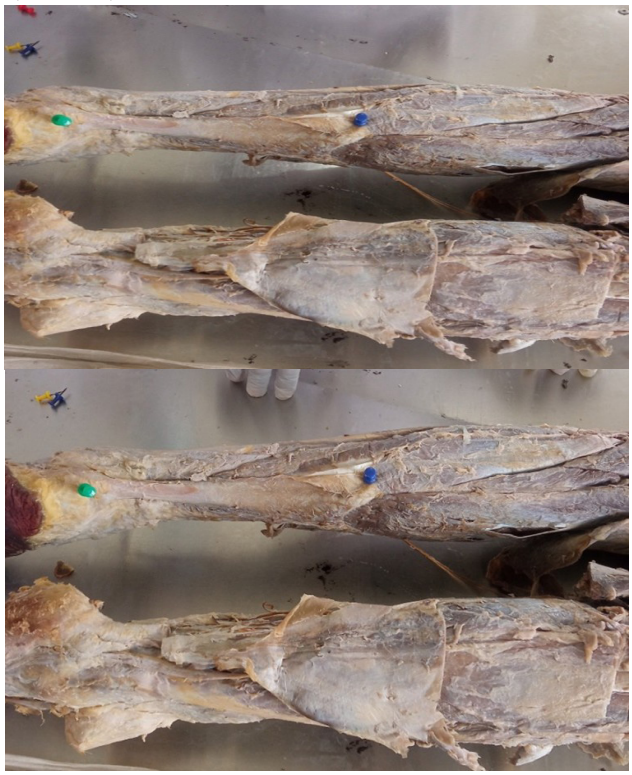

Figure 1: Tendon of Achilles.

DISCUSSION

The tendon of Achilles is commonly formed by the soleus and gastrocnemius muscles. Along the side of the muscle, and superficial to it, is the small saphenous vein. The sural nerve accompanies the small saphenous vein as it descends in the posterior leg, travelling inferolateral to it as it crosses the lateral border of the tendon of Achilles.[4] It can receive a load stress 3.9 times body weight during walking and 7.7 times body weight when running.[5] Running and walking are examples of functional activities in which the tendon of Achilles is of crucial importance. The tendon spreads out somewhat at its lower end so that its narrowest part is about 4 cm (1.6 in) above its insertion. Due to its restricted blood supply and poor vascularity via posterior tibial artery and the extreme strain it is expose to a wide range of various illnesses such as tendinopathies and ruptures of the tendons.[6] Natural degeneration, like wear and strain in tendinosis, causes the Achilles tendon to fluctuate in its thickness. All of these changes may affect the morphology, biomechanics, and morphometric parameters of the tendon of Achilles, which are primarily observed in Achilles tendinopathy.[7] Tendinopathy, tendinitis, and rupture are examples of minor to severe kinds of tendinopathy injuries.[8] Additionally, it has been shown by recent research that both amateur and professional athletes are increasingly suffering from Achilles tendinopathy. As such, determining and clarifying the risk factors associated with tendinopathy is crucial. Research in this field will benefit from an understanding of tendon anatomical variations as well as the anatomy of the tendon of Achilles.[9]

The present study revealed the morphometric parameters (length and width at variable location) of the Achilles tendon in male and female in correlation with height of cadavers of Nepalese origin. The mean length of the AT was 16.22 ± 2.09 cm in male and 14.75 ± 1.40 cm in female, which is similar to the study done in Nepal by *Lama CPet al.,*[10] where the average length was 16.65 ±1.72 cm. Similar result may be due to the geographical origin of the cadavers. Some of the study conducted in different part of India by different authors showed that the mean length of AT 7.8 ± 1.99 cm in right limb and 7.5 ± 2.2 in left limb by *Kumar et el.,* and 7.15±2.37 cm by *Singhalet et al.,* which is significantly less than the value obtained in the present study, may be because of the geographical variation and life style of the people. A study done in Italy by *Apaydin et al.,* showed the average length of AT ranges from 11 cm to 23 cm.[11] which is in accordance with the present study conducted in Nepalese population. The findings from the present study may be useful to the clinicians to compare the affected and non affected side of length and leg dominance. Results from some of the researchers concluded that there was significant proximal migration of the insertion point of AT on the calcaneum with advancing age.[12] The findings of the present study also revealed that the mean of the various parameters of the Achilles Tendon on the right side was greater than that of the left side (Table 1 & 2) which is in accordance with the study done by *Lama CP et al.,* and *Bohmet et al*., indicating that the dominance side parameters is relatively more because of its massive uses comparatively than that of left side.[13] In some of the study it was claimed that the type of foot had a direct relationship with the morphometry of the AT where thin AT was often associated with the tendinopathy compared to the thick AT. There are extensive reports on the thickness of the AT at various races and populations which depends upon the geographical distributions and the overall physique of the individual leading on a particular diets and life styles. The results of the present study is also compared with the Ultrasonographic study done by various researchers shown in table 5 below. The parameters compared with the study done by *Zellers et al.,* is 20.7 cm which is higher than the present study, it may be due to Ultrasonographic measurements.

In the present study the average width of the AT was 6cm at the proximal 4cm at middle and 3cm at the distal end. In a similar study conducted by *Emmanuel Peteret et al*., the average width of AT was 4.03 cm at proximal, 3.86 cm at the middle and 4.95 cm at the distal end in the Malawian population.[14] In this study the height of the cadavers were also taken in account to correlate the length of AT which is novel thing of the present study. The average height of the male cadavers were 157.28 ± 2.42 cm and of the female was 150.10 ± 4.40 cm. correlating with the length of AT it was found that the height of cadavers were 9.81 times in male and 10.16 times in female the length of TA. More number of study is required to locate the exact correlation between the height of cadavers and the length of AT.

Achilles tendinopathy is more common in athletes, particularly football players and runners. Since ultrasonography is currently the gold standard for detecting Achilles tendinopathy, it was employed in most of the earlier research on the Achilles tendon. A small number of cadaveric studies have been found, and it was determined that the cadaveric morphometric measures of the AT and the ultrasounds had the same relationship, indicating that the cadaveric measurements are more reliable and feasible and may be utilized as the gold standard.[15] The present study after comparing with the ultrasonographic value showed that the value are less and in some study it is greater. The more we use the tendon it increases dominantly in its length. Generally, the people of Nepal in the rural areas are Pedestrain stepping in the Hilly region, it may be the reason of higher value of TA compared to study of other parts of the world. Compared to children with delayed milestones in situations like cerebral palsy, congenital talipes equinovarus etc., children with regular daily activities will acquire extensive AT. The tendon's collagen bundles form a certain pattern

under prolonged tension. Excellent resistance to traction forces is provided by the collagen fibers in this tissue aligning with the linear orientation of the fibroblast in response to prolonged stressors applied in the same direction.[16] The quantity of load transfer in the AT changes depending on the individual's daily activity. The AT produces a load of 1.9-9 kN, respectively, during walking, hopping, squat leaping, jumping, and running.[17] So the morphometric values obtained in the present study will play important role in context of Nepal for carrying out various clinical procedures related to TA. The table 5 shows the comparison of the present study of Nepal with the studies conducted in different parts of the world.

Table 5: Comparison of Tendon of Achilles length with previous study (n=70).

Author & Year	Type of study	No. of lower limb used	Mean length of TA right limb (Male)	Mean length of TA left limb (Male)	Mean length of TA right limb (Female)	Mean length of TA left limb (Female
Manju et al.2019	Cadaver	108	7.24±2.25	6.34±1.61	-------	------
Nahar et. al. 2019	Cadaver	60	14.74±2.25	12.77±2.11	14.62±2.46	12.56±2.21
Chhiring et al.2022	Cadaver	40	16.65±1.72cm	16.35±1.49	---------	---------
Kumar et al.2017	Cadaver	64	7.8±1.9	7.5±2.2	-----	-----
Maria et al.2022	Cadaver	60	8.91±0.56	8.48±0.52	8.09±0.7	7.90±0.68
Szaro &Ghali 2021	MRI	74	8.1 cm	------	----	-------
Fukutani etal.2014	Ultrasonography	10	5.6±4.6mm	9.0±5.4mm	----------	---------
Pang et al.2006	Ultrasonography	40	11.74±24.71	11.72±22.87	----------	----------
Patel and labib2017	Ultrasonography	50	9.32±1.67	9.39±1.59	-----	-----
Zellers et al. 2018	Ultrasonography	42	20.7 cm	----	----	---
Present study, 2025	Cadaver (Nepal)	70	16.56±2.21 cm	16.23±1.97 cm	15.10±1.37 cm	14.40±1.50 cm

Limitations

Small sample size was considered as per availability of the cadavers. There may be some measurement issues depending upon the nature of cadavers. The probable age of the cadavers was considered as per documented records from the source of origin.

Conclusions

The present study has determined the basic morphometric parameters of the tendon of Achilles of adult male and female cadavers of Nepalese origin. This study conferred that the various parameters of TA are greater in Male compared to the female adults. The value was higher in the dominant limb. The average values of the TA obtained in the study in the Nepalese populations are generally according to the value in the standard text books available. In this study the height of cadavers is correlated with the length of TA, which is novel part of the study. These values will also serve as baseline measure and will definitely help the Physiotherapists, Orthopedic surgeons, Sports Medicine Physician and Radiologists in the diagnosis and evaluation of Achilles tendon overuse injuries and tendinopathy among the adults. Further study with large number of sample size is required to establish the exact correlation between the height and length of TA including the populations from other parts of the world.

Ethics approval: Ethical approval for the study was obtained from Institutional Review Committee of Nobel Medical College, Biratnagar (Ref. No.: 61/2024).

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Availability of data and materials: All data analysed during this study will be made available upon reasonable request from the corresponding author.

Author contributions

Conceptualization: Surendra Kumar Sah
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Formal analysis: Surendra Kumar Sah, Manisha Jha, Soni Kumari Shah
Investigation: Surendra Kumar Sah
Methodology: Surendra Kumar Shah, Manisha Jha, Soni Kumari Shah
Supervision: Surendra Kumar Shah
Writing-original draft: Surendra Kumar Sah
Writing-review & editing: Surendra Kumar Sah, Manisha Jha, Soni Kumari Shah

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