ORIGINAL ARTICLE

DOI: 10.20515/otd.1784851

Osmangazi Journal of Med, 2026;48(1):61-67

Osmangazi Journal of Medicine

e-ISSN: 2587-1579

Relationship of Achilles Tendon Dimensions with Balance in Young Men: A Cross-Sectional Study

Genç Erkeklerde Aşil Tendon Boyutlarının Denge ile İlişkisi: Kesitsel Bir Çalışma

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Received : 16.09.2025

Accepted : 17.10.2025

Abstract: This study investigated the relationship between Achilles tendon dimensions and balance in healthy young men. Eighty-eight healthy men aged 18-35 were included in the study. Dynamic balance was assessed using the Timed Up and Go (TUG) test, and static balance was assessed using the Fall Index via the Tetrax Interactive Balance System. Achilles tendon thickness and cross-sectional area (CSA) were measured ultrasonographically with a linear probe at a frequency of 8-13 Hz. Mean Achilles tendon thickness was 0.51 ± 0.15 cm, CSA was 0.58 ± 0.22 cm², TUG test was 7.77 ± 1.55 s, and Fall Index score was 33.68 ± 21.58. CSA was greater, and TUG test and Fall Index scores were lower in active individuals ($p < 0.001$). The Achilles tendon CSA was negatively correlated with both the TUG test and the Fall Index ($p < 0.001$). The results of this study suggest that greater Achilles tendon CSA may be associated with better balance.

Keywords: Achilles tendon, Cross-sectional area, Balance, Timed Up and Go, Fall Index.

Ethics Committee Approval: The study was approved by the Eskisehir Osmangazi University.Clinical Research Ethics Committee (Decision No: 26, Date: 10.09.2019).

Informed Consent: The authors declared that informed consent was not required as the study was based on retrospective data analysis.

Authorship Contributions: Concept: AMÇ, SDE, MÖ, Design: AMÇ, SDE, MÖ, Supervision: MÖ, FM, Data Collection or Processing: AMÇ, SDE, GS, MÖ, Analysis or Interpretation: AMÇ, SDE, GS, MÖ, FM, Literature Search: AMÇ, SDE, GS, Writing: AMÇ, SDE, GS, MÖ, FM, Critical Review: AMÇ, SDE, GS, MÖ, FM.

Copyright Transfer Form: Copyright Transfer Form was signed by all authors.

Peer-review: Internally peer-reviewed.

Conflict of Interest: The authors declare that there is no conflict of interest.

Financial Disclosure: This study was financially supported by the Eskisehir Osmangazi University Scientific Research Project Commission.

Özet: Bu çalışma sağlıklı genç erkeklerde aşil tendon boyutları ile denge arasındaki ilişkiyi araştırmaktadır. Çalışmaya 18-35 yaş aralığında 88 sağlıklı erkek dahil edilmiştir. Dinamik denge Timed Up and Go (TUG) testi ile, statik denge ise Tetrax Interactive Balance System üzerinden Fall Index kullanılarak değerlendirilmiştir. Aşil tendonu kalınlığı ve kesitsel alanı (CSA), 8-13 Hz. frekanslı lineer prob ile ultrasonografik olarak ölçülmüştür. Ortalama Aşil tendon kalınlığı 0.51 ± 0.15 cm, CSA 0.58 ± 0.22 cm², TUG testi 7.77 ± 1.55 sn ve Fall Index skoru 33.68 ± 21.58 olarak saptanmıştır. Aktif bireylerde CSA daha büyük, TUG testi ve Fall Index skorları ise daha düşük saptanmıştır ($p <0.001$). Aşil tendon CSA'sı hem TUG testi hem de Fall Index ile negatif korelasyon göstermiştir ($p <0.001$). Bu çalışmanın sonuçları daha büyük Aşil tendon CSA'sının daha iyi denge ile ilişkili olabileceğini düşündürmektedir.

Anahtar Kelimeler: Aşil tendonu, Kesit alanı, Denge, Timed Up and Go, Fall Index.

How to cite/ Atıf için: Çıracıoğlu AM, Dal Erdoğan S, Sarıçimen G, Özgen M, Mutlu F, Relationship of Achilles Tendon Dimensions with Balance in Young Men: A Cross-Sectional Study, Osmangazi Journal of Medicine, 2026;48(1):61-67

1. Introduction

Balance is a complex process achieved by the central nervous system, integrating and interpreting vestibular, somatosensory, and visual inputs and organizing appropriate motor responses through the musculoskeletal system (1,2). The biomechanical properties of lower extremity muscle and tendon structures are important in maintaining and safeguarding balance. The Achilles tendon is the thickest and strongest tendon in the human body, transferring force from the calf muscles to the foot, and plays a role in essential functions such as walking and running. While its ability to store and release energy during daily life and athletic activities increases movement efficiency, this mechanism also makes the tendon more susceptible to repetitive loading, increasing the risk of injury. Habitual, repetitive loading, such as regular training, has been shown to increase collagen synthesis and lead to tendon hypertrophy. It has been suggested that these structural adaptations may affect both dynamic and static balance by altering tendon mechanical properties (3,4).

Although there are many studies in the literature on the morphological characteristics of the Achilles tendon in healthy, young individuals, to our knowledge, there is no study directly examining the effect of these structural parameters on balance performance. Current research focuses on defining normative ultrasonographic measurements of the Achilles tendon and determining how these measurements vary with age, sex, body weight, and physical activity levels (5–7). Salinero et al reported increased Achilles tendon dimensions in runners compared to sedentary individuals. (8). However, the relationship between Achilles tendon dimensions and balance performance has generally been addressed in pathological conditions such as the aging process or tendinopathy. Scholes et al. found that men with Achilles tendinopathy experienced impaired balance on one leg (9). It has been shown that aging can negatively affect balance performance by causing changes in tendon elasticity and morphology (10). These findings highlight the need for further research that holistically evaluates tendon morphology and balance performance in healthy individuals to better understand the potential relationships between the structural properties of the Achilles tendon and postural control. This study evaluates the relationship between Achilles tendon dimensions and balance in young men. The results are expected to contribute to the generation of more comprehensive scientific data in the future.

2. Materials ve Methods

2.1.Study Design and Participants

This cross-sectional study was conducted with 88 healthy male participants aged 18–35 who attended the outpatient clinics of the Department of Physical Medicine and Rehabilitation. Participants were divided into two groups based on their physical activity levels: active individuals were defined as those who exercised regularly for at least four hours per week in the last three months (11); sedentary individuals were defined as those who did not exercise regularly.

Participation criteria for the study included being between 18 and 35 years old, being male, and agreeing to participate voluntarily. Exclusion criteria included musculoskeletal disorders affecting the lower extremities, professional athletics, Achilles tendon pathology detected by ultrasonography (USG), metabolic or rheumatic diseases, neurological diseases that could cause balance disorders, ear pathologies, hearing and vision problems, and cognitive impairments.

Demographic data included age, height, weight, and body mass index (BMI). Exercise habits were assessed through self-reporting by participants. dynamic balance was measured using the Timed Up and Go Test (TUG), and static balance was measured using the Fall Index determined by the Tetrax Interactive Balance System. Achilles tendon thickness and cross-sectional area (CSA) were examined by USG.

This study was approved by the Eskisehir Osmangazi University Clinical Research Ethics Committee with decision number 26, dated September 10, 2019. Written and verbal consent was obtained from all participants. The research was conducted in accordance with the principles of the Declaration of Helsinki.

2.2 Ultrasonography

The dimensions of the Achilles tendon in the dominant lower extremity was assessed by USG using a high-frequency linear probe (8–13 MHz). Measurements were performed with participants lying prone and the ankle passively held in neutral dorsiflexion to minimize artifacts. The medial malleolus level was used as the reference point. All measurements were performed by a single, experienced, and trained operator unaware of group assignment.

In the longitudinal plane, the Achilles tendon was visualized as parallel echogenic fibrillar structures, and the probe was positioned along the tendon fibers (Figures 1A, 1C).

In the transverse plane, the tendon was visualized as round echogenic fascicular bundles separated by hypoechoic loose connective tissue, and the probe was positioned perpendicular to the tendon (Figures 1B, 1D). Tendon thickness was measured in the longitudinal plane (Figure 1C), while CSA was calculated using the trace-ellipse method in the transverse plane (Figure 1D). The medial malleolus level was chosen as the measurement reference because it is a fixed and easily identifiable anatomical reference point that allows for standardization of the scanning procedure (12).

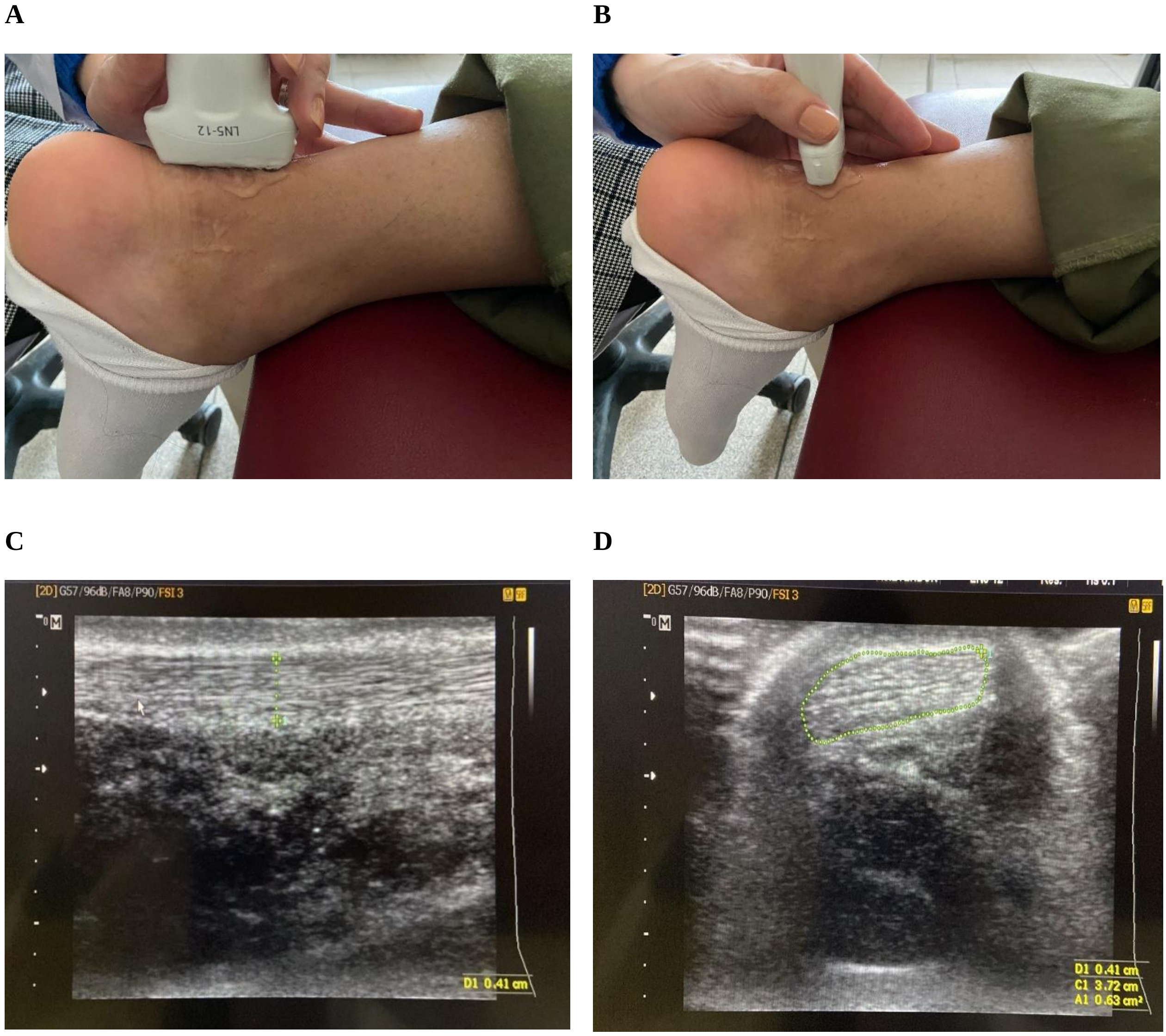

Fig 1. Ultrasound imaging of the Achilles tendon. ***(A)*** *The transducer is positioned parallel to the tendon to allow measurement of the tendon thickness in the sagittal plane.* ***(B)*** *The transducer is positioned transverse to the tendon at the medial malleolus level to allow measurement of the tendon cross-sectional area.* ***(C)*** *Achilles tendon thickness in the long axis.* ***(D)*** *Achilles tendon cross-sectional area in the transverse axis.*

2.3.Fall Index Measurement

The Tetrax Interactive Balance System (Tetrax-Sunlight Medical Ltd., Ramat Gan, Israel) was used to assess static fall risk. Participants were assessed in eight different test positions, both with eyes open and eyes closed. During these measurements, participants were tested on both a hard surface and a pillow, and different conditions were created by positioning the head midline, backward, or to the right or left. In each condition, participants were asked to hold the position for 32 seconds. A fall index was automatically calculated by the system's integrated software; higher index values were associated with an increased risk of falling (13).

2.4.Timed Up & Go Test

This test is administered to assess dynamic postural balance. The participant stands up from a 45 cm high chair without using their arms, then walks quickly in a straight line for 3 meters and circles the cone at the marked point. They then walk back to the chair and sit down. The test completion time is recorded by the researcher using a stopwatch. Prolonged completion time is related to factors such as the individual's sociocultural level, body mass index, various medical conditions, and perception of physical and mental health (14).

2.5. Statistical Analysis

The distribution of each continuous variable was tested for normality using the Shapiro-Wilk test. Normally distributed variables were performed using the unpaired t-test. Non-normally distributed variables were analyzed using the Mann-Whitney U test and are expressed as median value [% 25-%75] and mean± standard deviation (SD). The Pearson's Chi-square test was used to compare categorical variables. The categorical variables are expressed in frequencies and percentages. Spearman's rho correlation coefficient was used for correlation analysis. A p-value <0.05 was considered significant. All analyses were performed using the SPSS version 22.0 software SPSS et al., USA) — one-way analysis of variance (ANOVA) for continuous variables. Non-normally distributed variables were analyzed using the Mann-Whitney U or Kruskal-Wallis test (1).

3. Results

Participant demographics are shown in Table 1. Mean Achilles tendon thickness was 0.51 ± 0.15 cm, and CSA was 0.58 ± 0.22 cm² (Table 2).

Based on exercise habits, participants were categorized into two groups: active (n = 43) and sedentary (n = 45). No significant differences were found between the groups in terms of age, height, weight, or Achilles tendon thickness. However, active participants had significantly higher Achilles tendon CSA values (0.56–0.75 cm² vs. 0.42–0.53 cm², p<0.001). Additionally, active individuals demonstrated better dynamic balance performance compared to sedentary individuals (TUG: 6.61 ± 1.03 seconds vs. 8.97 ± 0.96 seconds, p<0.001) and had a lower fall index (9–22 vs. 37.25–64.25, p<0.001) (Table 3).

A significant positive correlation was found between Achilles tendon thickness and age. A positive correlation was also found between tendon cross-sectional area and body weight. Furthermore, Achilles tendon CSA values were negatively correlated with both TUG test and fall index. No significant correlation was observed between other parameters (Table 4).

Table 1. Demographic variables

	N=88
Age	25.04±3.58
Weight	80.3±14.23
Height	178.09±7.68
BMI	25.10±3.5
Dominant extremity	
• Right	68 (%86.1)
• Left	11 (%13.9)
Active sports	43 (%48.8)
Sedanter	45 (%51.1)
TUG test	7.77±1.55

Tetrax-fall index	33.68±21.58

mean±SD. TUG: Time Up and Go

Table 2. Achilles tendon dimensions

	N=88
USG-Thickness	0.51±0.15
USG-CSA	0.58±0.22

mean±SD.

USG: Ultrasonography, CSA: Cross-sectional Area

Table 3. Comparative analysis of the active and sedentary groups

	Active	**Sedentary**	
	N=43	**N=45**	**p**
Age	23-28	22.75-27.25	0.176
Weight	72-91	68.75-85	0.158
Height*	178.55±8.20	177.61±7.17	0.259
BMI	23.30-27.38	22.24-26.57	0.910
TUG test*	6.61±1.03	8.97±0.96	<0001
Tetrax-fall index	9-22	37.25-64.25	<0001
USG-Thickness	0.43-0.61	0.41-0.54	0072
USG-CSA	0.56-0.75	0.42-0.53	<0.001

*Mean 25-75, * median±SD, Mann-Whitney U.*

TUG: Time Up and Go, USG: Ultrasonography, CSA: Cross-sectional Area

Table 4. Correlation between Achilles tendon dimensions and demographic variables

		USG-Thickness	**USG-CSA**
Age	r	0.291	0.210
	p	0.007	0.053
Weight	r	-0.104	0.266
	p	0.343	0.014
Height	r	-0.109	0.194
	p	0.320	0.076
BMI	r	-0.033	0.212
	p	0.763	0.051
TUG test	r	-0.205	-0.715
	p	0.060	<0.001
Tetrax-fall index	r	-0.229	-0.645
	p	0.035	<0.001

BMI: Body Mass Index, TUG: Time Up and Go.

4. Discussion

This study examined the relationship between Achilles tendon dimensions and balance in young, healthy men. The Achilles tendon thickness and CSA were measured as 0.51 ± 0.15 cm and 0.58 ± 0.22 cm², respectively, in healthy young men. These findings are consistent with previous studies, such as Patel et al. (0.46 ± 0,04 cm thickness; 0.61 ± 0.11 cm² CSA), Ying et al. (5.23 ± 0.45 mm thickness; 56.91 ± 7.58 mm² CSA), and Visser et al. (4.9 (3.8–6.9) mm thickness) (5,6,12). However, thicker tendon structures reported in the Turkish population by Canbolat et al. (4.38 mm thickness; 55 mm² CSA) suggest potential influences of genetic, environmental, and physical activity differences (4). These variations highlight the need for standardized measurement protocols and further population-specific research.

The decrease in collagen fibril size and density with increasing age makes the Achilles tendon more susceptible to repetitive microtrauma and microtears. This process leads to structural remodeling of the tendon and subsequent hypertrophy (15). Pang et al. identified a significant relationship between age and Achilles tendon CSA but found no similar association for tendon thickness (7). Patel et al. reported significant correlations between tendon length, thickness, and CSA with height parameters (6). Conversely, Canbolat et al. found a relationship only between tendon sizes and weight, with no significant associations observed for other demographic variables (4). In our study, significant correlations were observed between tendon thickness and age and CSA and weight. However, the heterogeneity of participants in age, height, weight, and ethnicity poses challenges for cross-study comparisons.

The Achilles tendon is critical in maintaining balance due to its biomechanical properties. The elastic and viscoelastic properties of the tendon help regulate changes in center of gravity that occur during postural balance. Together with the triceps surae muscle group, the Achilles tendon supports the body against the effects of gravity, allowing for precise adjustments that provide balance. (16–18). Scholes et al. found that male patients with Achilles tendinopathy exhibited impaired balance on the affected side and a significant positive relationship between Achilles tendon thickness and COP width (9). In our study, a significant negative correlation was observed between CSA and both TUG test and fall risk. This finding suggests that tendon dimensions may have a considerable influence on balance and postural control. However, due to the cross-sectional design of the study, the causal direction of these relationships cannot be definitively assessed. Furthermore, it should be noted that balance control cannot be explained solely by tendon structures; multiple components, such as the vestibular system, visual inputs, muscle strength, and neuromuscular coordination, also play a decisive role in this process.

Regular exercise leads to significant structural adaptations in tendons. Long-term mechanical loading results in microtears and degenerative changes in tendons, followed by a repair process and ultimately hypertrophy (19). In our study, 50.5% of the participants were active in sports, while 49.4% had a sedentary lifestyle. Active sports participants had larger CSA areas than sedentary individuals, consistent with the findings of Salinero et al. (8), Tüfekçi et al. (20), Milgrom et al. (21), and Ying et al. (12). The fact that active individuals performed better than sedentary individuals in both dynamic and static balance tests supports the notion that the structural and functional adaptations acquired by tendons through exercise have positive effects on motor skills such as balance.

In this study, USG was used to evaluate the morphological characteristics of the Achilles tendon. Ultrasound was chosen because of its non-invasive nature, its lack of ionizing radiation, and its lack of known adverse effects on patient health (22). It is a reliable method that allows for high-precision imaging of details, especially in superficial anatomical structures such as the Achilles tendon. Its high-resolution imaging capacity enables accurate measurements of tendon thickness and cross-sectional area. Furthermore, its low cost and portability facilitate its applicability to large groups of participants. (23).

The main limitations of the study include a small sample size, the absence of elastography, and the lack of a detailed analysis of exercise duration, frequency, or type in the active group. These factors limit the generalizability of the findings. Considering the effects of various parameters on balance, longitudinal and interventional studies with larger sample sizes are needed to better understand the relationship between tendons and balance. Moreover, as cross-sectional designs are inadequate for evaluating cause-and-effect relationships, it was not possible to determine the causal aspects of the relationship between tendon morphology and balance.

In conclusion, this study, unlike research in the literature that focuses primarily on tendon characteristics associated with aging or pathological conditions such as tendinopathy, examined the relationship between Achilles tendon size and balance in healthy young men. The findings suggest that a larger tendon size is associated with improved balance performance and a reduced risk of falls. These results support the potential positive effects of physical activity on tendon morphology and balance capacity. The data provide valuable insights into improving athletic performance, reducing the risk of falls in older individuals, and developing effective rehabilitation protocols.

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