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Differences at the Achilles Insertion Between Adults with Insertional and Midportion Achilles Tendinopathy as Observed Using Ultrasound

N. Hamdan Alghamdi[1,2], R. T. Pohlig[3], J. M. Sions[2], K. Grävare Silbernagel[2]

[1] *Department of Physical Therapy, King Abdulaziz University, Jeddah, Saudi Arabia*
[2] *Department of Physical Therapy, University of Delaware, Newark (DE), U.S.A.*
[3] *Biostatistics Core, University of Delaware Newark (DE), U.S.A.*

CORRESPONDING AUTHOR:
Karin Grävare Silbernagel
Department of Physical Therapy
University of Delaware
540 South College Avenue
Newark (DE), U.S.A.
E-mail: ghamdinh@udel.edu

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SUMMARY

Background. The purpose of this study was to determine structural and pathological differences of Achilles tendon insertion between insertional Achilles tendinopathy (IAT) and midportion Achilles tendinopathy (MidAT) in both injured and uninjured sides.

Methods. Patients (n = 34; 58.8% male) with unilateral Achilles tendinopathy (50% with IAT; 50% with MidAT) were recruited. Median age 52 years and Victorian Institute of Sport Assessment – Achilles (VISA-A) score mean 59, and 17 (12 male) had MidAT, median (range) age of 58 (48) years, and VISA-A score mean (SD) 59.1 (19.7). Ultrasound imaging was used to evaluate structural measurements at the insertion (insertional length, bone-to-insertion length, and tendon insertion angle), tendon length (calcaneus to soleus), tendon thickness at the calcaneal edge, and the presence of pathological changes (boney deformity and/or calcification). A 2 × 2 mixed Analysis of Variance (group by side) was used to compare IAT and MidAT groups and injured and uninjured sides.

Results. Tendon thickness at the calcaneus on the injured side was significantly greater than the uninjured side in the IAT group but not in the MidAT group (p = .001). VISA-A score was 59.9 (18.7) in IAT group and 59.1 (19.7) for MidAT group (p = 0.909). There were no significant group-by-side interactions for structural measurements at insertion site.

Conclusions. Calcaneal edge tendon thickness was the only significant structural difference observed between involved and uninvolved sides in IAT, although this was not found in in MidAT.

KEY WORDS

Achilles disorders; ultrasound imaging; ultrasonography; enthesopathy; tendon morphology.

BACKGROUND

Achilles tendinopathy is a clinical diagnosis characterized by pain, swelling, and load-bearing impairment (1). It can be categorized into two distinct diagnoses: insertional Achilles tendinopathy (tendon pathology less than 2 cm proximal to the calcaneus) or midportion Achilles tendinopathy (tendon pathology 2-7 cm proximal to the calcaneal insertion) (1). These disorders are considered different regarding their underlying pathophysiology, clinical features, and treatment response (2-6). While it is clear that the mechanism of Achilles tendinopathy is mainly a result of overloading, the reason why someone develops insertional *versus* midportion tendinopathy, is poorly understood.

Patients with either of these disorders may present in the clinic with similar symptoms and performance impairments, but a simple way to differentiate between insertional and midportion Achilles tendinopathy is by physical examination (7). Specifically, tendon palpation and subjective reporting are reliable and valid tests for diagnosing midportion Achilles tendinopathy (8, 9). Palpation reveals pain location, which is useful when distinguishing between insertional and midportion Achilles tendinopathies and other differential diagnoses (7). Special tests, including the Royal London Hospital test and the arc sign are also helpful tests for confirming midportion Achilles tendinopathy (10, 11). In general, the capability of these clinical measures is more diagnostic than just screening (12). Magnetic resonance imaging or ultrasonographic examinations are helpful to determine tendinosis presence and location and other pathological changes (3, 13). Pathological changes, such as insertion-site calcifications and boney deformity, are associated with metabolic disorders and increased with age among individuals with insertional symptoms (14, 15), but their presence among those with midportion symptoms, has not been evaluated. Imaging of tendinopathy has also been suggested to be useful for monitoring clinical progress (16-18).

The prognosis for patients with insertional Achilles tendinopathy is not as optimistic compared to midportion Achilles tendinopathy (5, 19). Insertional Achilles tendinopathy is known as a recalcitrant injury, and responds poorly to nonsurgical treatments (5, 19-21). Patients with insertional Achilles tendinopathy have been reported to experience more symptoms, including pain, and more significant disability, compared to those with midportion injuries (22). Non-surgical treatments have also been found to be less successful for insertional Achilles tendinopathy compared to midportion Achilles tendinopathy (5, 19). For example, the success rate of using traditional eccentric exercise (without limiting dorsiflexion range of motion) was ~ 30% in patients with insertional Achilles tendinopathy (5, 23).

Insertion anatomical features might lead to a predisposition for insertional Achilles tendinopathy and affect treatment outcomes, since compression between the tendon and calcaneus is considered a mechanistic explanation of the injury itself (21). Differences in insertional structural measurements between insertional Achilles tendinopathy and midportion Achilles tendinopathy groups on injured and/or uninjured sides may indicate that these differences are injury related. We have developed reliable ultrasound measurements for evaluating the Achilles tendon insertion (24) that can be used to compare the anatomical features between patients with insertional *versus* midportion Achilles tendinopathy. The size of the tendon attachment on the calcaneus may influenc the load distribution and have effect on tendon injury location. Therefore, the purpose of this study was to evaluate for structural differences of the Achilles tendon insertion, tendon geometry, and pathological changes between insertional and midportion Achilles tendinopathy patient groups, on both the injured and uninjured sides. In both injured and uninjured sides, we hypothesized that bone-to-insertion length would be longer, and insertional length and length to soleus would be shorter among the insertional Achilles tendinopathy group when compared to the midportion Achilles tendinopathy group. We also hypothesized the tendon insertion angle would be smaller, and tendon thickness would be greater in the injured sides as compared to the uninjured sides in patients with insertional Achilles tendinopathy but not among those with midportion Achilles tendinopathy. Finally, we hypothesized that pathological changes (presence of boney deformity and/or calcification) in injured sides (but not in uninjured sides) would be present more frequently in individuals with insertional Achilles tendinopathy as compared to individuals with midportion Achilles tendinopathy.

MATERIALS AND METHODS

Study design and participants selection

This is a retrospective analysis of a cross-sectional study including 34 participants diagnosed with Achilles tendinopathy (n = 17 insertional and n = 17 midportion). The participants were included from two prospective studies of individuals with Achilles tendinopathy between November 2014 and June 2019. All participants were clinically-diagnosed by a physical therapist or physician prior to enrollment. We included participants who were at least 18 years-old and had a unilateral Achilles tendon injury. The criteria for clinical diagnosis of Achilles tendinopathy (25) are: 1) localized pain, swelling with palpation and sometimes stiffness at 2-7 cm proximal to the calcaneal insertion for midportion, and at the tendon-bone junction (but not extending more than 2 cm proximal to calcaneus) for insertional Achilles tendinopathy; 2) increased symptoms with loading; and 3) impaired performance. Exclusion criteria included a history of Achilles tendon rupture, and/or foot and/or ankle surgery. Participants with symptoms on the uninjured side, as indicated by a scoring < 90 on the VISA-A questionnaire, were excluded. The VISA-A consists of eight questions that are scored from 0 to 100, where 100 indicates symptom-free and physically active. The study was approved by the Institutional Review Board for Human Subjects Research at the University of Delaware (approval numbers: 670923-15 and 1090153-4. Date of approval: 12/02/2019 and 08/20/2018) and written consents were obtained from all participants prior to participation.

Patient-reported measures

Participants completed questionnaires regarding their demographics, past medical history, physical activity level, and injury severity. Current physical activity level was assessed with the Physical Activity Scale (PAS) questionnaire, which is a 6-level scale, where level-one indicate the person hardly participate in any physical activity; and level-6 person participate in very hard exercise regularly and several times a week (26, 27). While an index of the clinical severity of Achilles tendinopathy was determined using the Victorian Institute of Sports Assessment-Achilles (VISA-A) questionnaire, the VISA-A questionnaire is reliable and valid measurement tool (28).

Measurement of Achilles tendon structure

Achilles tendon structure was measured using a LOGIQe ultrasound imaging system (GE Healthcare, Milwaukee, WI) using a wide-band linear transducer (10.0 MHz) with a depth setting of 3.5 cm. The first author, who has formal musculoskeletal ultrasound imaging training and has over 2 years of expertise with ultrasound imaging of the Achilles tendon, obtained and measured the ultrasound images. We followed a previously published protocol for imaging Achilles tendon structure bilaterally (24, 29). In brief, we used long-axis and extended field-of-view to obtain three images in prone where participants' knees and hips were extended, and feet were hanging freely over the edge of the bed. The images were exported to an external computer and measured by a single examiner (24) using OsiriX imaging software (Pixmeo SARL, Bernex, Switzerland). On each image the following measurements were taken: insertional measurements, including insertional length, bone-to-insertion, and tendon insertion angle (24); tendon length (*i.e.*, calcaneus to soleus) (29), tendon thickness at the posterosuperior calcaneal edge; and presence of pathological changes (*i.e.*, boney deformity and/or calcification; see **figure 1**). Mean value of three images per side were used in analyses.

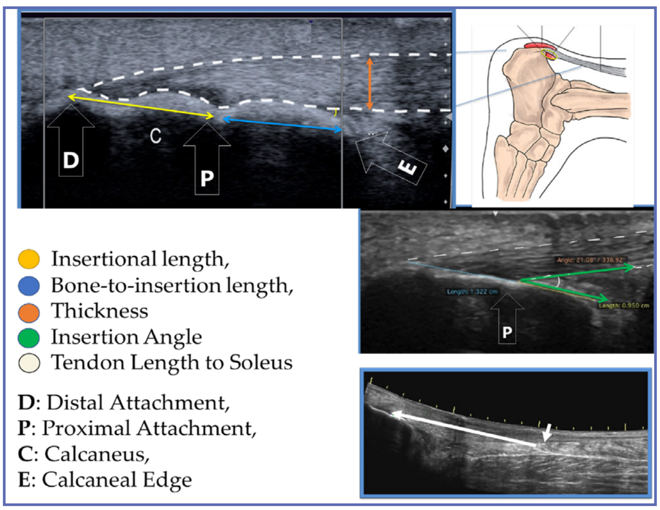

Figure 1. Ultrasound measurements for insertional length, bone to insertion tendon insertion angle, tendon length (calcaneus to soleus) and tendon thickness at the posterosuperior calcaneal edge for healthy Achilles tendon insertion.

Statistical analysis

A priori power analysis was completed to estimate the sample size needed for this study. For the interaction effect in a 2 × 2 mixed Analysis of Variance (ANOVA), a sample size of 34 (n = 17 per group) would be powered (power =. 90), to detect a moderately large effect, (η_p^2 = .10) with nominal alpha, α = .05, and a moderately low correlation among repeated measures, r = .30. This effect size was chosen based on prior research hypothesized differences of insertional length, tendon insertion angle, and tendon thickness.

All statistical analysis were performed using SPSS version 26 (IBM Corp., Released 2019. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp) of all data. Descriptive analysis of demographic and symptoms severity were reported. Independent t-test and Chi-square were used to compare patient demographics between groups (*i.e.*, age, sex, BMI, symptom severity and physical activity level). Differences in insertional Achilles tendon measurements (insertional length, bone-to-insertion, and tendon insertion angle), tendon thickness and tendon length to soleus between insertional and midportion Achilles tendinopathy groups and injured and uninjured sides were analyzed using 2 × 2 mixed ANOVA. Bonferroni correction was applied to group and side comparisons. Differences in the ratio of the presence of calcification and/or boney deformity between groups and injured and uninjured sides were evaluated using z-test for dependent proportions. Partial eta-squared (η^2_p) effect sizes are reported and interpreted as suggested by Cohen (30) as no effect (< 0.01), small effect (≈ 0.06), medium effect (< 0.14), and large effect (≥ 0.14). Also, the size of effect, Cohen's H, was used for z-score test and interpreted as suggested by Cohen (30) as H near 0.2 is a small effect, an H near 0.5 is a medium effect, and an H near 0.8 is a large effect. The level of significance for all tests were set at $p < 0.05$

RESULTS

Patients' characteristics

Overall, 34 participants with unilateral injury were included in the study (17 insertional, and 17 midportion Achilles tendinopathy). The results showed there were no significance differences between the groups for age, sex, height, weight, BMI, VISA-A injured side, VISA-A uninjured side, and PAS (**table I**).

Measurement outcomes

Tendon thickness at the calcaneus on the injured side was significantly greater than the uninjured side in within the insertional Achilles tendinopathy group but not within the

Table I. Characteristics of patients with insertional and midportion Achilles tendinopathy.

	Insertional Achilles Tendinopathy n = 17				Midportion Achilles Tendinopathy n = 17					
	Mean	**SD**	**Median**	**Range**	**Mean**	**SD**	**Median**	**Range**	**p**	**Cohen's d**
Age (years)	48	14	49	46	50	16	58	48	0.610	0.091*
Sex (M:F)	8 Male:9 Female				12 Male:5 Female				0.300	NA
Height (cm)	174.8	11.6	173.9	39.9	175.5	8.5	176.5	31.8	0.832	- 0.073
Weight (kg)	74.5	14.7	77.2	51.6	78.1	16.1	78.1	60.9	0.502	- 0.233
BMI (kg/cm²)	24.2	3.7	23.7	15.2	25.2	3.9	25.2	14.3	0.503	- 0.232
VISA-A injured	59.9	18.7	62.0	62.0	59.1	19.7	67.0	71.0	0.973	0.006*
VISA-A uninjured	96.5	3.0	97.0	10.0	94.8	3.9	94.0	10.0	0.205	0.227*
PAS	4.5	1.3	5.0	4.0	4.2	1.6	5.0	5.0	0.734	0.063*
Symptoms duration (month)	18.5	30.8	6.7	126.9	17.1	36.2	4.4	149.3	0.357	0.162*

*Effect size r was reported for non-parametric test.

midportion Achilles tendinopathy group $F_{(1,32)} = 14.53$, p = .001, $\eta^2_p = 0.31$ (**figure 2**). There were no significant group-by-side interactions for structural measurements for insertional length, $F_{(1,32)} = 1.68$, p = .204, $\eta^2_p = 0.05$, bone-to-insertion length, $F_{(1,32)} = 1.70$, p = 0.202, $\eta^2_p = 0.5$, insertion angle, $F_{(1,32)} = 0.91$, p = 0.346, $\eta^2_p = 0.03$, nor tendon length to soleus, $F_{(1,32)} = 1.73$ p = 0.198, $\eta^2_p = 0.05$. There were no significant main effects (side or group) for insertional length, bone-to-insertion length, insertion angle, nor length to soleus (**figure 3**).

On the injured sides, the insertional Achilles tendinopathy group had a significantly greater number of pathological changes (calcification/boney deformity) present than midportion Achilles tendinopathy group (difference sample proportion 0.48 ± 0.51, z = 2.78, p = .006, Cohen's H= 0.99); no significant between-group difference were found for uninjured sides (difference sample proportion 0.18 ± 0.47, z = 1.09, p = .28, Cohen's H = 0.38) (**figure 4**).

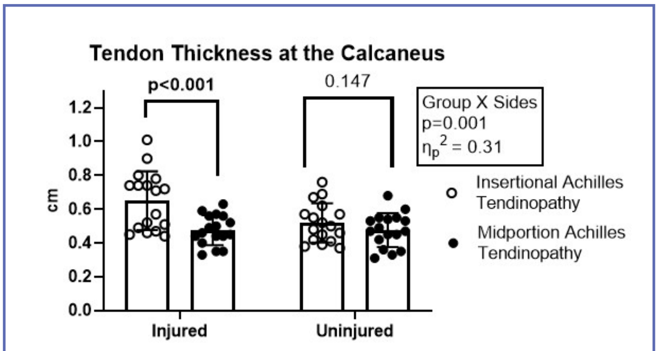

Figure 2. Mean (SD) tendon thickness at the calcaneus differences between groups and sides.

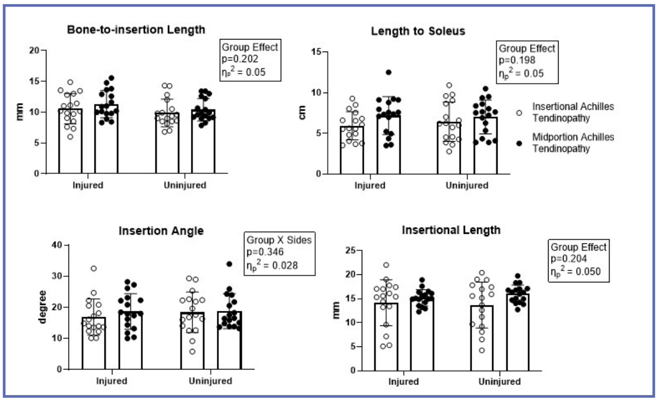

Figure 3. Mean (SD) for anatomical features measurements differences between groups and sides.

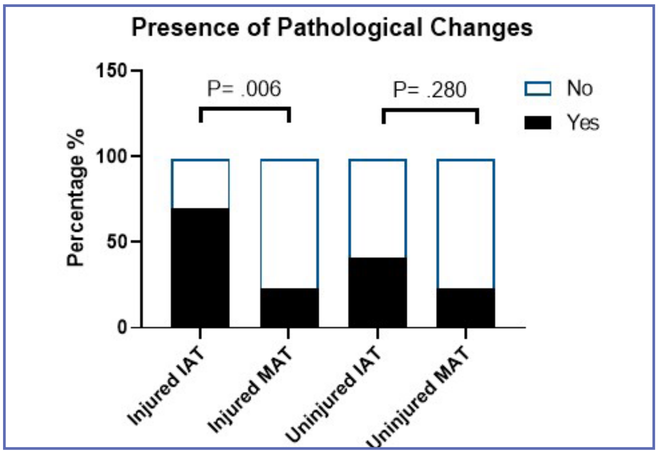

Figure 4. Between-group differences in side-to-side for the proportion of presence of pathological changes.
IAT: insertional Achilles tendinopathy; MAT: midportion Achilles tendinopathy.

DISCUSSION

The aim of this study was to evaluate Achilles tendon insertion using ultrasound imaging and compare the structural measurements of the injured and uninjured sides between patients with insertional and midportion Achilles tendinopathy. We hypothesized structural measurements at the calcaneal insertion (*i.e.*, insertional length, bone-to-insertion length, and tendon insertion angle) would differ between tendinopathy groups and within sides. Our main findings showed differences in ultrasound-imaging obtained measurements of pathological changes (tendon thickness and presence/absence of calcification and/or boney deformity) but not for anatomical feature measurements at Achilles tendon insertion between the sides and groups. The injured side in the insertional Achilles tendinopathy group had significantly greater tendon thickness and more pathological insertional changes than the healthy side, and midportion tendinopathy group's healthy and injured sides. Importantly, no significant differences were detected between sides or groups for measurements related to anatomical features (*i.e.*, bone-to-insertion length, insertional length, tendon insertion angle, nor length to soleus) that may lead to developing insertional Achilles tendinopathy. In summary, measurement variables related to structural pathological changes, but not anatomical features were different between groups.

Increased structural enlargement at the calcaneal insertion could be the cause of injury chronicity in the insertional Achilles tendinopathy group but not in the midportion Achilles tendinopathy group, according to the findings. Findings may explain why eccentric exercise (31) into full dorsiflexion is not beneficial for individuals with insertional Achilles tendinopathy, since at full dorsiflexion the distal tendon, and possibly the areas of pathological changes, are compressed. However, further evidence is required to understand if structural pathology at the calcaneal insertion contributes substantially to increased impingement and/or injury severity.

On the other hand, our results showed that anatomical features of the Achilles tendon and its insertion did not differ between tendinopathy groups, and thus, may not be of relevance in the development of insertional *versus* midportion Achilles tendinopathy. However, we did not include uninjured participants for this study, so we do not have normative values for comparison. In our reliability study, we presented typical average values of bone-to-insertion length and tendon insertion angle in healthy individuals, 9.34 mm and 15.33 degrees, respectively, but they were younger than the groups in this study (24). These two values are lower than our results by few millimeters or degrees and may be related to the age (32) and not the injury development.

Different measurement methods have been applied in imaging studies of patients with insertional Achilles tendinopathy. Kang *et al*. compared radiographic measurements for Haglund's deformity from patients with and without insertional Achilles tendinitis (33). The radiographic measurements evaluated calcification size; between-group differences were not found (33), which is consistent with this study. Two other studies report calcification was present in 70% (33) and 65% (34) of patients with insertional Achilles tendinopathy (on the symptomatic side), which is consistent with our study results. The mechanism of calcium deposition at the insertion, however, is not clear but one theory suggests deposition as an adaptation to increased compression load (35). Measuring the size of calcification/boney deformity is feasible on ultrasound images (34). While in our study we did not measure the size of calcification/bony deformity, insertional length may reflect the size of the deformity. Specificall , patients who showed presence of calcific -tion/boney deformity usually exhibited smaller insertional length. The reason is that calcification/boney deformity is commonly located at the distal insertion, so a larger deformity effectively decreases the insertional length.

Another measurement method was addressed by Sella *et al.* at the heel bone, where varying angle measurements at the calcaneus from plain radiographs (made with patient standing) in patients with different Achilles tendon disorders were obtained (36). The radiographic measurements were used to identify calcaneal deformity before planning treatment. Our study, however, is the first, to our knowledge, to compare and evaluate tendon insertional angle obtained from ultrasound imaging with the ankle at rest; however, no differences between groups were found as this measurement did not show differences of the height of the superior aspect of the calcaneus. Future studies should consider measuring the insertion using a standardized ankle position, along with the resting angle, since the resting angle might vary between individuals.

We hypothesized that the direction of pull on the Achilles tendon insertion would depend on how far distally the soleus attached, such that a more distally attached soleus (resulting in a shorter free tendon) would cause more of an anterior pull on the Achilles tendon insertion helping to explain injury development; however, our hypothesis was not confirmed The soleus length measurement was similar between groups. Perhaps individuals with insertional Achilles tendinopathy developed soleus muscle atrophy leading to an increase distance between the proximal Achilles tendon attachment and the soleus muscle as seen in patients with Achilles tendon rupture (37). It may be worth studying side-to-side differences of the length to soleus tendon in patients with acute *versus* chronic Achilles tendinopathy due to disuse atrophy

of the soleus muscle to determine changes in tendon to soleus length. The majority of our sample had symptoms duration slightly greater than 6 months. Prolonged symptoms duration has been associated with musculoskeletal disuse (38), and soleus muscle is commonly impaired in Achilles tendon injuries (39). Further evidence is needed to explore if tendon to soleus length increases are associated with prolonged symptom duration in patients with Achilles tendinopathy.
Medial pain and tenderness have been reported in about 50% of patients with chronic insertional Achilles tendinopathy as a result of plantaris tendon involvement (40). The amount of compression at the calcaneal insertion may also be uneven as a result of the degree of twisting of the fascicles from the aponeuroses of gastrocnemius to the tendon insertion (41). Unfortunately, our ultrasound imaging measurements were obtained at the tendon insertion midline, and therefore would not have detected any between-group differences of the medial or lateral tendon attachments.

Limitations

Additional study limitations include a heterogeneous sample in terms of age and symptom severity (which might reflec differing stages of injury recovery) and might have influence the results. Given the cross-sectional study design, we cannot evaluate causation, *i.e.*, understand the role of structure on injury characteristics (chronicity and symptom severity). While measurement procedures have established reliability, the measurements were taken in ankle resting position instead of a standardized position. It may be beneficial to perform the US measurements in various ankle positions to understand the influence of structure on possible compression at the insertion. Further, having a healthy comparison group could have aided with results interpretation as these results cannot be applied to those with bilateral Achilles tendinopathy. Finally, we did not evaluate other pathological features such as bursitis or neovascularization, and/or anatomical features such as the presence of a plantaris tendon.

CONCLUSIONS

We found greater tendon thickness on the posterior aspect of the calcaneus and more presence of pathological changes in patients with insertional Achilles tendinopathy compared to midportion Achilles tendinopathy on the injured sides. In addition, measurements of anatomical features were not different between groups or sides and may not be related to injury development.

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DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

NA, KS: conceptualization, project administration, investigation and resources. NA, RP: formal analysis. KS: funding acquisition. NA, RP, MS, KS: methodology. RP, MS, KS: supervision, reading and approving the final manuscript. NA: visualization and writing – original draft.

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CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

REFERENCES

1. Clain MR, Baxter DE. Achilles Tendinitis. Foot Ankle 1992;13(8):482–7.
2. Tan SC, Chan O, Tan SC, Chan O. Achilles and patellar tendinopathy : Current understanding of pathophysiology and management. 2018;8288.
3. Maffulli N, Longo UG, Kadakia A, Spiezia F. Achilles tendinopathy. Foot Ankle Surg 2020;26(3):240–9.
4. Alfredson H, Spang C. Clinical presentation and surgical management of chronic Achilles tendon disorders — A retrospective observation on a set of consecutive patients being

operated by the same orthopedic surgeon. Foot Ankle Surg 2018;24(6):490–4.
5. Fahlström M, Jonsson P, Lorentzon R, Alfredson H. Chronic Achilles tendon pain treated with eccentric calf-muscle training. Knee Surgery Sports Traumatol Arthrosc 2003;11(5):327–33.
6. Sederberg M, Cushman DM. Current Treatments of Insertional Achilles Tendinopathy. Curr Phys Med Rehabil Rep 2020;8:354–63.
7. Silbernagel KG, Hanlon S, Sprague A. Current Clinical Concepts: Conservative Management of Achilles Tendinopathy. J Athl Train 2020;55(5):438–47.
8. Hutchison AM, Evans R, Bodger O, *et al*. What is the best clinical test for achilles tendinopathy? Foot Ankle Surg 2013;19(2):112–7.
9. Divani K, Chan O, Padhiar N, *et al*. Site of maximum neovascularisation correlates with the site of pain in recalcitrant mid-tendon Achilles tendinopathy. Man Ther 2010;15(5):463–8.
10. Martin RL, Chimenti R, Cuddeford T, *et al*. Achilles Pain, Stiffness, and Muscle Power Deficits: Midportion Achilles Tendinopathy Revision 2018. J Orthop Sport Phys Ther 2018;48(5):A1–38.
11. Maffulli N, Kenward MG, Testa V, Capasso G, Regine R, King JB. Clinical diagnosis of Achilles tendinopathy with tendinosis. Clin J Sport Med 2003;13(1):11–5.
12. Reiman M, Burgi C, Strube E, Prue K, Ray K, Elliott A, *et al*. The Utility of Clinical Measures for the Diagnosis of Achilles Tendon Injuries: A Systematic Review With Meta-Analysis. J Athl Train 2014;49(6):820–9.
13. Shaikh Z, Perry M, Morrissey D, Ahmad M, Del Buono A, Maffulli N. Achilles Tendinopathy in Club Runners. Int J Sports Med 2012;33(05):390–4.
14. Zellers JA, Bley BC, Pohlig RT, Alghamdi NH, Silbernagel KG. Frequency of pathology on diagnostic ultrasound and relationship to patient demographics in individuals with insertional Achilles tendinopathy. Int J Sports Phys Ther 2019;14(5):761–9.
15. Giai Via A, Oliva F, Padulo J, Oliva G, Maffulli N. Insertional Calcific Tendinopathy of the Achilles Tendon and Dysmetabolic Diseases. Clin J Sport Med 2022 Jan 1;32(1):e68-e73.
16. Khan KM, Forster BB, Robinson J, *et al*. Are ultrasound and magnetic resonance imaging of value in assessment of Achilles tendon disorders? A two year prospective study. Br J Sports Med 2003;37(2):149–53.
17. Galletti S. Sonoelastography in the diagnosis of tendinopathies: an added value. Muscles Ligaments Tendons J 2015;325–30.
18. Chianca V, Zappia M, Oliva F, Luca B, Maffulli N. Post - operative MRI and US appearance of the Achilles tendons. J Ultrasound 2020;23(3):387–95.
19. Bernstein DN, Anderson MR, Baumhauer JF, *et al*. A Comparative Analysis of Clinical Outcomes in Noninsertional Versus Insertional Tendinopathy Using PROMIS. Foot Ankle Spec 2019;12(4):350–6.
20. Verrall G, Schofield S, Brustad T, Physio D. Chronic Achilles Tendinopathy Treated With Eccentric Stretching Program. Foot Ankle Int 2011;32(9):843–9.
21. Maffulli N, D'Addona A, Gougoulias N, Oliva F, Maffulli GD. Dorsally Based Closing Wedge Osteotomy of the Calcaneus for Insertional Achilles Tendinopathy. Orthop J Sport Med 2020;8(3):1–8.
22. Silbernagel KG, Alghamdi NH, Corrigan P. Structural, Functional, and Symptomatic Differences In Patients with Insertional or Midportion Achilles Tendinopathy. 5th Int Sci Tendinopathy Symp from Sept 27-29, 2018 Oral Present.
23. Rompe JD, Furia J, Maffulli N. Eccentric Loading versus Eccentric Loading plus Shock-Wave Treatment for Midportion Achilles Tendinopathy. Am J Sports Med 2009;37(3):463–70.
24. Alghamdi NH, Killian M, Aitha B, Pohlig RT, Silbernagel KG. Quantifying the Dimensions of Achilles Tendon Insertional Area Using Ultrasound Imaging A Validity and Reliability Study. Muscles Ligaments Tendons J 2019;9(4):544–51.
25. van Dijk CN, van Sterkenburg MN, Wiegerinck JI, Karlsson J, Maffulli N. Terminology for Achilles tendon related disorders. Knee Surgery Sports Traumatol Arthrosc 2011;19(5):835–41.
26. Grimby G. Physcial activity and muscle training in the elderly. Acta Med Scand 1986;711:233–7.
27. Washburn RA, Smith KW, Jette AM, Janney CA. The physical activity scale for the elderly (PASE): Development and evaluation. J Clin Epidemiol 1993;46(2):153–62.
28. Robinson JM, Cook JL, Purdam C, *et al*; Victorian Institute Of Sport Tendon Study Group. The VISA-A questionnaire: a valid and reliable index of the clinical severity of Achilles tendinopathy. Br J Sports Med 2001;35(5):335-41.
29. 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 Tendons J 2016;6(1):104–10.
30. Cohen J. Statistical Power Analysis for the Behavioral Sciences. New Jersey: Lawrence Erlbaum Associates, 1988.
31. Fahlström M, Jonsson P, Lorentzon R, Alfredson H. Chronic Achilles tendon pain treated with eccentric calf-muscle training. Knee Surg Sports Traumatol Arthrosc 2003;11(5):327–33.
32. Novotny SA, Warren GL, Hamrick MW. Aging and the Muscle-Bone Relationship. Physiology 2015;30(1):8–16.
33. Kang S, Thordarson DB, Charlton TP. Insertional Achilles Tendinitis and Haglund's Deformity. Foot Ankle Int 2012;33(6):487–91.
34. Chimenti RL, Chimenti PC, Buckley MR, Houck JR, Flemister AS. Utility of Ultrasound for Imaging Osteophytes in Patients with Insertional Achilles Tendinopathy. Arch Phys Med Rehabil 2016;97(7):1206–9.
35. Zhang Q, Zhou D, Wang H, Tan J. Heterotopic ossification of tendon and ligament. J Cell Mol Med 2020;24(10):5428–37.
36. Sella EJ. Disorders of the Achilles tendon and its insertion. Clin Podiatr Med Surg 2005;22(1):87–99.
37. Heikkinen J, Lantto I, Flinkkila T, *et al*. Soleus Atrophy Is Common After the Nonsurgical Treatment of Acute Achilles Tendon Ruptures: A Randomized Clinical Trial Comparing Surgical and Nonsurgical Functional Treatments. Am J Sports Med 2017;45(6):1395–404.
38. Faur C, Patrascu JM, Haragus H, Anglitoiu B. Correlation between multifidus fatty atrophy and lumbar disc degeneration in low back pain. BMC Musculoskelet Disord 2019;20(1):414.
39. Hoffmann A, Mamisch N, Buck FM, Espinosa N, Pfirrmann CWA, Zanetti M. Oedema and fatty degeneration of the soleus and gastrocnemius muscles on MR images in patients with achilles tendon abnormalities. Eur Radiol 2011;21(9):1996–2003.
40. Alfredson H, Masci L, Spang C. Ultrasound and surgical inspection of plantaris tendon involvement in chronic painful insertional Achilles tendinopathy: a case series. BMJ Open Sport Exerc Med 2021;7(1):e000979.
41. Mahan J, Damodar D, Trapana E, *et al*. Achilles tendon complex: The anatomy of its insertional footprint on the calcaneus and clinical implications. J Orthop 2020;17(April 2019):221–7.