

Use of ultrasound to identify chronic Achilles tendinosis in an active asymptomatic population

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ABSTRACT

Objectives. The aim of the study was to identify the prevalence of degenerative change in the Achilles tendons of currently asymptomatic individuals and correlate it with their degree of physical activity.

Methods. We recruited 126 healthy subjects, mean age 33.1, range 20 – 50 (78 males and 48 females). Their levels of physical activity were assessed by a questionnaire and scored using the Allied Dunbar Fitness Survey criteria, modified to exclude non-weight bearing activity. One investigator, who was blinded to the activity levels, ultrasound scanned all 252 tendons. Tendons were examined for evidence of hypoechoic regions, localised fusiform thickening, and the cross-sectional diameter of each was measured.

Results. Overall 59% (149) of tendons had ultrasound evidence of hypoechoic regions. In 50 tendons (in 31 patients) there was a history of previous Achilles pain and 84% of these had hypoechoic regions. Thirty three percent of subjects in the lowest quartile of activity had evidence of hypoechoic regions compared to 72.6% in the most active quartile (Pearson χ^2 $p < 0.01$). Only 5.6% of all Achilles tendons had ultrasound evidence of localised fusiform thickening, with none in the inactive group compared to 6.4% in the very active group (Pearson χ^2 $p = 0.03$).

Conclusions. Degenerative changes, identified by ultrasound, are common in the Achilles tendon and are often asymptomatic. There is a direct relationship between these changes and levels of current and lifetime activity. The natural history of asymptomatic chronic Achilles tendinosis and their relationship to future pain or tendon pathology is unknown.

INTRODUCTION

Chronic painful conditions arising in the Achilles tendon are a relatively common injury in athletes, particularly in distance runners when there is repetitive loading of the tendon (1). It is most commonly seen in

athletes aged between 35 and 45 years, but it can present much earlier, particularly in military populations when there is the potential for injury from repetitive and unaccustomed overuse during training (2).

Most of the areas of degenerative change found in chronic Achilles tendinosis develop in the middle third of the tendon, between 2 and 6cm above its insertion into the calcaneus (3). It is now recognised that microcirculatory blood flow is elevated in symptomatic patients with midportion tendinopathy, but not in asymptomatic normal tendons (4). Histopathology of patients with chronic Achilles pain has demonstrated that the vast majority have an underlying degenerative process characterised by an absence of inflammatory cells and a poor healing response (5). These findings are consistent across the other tendinopathies, with similar results from examining both patellar (6) and rotator cuff tendons (7).

Chronic tendinosis does not always appear to be symptomatic. Post mortem studies have indicated Achilles tendon degeneration in 30% of previously asymptomatic individuals (8), and areas of degenerative patellar tendons have also been identified by ultrasound in asymptomatic elite athletes with no history of 'jumper's knee' (9 – 11). On average, only 10% (range 1% to 36%) of individuals with complete Achilles tendon rupture are symptomatic before the event, yet research has shown that nearly every tendon studied early after spontaneous rupture had obvious pre-existing histopathological degenerative changes at the rupture site (12 – 14).

Ultrasound is now being used extensively as a diagnostic tool in musculoskeletal radiology, particularly in relation to tendon disease. Ultrasound imaging is a safe, objective and relatively inexpensive means of examining the musculoskeletal system, but most importantly, it is a dynamic process (15). The Achilles tendon, being both accessible and superficial, is relatively easy to examine with ultrasound, and with the introduction of high frequency transducers, good quality images can be achieved (16 – 19). A normal Achilles tendon on high resolution real-time ultrasound appears as an echogenic structure with an internal architecture of longitudinally orientated lines or bundles (20). An abnormal Achilles tendon, with degenerative changes that are consistent with chronic Achilles tendinosis, has irregular tendon structure and

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fibre orientation, separation of the tendon fibres (due to an increase in the ground substance, and therefore hypoechoic on ultrasound), and local fusiform thickening of the tendon in the more severe cases (21 – 24).

Accurate measurement of physical activity and exercise has been a challenge for researchers for many years. Although there is no 'gold standard' for measurement in this field, physical activity questionnaires are being increasingly used for assessment, intervention and evaluation (25). A variety of questionnaires have now been developed in an attempt to measure the range of physical activities seen between work, home and in leisure time (26). The Allied Dunbar National Fitness Survey (27) is a valid and reliable study which assessed recent levels of physical activity in a large population, and has been modified to exclude non weight-bearing activity (28).

We undertook to test the hypothesis that the ultrasound findings consistent with chronic Achilles tendinosis exist in a physically active population who are currently asymptomatic. The secondary aim was to examine the relationship between any identified ultrasound changes and their current or previous levels of physical activity.

METHODS

Study design.

This was a cross-sectional study of a population with different physical activity levels and no current Achilles tendon symptoms. The subjects, all volunteers, were recruited from the staff based at the Defence Medical Rehabilitation Centre, Headley Court. Both male and female subjects were recruited, within the age range 20 to 50 years old (inclusive). Subjects with a history of Achilles pain were included, but those who were currently complaining of Achilles pain in either tendon (defined as pain in or around the Achilles tendon in the past 4 weeks) were excluded.

The study received ethics approval from the Defence Medical Services Research Committee and all study subjects provided written informed consent.

Validation study

Prior to the main study, a validation study was undertaken to assess both reliability and reproducibility of the principle investigator's (AN) scanning technique. His scanning was validated for reliability against an experienced musculoskeletal radiologist. An Achilles tendon abnormality identified on ultrasound was defined as either the presence of a hypoechoic region within the tendon itself or a localised fusiform thickening (to the naked eye on the ultrasound screen) with loss of the uniform fibrillar arrangement of the collagen fibres of the tendon. Agreement for evidence of a hypoechoic region between the two observers gave a Kappa of 0.85 ($p = 0.001$),

and when looking for evidence of local tendon fusiform thickening on a longitudinal image a Kappa of 0.65 ($p = 0.015$). Achilles diameter measurements between the two observers were compared, with the Pearson correlation coefficient ($r = 0.85$ ($p = 0.0001$)). In the reproducibility study the coefficient of variation for the cross-sectional diameter measurements was 2.04 % – 3.25 %. This demonstrated repeatability and accepted levels of reproducibility of AN's scanning technique for the parameters examined in this study.

Outcome measures.

Ultrasound. Ultrasound imaging was performed and analysed in real time using a high-resolution linear array 8 – 16 MHz ultrasound transducer (Diasus, Dynamic Imaging Ltd, Livingstone, Scotland). The settings on the ultrasound machine were standardised prior to each examination and no stand off medium was required. The scanner (AN) was blinded to the subject's history, and did not have access to the completed questionnaire until after the scanning. The subjects were asked to lie prone with both ankles hanging over the end of the examination couch, and each Achilles was examined with the foot slightly dorsiflexed to reduce any bow stringing of the tendon. Each Achilles tendon was examined in both the longitudinal and the transverse (axial) plane, and the antero-posterior thickness was measured at the thickest point on three separate occasions, (each on different images, but taken at the same sitting), from which an average maximum thickness of the tendon was calculated. The ultrasound was only used to identify the presence or absence of the parameters consistent with chronic tendinosis; hypoechoic areas or localised fusiform thickening. There was no intention to try and quantify the severity of any pathology; the subjects were categorised as having the ultrasound changes or not.

Physical activity questionnaire. The subjects were asked on the questionnaire to declare their average weekly level of physical activity over the previous month in minutes of moderate or vigorous activity. Vigorous activity was classified as activity during which the subject was breathless or sweating, and included all multiple sprint sports eg football, squash. Moderate exercise was any other form of physical activity, which did not result in the subject becoming breathless or sweating. The time declared in minutes was then translated into units of physical activity, with one unit the equivalent of 15 minutes of vigorous exercise, or 30 minutes of moderate exercise. We then categorised the subjects into four groups dependant on their stated levels of physical activity; 0 – 1 units were grouped 'Low', 2 – 4 units 'Mild', 5 – 9 units 'Moderate' and 10 or above 'Very Active'.

Data analysis.

A power calculation performed using Arcus Pro-Stat using an acceptable power of 80% and an alpha of 5% indicated that at least 54 subject tendons were required in each group to minimise the probability of failing to detect a real effect. We recruited more than 54 tendons in three of the groups (see Table 1). Data were tested for normal distribution using the Kolmogorov Smirnov test. As the data were normally distributed an independent sample t-test was used to compare groups of activity. The proportion of subjects with hypoechoic regions or localised thickness within each group was tested for significance using the Pearson Chi-square test. One way analysis of variance was used to measure difference in cross-sectional diameter across quartiles.

RESULTS

We recruited 126 healthy asymptomatic subjects (252 tendons) aged between 20 and 50 (mean age 33.1 [SD 6.8], 78 males and 48 females) for this study.

Subjects with hypoechoic regions were significantly more common in the active groups compared to the low activity group (Pearson Chi-Square = 27.4 across the groups, $p < 0.001$). Although the number of thickened tendons was not significant across the groups (Pearson Chi-Square = 7.5, $p = 0.056$), when comparing the low activity group with the very active group, it was significant (Pearson Chi-square = 4.8, $p = 0.029$).

In 50 tendons (from 31 subjects), there was a history of previous injury, and 42 (84%) of these tendons had a hypoechoic region on ultrasound. Only 4 (8%) of these tendons had evidence of thickening.

Activity level (modified Allied Dunbar Units)

	Low	Mild	Moderate	Very active	Total
n (tendons)	72	52	66	62	252
Mean age (range)	37.1 (28-49)	34.5 (20-50)	31.7 (21-46)	32.3 (21-50)	33.1 (20-50)
Mean BMI (range)	24.9 (19.1-37.8)	24.9 (21.1-29.7)	24.8 (19.0-33.4)	24.3 (18.0-30.9)	24.6 (18.0-37.8)
Total No. of tendons with hypoechoic region (% within that group)	24 (33.3%)	35 (67.3%)	44 (66.7%)	45 (72.6%)	148 (58.7%)
No. of tendons with thickened regions (% within that group)	0	3	(5.8%)	7	(10.6%)
Years in sport (mean)	3.8	14.7	17.8	17.8	14.2
No. with a previous Achilles injury	8	11	16	15	50

Table 1. Descriptive statistics and prevalence of ultrasound findings consistent with chronic Achilles tendinosis in subjects of differing activity levels.

Activity group	Tendons (n)	Mean (mm)	Range (mm)	SD
Low	72	4.6	3.6 – 5.9	0.63
Mild	52	4.9	3.1 – 6.0	0.63
Moderate	66	4.9	3.5 – 6.4	0.95
Very active	62	5.0	3.8 – 8.7	0.72
Total	252	4.8	3.1 – 8.7	0.76

Table 2. Achilles diameter in subjects of differing activity levels.

One-way analysis of variance (ANOVA) was used to test for significance in the difference between the groups; ($F = 3.856$, $p = 0.01$).

DISCUSSION

This study has demonstrated that ultrasound evidence of the degenerative changes associated with chronic Achilles tendinosis are present in a large number of subjects who are currently asymptomatic. It also shows that asymptomatic chronic Achilles tendinosis was more prevalent in those subjects who were either currently physically active or had been physically active for many years. This suggests that exposure to weight-bearing exercise plays a significant role in the development of asymptomatic Achilles tendon degeneration. In addition, a history of previous injury in the Achilles tendon was a marker for an increased chance of finding degenerative changes within the tendon.

The causes of Achilles tendinopathy in general, and chronic Achilles tendinosis specifically, remain unclear. There are many factors thought to be associated with the development of the condition, and excessive loading of the tendon during repetitive training activities is often regarded as the main pathological stimulus (2). Twenty four (33%) tendons in subjects who were in the low activity group had ultrasound evidence of chronic Achilles tendinosis, whereas the two most active groups had 44 (67%) and 45 (72%) tendons with ultrasound changes. The classification of 'low activity' was based on the 4-week period prior to the study. These subjects did have a mean of 3.8 years active sport, so many of them had been exposed to some degree of activity in the past. This study demonstrates a clear association between physical activity level and asymptomatic chronic Achilles tendinosis. The tendinosis in the relatively inactive subjects may be accounted for by their past activity level or may indicate there are other factors operating in the development of these changes.

These results also suggest that a history of previous injury to the Achilles tendon is associated with chronic Achilles tendinosis. In the subjects who had a history of at least one painful episode in or around their Achilles but were asymptomatic now, 84% of them had ultrasound findings of degenerative regions within their tendons. The questionnaire did not differentiate between acute episodes of paratenonitis and chronic painful Achilles tendons, so it is not possible to say whether the pain they declared had been due to paratenonitis that may have resolved or microtears that may have progressed to degeneration of the tendon.

The frequency probe used on the ultrasound machine in this study was a high resolution linear array 8 – 16 MHz transducer. It is now recognised that higher frequency probes, as used in this study, are more accurate than the older low frequency probes in visualising abnormal pathology in the Achilles tendon (18). It was postulated that small hypoechoic areas identified within the Achilles tendon may be either microtears or

early degenerative changes (29). As we do not know their natural history, identification of these small hypoechoic areas with very accurate high frequency ultrasound transducers could be confusing the picture and overestimating the extent of asymptomatic chronic Achilles tendinosis. Longitudinal studies would be necessary to examine the natural history of these small hypoechoic regions to see whether they heal, extend or become larger degenerative areas, and identify their association with symptoms and tendon rupture.

Hypoechoic regions are known to exist in asymptomatic patellar tendons (9) with an increased prevalence in the patellar tendons of elite athletes compared to normal controls. We were only able to find two studies in the published evidence regarding significant asymptomatic tendinosis in Achilles tendons (29, 30). Gibbon *et al* found up to 30% of normal asymptomatic subjects had ultrasound evidence of at least one microtear within the Achilles tendon. Although these asymptomatic volunteers were matched for age and sex with the group of symptomatic athletes, there was no mention of their current or previous activity levels and the number of tendons they examined in the study was relatively small (n = 38). Fredberg and Bolvig examined more tendons (n = 98) but only recorded spindle-shaped (ie fusiform) thickening in the Achilles, not the presence of hypoechoic areas (despite doing so for the patellar tendons in the same subjects).

The principle investigator (AN) was not a radiologist and had little prior experience of musculoskeletal ultrasound. His scanning technique for imaging the Achilles tendon was however validated for both reliability and reproducibility before the study. In addition, the design of the study was such that it was the presence of abnormal findings on ultrasound, and not the extent of them, that were recorded. Archambault (21) in 1998 had validated a simple ultrasound grading scheme for examining patients with Achilles tendinopathy. The Achilles was either normal, the presence of a hypoechoic region was identified (regardless of size) or there was localised fusiform thickening of the tendon. The same principle was adapted for this study.

In conclusion, this study has demonstrated that some of the ultrasound findings of chronic Achilles tendinosis are often present in an asymptomatic population, who may have a normal diameter of Achilles tendon. It is relatively common within the 20 to 50 year age group, with a higher prevalence in the physically active population and those with a history of previous injury. Longitudinal well structured research studies need to be undertaken to get a better understanding of the natural history of this condition and see what percentage of this asymptomatic population go on to become either painful or rupture acutely.

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REFERENCES

- Maffulli N, Regine R, Angelillo M, *et al.* Ultrasound diagnosis of Achilles tendon pathology in runners. *Br J Sports Med* 1987; **21**:158-62.
- Alfredson H and Lorentzon R. Chronic Achilles tendinosis: recommendations for treatment and prevention. *Sports Med* 2000; **29**:135-46.
- Waterson SW, Maffulli N and Ewen SWB. Subcutaneous rupture of the Achilles tendon: basic science and some aspects of clinical practice. *Br J Sports Med* 1997; **31**:285-98.
- 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):92-7.
- Alfredson H. The chronic painful Achilles and patellar tendon: research on basic biology and treatment. *Scand J Med Sci Sports* 2005; **15**(4):252-9.
- Khan KM, Bonar F, Desmond PM, *et al.* Patellar tendinosis (jumper's knee): findings at histopathological examination, US and MR imaging. Victorian Institute of Sport Tendon Study Group. *Radiology* 1996; **200**:821-27.
- Uthoff HK and Sano H. Pathology of failure of the rotator cuff tendon. *Orthop Clin North Am* 1997; **28**:31-41.
- Kannus P and Jozsa L. Histopathological changes preceding spontaneous rupture of a tendon: a controlled study of 891 patients. *J Bone Joint Surg Am* 1991; **73**:1507-25.
- Cook JL, Khan KM, Harcourt PR, *et al.* Patellar tendon ultrasonography in asymptomatic active athletes reveals hypochoic regions: a study of 320 tendons. *Clin J Sport Med* 1998; **8**:73-7.
- Cook JL, Khan KM, Kiss ZS, *et al.* Patellar tendinopathy in junior basketball players: a controlled clinical and ultrasonographic study of 268 patellar tendons in players aged 14 – 18 years. *Scand J Med Sci Sports* 2000; **10**:216-20.
- Cook JL, Khan KM, Kiss ZS, *et al.* Prospective imaging study of asymptomatic patellar tendinopathy in elite junior basketball players. *J Ultrasound Med* 2000; **19**:473-9.
- Leppilähti J and Orava S. Total Achilles tendon rupture: a review. *Sports Med* 1998; **25**:79-100.
- Maffulli N, Barrass V and Ewen SWB. Light microscopic histology of Achilles tendon ruptures. *Am J Sports Med* 2000; **28**:857-63.
- Tallon C, Maffulli N and Ewen SW. Ruptured Achilles tendons are significantly more degenerated than tendinopathic tendons. *Med Sci Sports Exerc* 2001; **33**:1983-90.
- Stokes M, Hides J and Nassiri DK. Musculoskeletal ultrasound imaging: diagnostic and treatment aid in rehabilitation. *Phys Ther Rev* 1997; **2**:73-92.
- Bagnolesi P, Cilotti A, Lencioni R, *et al.* The Achilles tendon: echography at different frequencies. Comparative study. *Radiologia Medica* 1993; **85**:741-7.
- Bertolotto M, Perrone R, Martinoli C, *et al.* High resolution ultrasound anatomy of normal Achilles tendon. *Br J Radiol* 1995; **68**:986-91.
- Fornage BD and Rifkin MD. Ultrasound examination of tendons. *Radiol Clin North Am* 1988; **26**:87-107.
- Gibbon WW. Musculoskeletal ultrasound. [Review] *Baillieres Clin Rheumatol* 1996; **10**:561-88.
- Martinoli C, Derchi LE, Pastorino C, *et al.* Analysis of echo-texture of tendons with ultrasound. *Radiology* 1993; **86**:839-43.
- Archambault JM, Wiley JP, Bray RC, *et al.* Can sonography predict the outcome in patients with achillodynia? *J Clin Ultrasound* 1998; **26**:335-9.
- Astrom M, Gentz CF, Nilsson P, *et al.* Imaging in chronic tendinopathy: a comparison of ultrasonography, magnetic resonance imaging and surgical findings in 27 histologically verified cases. *Skeletal Radiol* 1996; **25**:615-20.
- Movin T, Kristoffersen-Wiberg M, Shalabi A, *et al.* Intratendinous alterations as imaged by ultrasound and contrast medium enhanced magnetic resonance in chronic achillodynia. *Foot Ankle* 1998; **19**:311-7.
- Paavola M, Paakkala T, Kannus P, *et al.* Ultrasonography in the differential diagnosis of Achilles tendon injuries and related disorders. *Acta Radiologica* 1998; **39**:612-9.
- Halfmann PL, Keller C and Allison M. Pragmatic assessment of physical activity. *Nurse Practitioner Forum* 1997; **8**:160-5.
- Torgen M, Alfredsson L, Koster M, *et al.* Reproducibility of a questionnaire for assessment of present and past physical activities. *Int Arch Occup Environ Med* 1997; **70**(2):107-18.
- Health Education Council and Sports Council. Allied Dunbar National Fitness Survey 1992. Belmont Press, London, UK.
- Etherington J, Harris PA, Nandra D, *et al.* The effect of weight-bearing exercise on bone mineral density: a study of female ex-elite athletes and the general population. *J Bone Miner Res* 1996; **11**:1333-8.
- Gibbon WW, Cooper JR and Radcliffe GS. Sonographic incidence of tendon microtears in athletes with chronic Achilles tendinosis. *Br J Sports Med* 1999; **33**:129-30.
- Fredberg U and Bolvig L. Significance of ultrasonographically detected asymptomatic tendinosis in the patellar and Achilles tendons of elite soccer players: A longitudinal study. *Am J Sports Med* 2002; **30**:488-91.