Achilles tendinopathy is extremely common in runners, with an estimated annual incidence of 9%. The lifetime risk is estimated at 52% for elite long-distance runners and 23.9% for athletes in general, in comparison with 5.9% for a control population drawn from a military conscription database. The prevalence in the general population is at least 0.2% in general practice; this may underestimate true general population figures because many patients would present to sports physicians and physiotherapists.

It is in the tendon midportion, typically 2 to 7 cm from the calcaneal insertion, that blood supply is at its most tenuous and degeneration is most common. At ultrasound, tendinopathy is characterized by thickening, hypoechogenicity, and neovascularity, although these changes may also be seen in asymptomatic tendons. Achilles tendinopathy may also be insertional, with a variety of potential causes, although our study focused on midportion tendinopathy as this is the more common pattern we see at our institution.

Pattern of Fascicular Involvement in Midportion Achilles Tendinopathy at Ultrasound

Peter Counsel, MBBS(Hons), FRANZCR, DCH,*† Jules Comin, MBBS(Hons), FRANZCR,‡ Marcus Davenport,† and David Connell, MBBS(Hons), MMed, FRANZCR, FFSEM(UK)†‡

Background: The Achilles tendon is composed of fascicles from the soleus and gastrocnemius muscles, which are identifiable as discrete components at anatomical dissection.

Hypothesis: The pattern of fascicular involvement in Achilles tendinopathy may be characterized at ultrasound, and this characterization is reliable between different observers.

Study Design: Cross-sectional diagnostic study.

Level of Evidence: Level 3.

Methods: One hundred cases of Achilles tendinopathy were retrospectively evaluated by 2 blinded musculoskeletal radiologists. Using a short-axis anatomical map, each case was categorized as involving the fascicular territories of the medial head of gastrocnemius, lateral head of gastrocnemius, soleus, or combinations of these, or as indeterminate.

Results: Both radiologists agreed on the fascicular involvement pattern in 93 of 100 cases; 20 involved only medial gastrocnemius territories, 8 lateral gastrocnemius, 15 soleus, 3 medial and lateral gastrocnemius, 21 medial gastrocnemius and soleus, 9 soleus and lateral gastrocnemius, and 16 the entire tendon, and 1 case was classified as indeterminate. In 7 cases, the interpretations were discordant. The kappa value was calculated as 0.92 (95% CI, 0.86-0.98) in keeping with a high level of interobserver agreement.

Conclusion: As assessed at ultrasound, most cases of Achilles tendinopathy involve the medial head of gastrocnemius and/or soleus fascicles.

Clinical Relevance: The provided observational data will increase understanding of patterns of Achilles tendinopathy.

Keywords: Achilles tendon; tendinopathy; ultrasound

From †Imaging at Olympic Park, Melbourne, Victoria, Australia, and ‡Department of Medical Imaging, Faculty of Medicine, Nursing and Healthcare, Monash University, Melbourne, Victoria, Australia

*Address correspondence to Peter Counsel, MBBS(Hons), FRANZCR, DCH, Imaging at Olympic Park, 60 Olympic Boulevard, Melbourne, Victoria 3004, Australia (email: p.counsel@iop.net.au).

The authors report no potential conflicts of interest in the development and publication of this article.

DOI: 10.1177/1941738115595226
© 2015 The Author(s)
The Achilles tendon is the largest tendon in the body, formed by the confluence of the distal tendons of soleus as well as the medial and lateral heads of gastrocnemius (MHG and LHG, respectively). As the Achilles descends toward the calcaneus, there is rotation of these fascicles such that those from gastrocnemius rotate to the lateral side and those from soleus rotate medially. Assessing 40 cadaveric Achilles tendons, Szaro et al demonstrated that the fascicles remained distinct from each other and assumed a characteristic arrangement of tendinous components in the axial plane. The medial gastrocnemius fascicles formed the posterolateral as well as part of the posteromedial Achilles, the lateral gastrocnemius fascicles formed the anterolateral and a portion of the anteromedial Achilles, and the soleus fascicles formed the central and medial part of the tendon (Figure 1). Assessment at ultrasound has shown that degenerative changes of the tendon are frequently localized to only 1 part of the tendon in the axial plane, most often the posterior and medial portions.

Achilles tendinopathy has traditionally been considered a homogeneous entity, although findings of involvement of particular territories within the tendon, in addition to differential electromyographic abnormalities, raise the possibility that rehabilitation could be targeted to individual components of the calf muscle complex. However, this is theoretical, with no clinical evidence to support isolated therapy of individual calf muscle components.

The aim of this study was to identify the fascicular involvement pattern in midportion Achilles tendinopathy by correlating the pattern of tendinopathy in the short axis with a map of the fascicular territorial anatomy as described above, as well as the interobserver reliability for use of this map.

METHODS

Participants
A search was performed of all ultrasound examinations of the Achilles tendon, performed to investigate calf or heel pain, at our imaging center between January 2011 and March 2012. Institutional review board ethical approval was obtained for this retrospective study. Inclusion criteria were an ultrasound referral for calf or heel pain and subsequent findings of midportion tendinopathy, manifest as hypoechogenicity and architectural distortion. Exclusion criteria were a sonographically normal tendon or demonstration of other pathology such as Achilles tendon rupture, retrocalcaneal bursitis, enthesopathy, or abnormality of plantaris.

The first 100 consecutive cases demonstrating midportion Achilles tendinopathy, in the absence of exclusion criteria, were included for assessment. This represented approximately 24% of consecutive Achilles ultrasound referrals during this period, with a further 312 studies excluded.

Test Methods
All ultrasound examinations had been performed by a single operator following a standardized protocol of transverse and longitudinal images along the length of the tendon that was performed as a matter of routine clinical practice. All studies were performed on a Philips iU22 (Bothell) ultrasound machine using a 17.5-MHz linear probe.

Two musculoskeletal radiologists (J.C. and D.C.) then examined each image independently and in a blinded fashion, and described the pattern of tendinopathy as per the territorial distribution on a short axis map adapted from the description of Szaro et al. Tendinopathy was described as affecting the MHG territory, LHG territory, soleus (S) territory, any combination of the above, or as indeterminate and not conforming to the described anatomical distribution. The indeterminate designation also included lack of satisfaction with image quality at the time of review.

Statistical Methods
The kappa value for interobserver agreement was calculated using an unweighted Cohen kappa. The proportion of indeterminate cases was determined for each radiologist.

RESULTS

Participants
One hundred cases of midportion Achilles tendinopathy were identified in 95 patients, with some of the included patients having bilateral abnormality. There were 61 left and 39 right tendons, with an average age of 43.7 years (range, 17-89 years; median, 46 years). The breakdown of participants by sex was 66% male and 34% female.

Test Results
Agreement between the 2 examiners was present in 93 of 100 cases (93%) (Table 1). Examples of several cases are shown in Figures 2 through 5.

There were 3 cases that one examiner described as MHG involvement and the other examiner described as diffuse (MHG + LHG + S), 2 with disagreement as to whether there was an
MHG + S versus just an MHG pattern, and 1 case of an LHG vs LHG + S pattern. There was no case where the description involved a completely different pattern (eg, 1 examiner determining MHG and the other determining LHG).

One of the radiologists described 1 case as indeterminate, and the other radiologist noted 2 indeterminate cases, 1 of which was the same case that the first radiologist identified. The case that both readers called indeterminate was considered as agreement, and the other as a discrepancy.
The kappa value was calculated as 0.92 (95% CI, 0.86-0.98), in keeping with a high level of interobserver agreement.

**DISCUSSION**

Our findings are in agreement with a previous ultrasound study describing tendinopathy occurring most commonly in the posteromedial part of the Achilles tendon, which if correlated with the short-axis map, would correspond to the territories of the MHG and soleus. In addition to differential anterior and posterior forces, shear forces may also result from the varying contribution of the gastrocnemius muscles and soleus to the Achilles tendon. An uneven mediolateral force distribution has been shown experimentally in a cadaveric biomechanical study, showing that the mediolateral force distribution was dependent on relative loading of the different calf muscles.

Potential reasons for the MHG- and soleus-dominant pattern of involvement include hyperpronation of the foot and the proximity of the plantaris tendon to the MHG. Muscle strains and tears also more commonly involve MHG and the medial part of the soleus, also suggesting an increased load across the medial musculature. In the series by Koulouris et al, 86% (68 of 79) of calf injury sites involved the MHG or soleus, and of the soleus injuries, 85% (29 of 34) were medial.

In a series of 73 patients undergoing operative treatment of midportion Achilles tendinopathy, 58 were found to have an invaginated or closely related plantaris tendon. In a cadaver study, the plantaris tendon was found to be stiffer, stronger, and less extensible, which creates the opportunity for differential motion and shear stresses as a possible mechanism of action. In another cadaver study, in addition to 2.8% of plantaris tendons inserting in the Achilles tendon as a recognized normal variant, a further 10% had firm connections to the Achilles in the midportion that the authors postulated were acquired adhesions. The authors suggested that since the plantaris crosses the knee joint while soleus does not, resultant differential motion may induce subsequent traction on the paratenon.

There are several limitations of this study in addition to its retrospective design. There is variable torsion of the Achilles tendon, in that the fascicles rotate to different degrees from patient to patient. In addition to differential anterior and posterior forces, shear forces could result from the varying contribution of the gastrocnemius muscles and soleus to the Achilles tendon. An uneven mediolateral force distribution has been shown experimentally in a cadaveric biomechanical study, showing that the mediolateral force distribution was dependent on relative loading of the different calf muscles.

Potential reasons for the MHG- and soleus-dominant pattern of involvement include hyperpronation of the foot and the proximity of the plantaris tendon to the MHG. Muscle strains and tears also more commonly involve MHG and the medial part of the soleus, also suggesting an increased load across the medial musculature. In the series by Koulouris et al, 86% (68 of 79) of calf injury sites involved the MHG or soleus, and of the soleus injuries, 85% (29 of 34) were medial.

In a series of 73 patients undergoing operative treatment of midportion Achilles tendinopathy, 58 were found to have an invaginated or closely related plantaris tendon. In a cadaver study, the plantaris tendon was found to be stiffer, stronger, and less extensible, which creates the opportunity for differential motion and shear stresses as a possible mechanism of action. In another cadaver study, in addition to 2.8% of plantaris tendons inserting in the Achilles tendon as a recognized normal variant, a further 10% had firm connections to the Achilles in the midportion that the authors postulated were acquired adhesions. The authors suggested that since the plantaris crosses the knee joint while soleus does not, resultant differential motion may induce subsequent traction on the paratenon.

There are several limitations of this study in addition to its retrospective design. There is variable torsion of the Achilles tendon, in that the fascicles rotate to different degrees from patient to patient. In addition to differential anterior and posterior forces, shear forces could result from the varying contribution of the gastrocnemius muscles and soleus to the Achilles tendon. An uneven mediolateral force distribution has been shown experimentally in a cadaveric biomechanical study, showing that the mediolateral force distribution was dependent on relative loading of the different calf muscles.

Potential reasons for the MHG- and soleus-dominant pattern of involvement include hyperpronation of the foot and the proximity of the plantaris tendon to the MHG. Muscle strains and tears also more commonly involve MHG and the medial part of the soleus, also suggesting an increased load across the medial musculature. In the series by Koulouris et al, 86% (68 of 79) of calf injury sites involved the MHG or soleus, and of the soleus injuries, 85% (29 of 34) were medial.

In a series of 73 patients undergoing operative treatment of midportion Achilles tendinopathy, 58 were found to have an invaginated or closely related plantaris tendon. In a cadaver study, the plantaris tendon was found to be stiffer, stronger, and less extensible, which creates the opportunity for differential motion and shear stresses as a possible mechanism of action. In another cadaver study, in addition to 2.8% of plantaris tendons inserting in the Achilles tendon as a recognized normal variant, a further 10% had firm connections to the Achilles in the midportion that the authors postulated were acquired adhesions. The authors suggested that since the plantaris crosses the knee joint while soleus does not, resultant differential motion may induce subsequent traction on the paratenon.

There are several limitations of this study in addition to its retrospective design. There is variable torsion of the Achilles tendon, in that the fascicles rotate to different degrees from patient to patient. In addition to differential anterior and posterior forces, shear forces could result from the varying contribution of the gastrocnemius muscles and soleus to the Achilles tendon. An uneven mediolateral force distribution has been shown experimentally in a cadaveric biomechanical study, showing that the mediolateral force distribution was dependent on relative loading of the different calf muscles.

Potential reasons for the MHG- and soleus-dominant pattern of involvement include hyperpronation of the foot and the proximity of the plantaris tendon to the MHG. Muscle strains and tears also more commonly involve MHG and the medial part of the soleus, also suggesting an increased load across the medial musculature. In the series by Koulouris et al, 86% (68 of 79) of calf injury sites involved the MHG or soleus, and of the soleus injuries, 85% (29 of 34) were medial.

In a series of 73 patients undergoing operative treatment of midportion Achilles tendinopathy, 58 were found to have an invaginated or closely related plantaris tendon. In a cadaver study, the plantaris tendon was found to be stiffer, stronger, and less extensible, which creates the opportunity for differential motion and shear stresses as a possible mechanism of action. In another cadaver study, in addition to 2.8% of plantaris tendons inserting in the Achilles tendon as a recognized normal variant, a further 10% had firm connections to the Achilles in the midportion that the authors postulated were acquired adhesions. The authors suggested that since the plantaris crosses the knee joint while soleus does not, resultant differential motion may induce subsequent traction on the paratenon.

There are several limitations of this study in addition to its retrospective design. There is variable torsion of the Achilles tendon, in that the fascicles rotate to different degrees from patient to patient. In addition to differential anterior and posterior forces, shear forces could result from the varying contribution of the gastrocnemius muscles and soleus to the Achilles tendon. An uneven mediolateral force distribution has been shown experimentally in a cadaveric biomechanical study, showing that the mediolateral force distribution was dependent on relative loading of the different calf muscles.
12. Khan K, Forster B, 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;37:149-153.

13. Koulouris G, Ting A, Jhamb A, Connett D, Kavanagh E. Magnetic resonance imaging findings of injuries to the calf muscle complex. Skeletal Radiol. 2007;36:921-927.

14. Kujala UM, Sarra S, Kupro J. Cumulative incidence of Achilles tendon rupture and tendinopathy in male former elite athletes. Clin J Sport Med. 2005;15:153-155.

15. Lintz F, Higgs A, Millett M, et al. The role of plantaris longus in Achilles tendinopathy: a biomechanical study. Foot Ankle Surg. 2010;17:252-255.

16. Lysholm J, Wiklander J. Injuries in runners. Am J Sports Med. 1987;15:168-171.

17. Szaro P, Witkowski G, Smagielski R, Krajewski P, Ciszek B. Fascicles of the adult human Achilles tendon—an anatomical study. Ann Anat. 2009;191:586-593.

18. Van Dijk C, van Sterkenburg M, Wijgerinck J, Karlsson J, Maflali N. Terminology for Achilles tendon related disorders. Knee Surg Sports Traumatol Arthrosc. 2011;19:835-841.

19. Van Gils C, Steed R, Page J. Torsion of the human Achilles tendon. J Foot Ankle Surg. 1999;35:41-48.

20. van Sterkenburg MN, Kerkhoffs GM, Kleipool BP, van Dijk CN. The plantaris tendon and a potential role in mid-portion Achilles tendinopathy: an observational anatomical study. J Anat. 2011;218:536-541.

21. Wyndow N, Gowan SM, Wrigley TV, Crossley KM. Triceps surae activation is altered in male runners with Achilles tendinopathy. J Electromyogr Kinesiol. 2013;23:166-172.

For reprints and permission queries, please visit SAGE’s Web site at http://www.sagepub.com/journalsPermissions.nav.