UNDERSTANDING ACHILLES TENDINOPATHY AND TENDON REHABILITATION THROUGH THE ACHILLES TENDON DIAMETRAL STRAIN RESPONSE TO ECCENTRIC EXERCISE

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INTRODUCTION
Eccentric exercise has become the treatment of choice for Achilles tendinopathy [1]. However, little is known about the acute response of the tendon to eccentric exercise or the mechanisms underlying its beneficial effect [2].

We have previously demonstrated that eccentric exercise results in an immediate decrease in tendon thickness in healthy young adults [3]. Based on in vitro evidence, it was proposed that the marked diametral strain response (≈ 20%) observed in vivo primarily reflected the radial extrusion of fluid from the tendon [4, 5]. Such convective fluid movement likely plays a vital role in tendon homeostasis by enhancing molecular perfusion [6] and may represent a biologically plausible mechanism by which eccentric exercise promotes tendon healing. To date, however, the diametral strain response of tendon to eccentric exercise has only been examined in participants without tendinopathy. It is imperative to determine the diametral strain response in tendinopathy as the condition is associated with structural changes including collagen fibril disorganisation and thinning as well as an increase in the concentration of hydrophilic glycosaminoglycans (GAGs) [2, 7]. These structural changes may impact upon the proportion of free water within the tendon and the way in which collagen extends and realigns with loading. As such, convective fluid movement may be reduced in the presence of tendinopathy.

The aim of the current research was to evaluate the sonographic characteristics and acute diametral strain response of control (healthy), asymptomatic and symptomatic Achilles tendons to eccentric exercise.

METHODS
Eleven male adults with unilateral Achilles tendinopathy (mean age 48.2 ± 3.8 years, height 181.6 ± 2.0 cm and mass 97.3 ± 6.9 kg) and nine control adults without tendinopathy (mean age 49.0 ± 4.5 years, height 180.6 ± 2.2 cm and mass 92.6 ± 5.6 kg) consented to participate in the research. All participants refrained from physical activity 24 hours prior to and during the study period. Sagittal sonographic images of each Achilles tendon (control, asymptomatic and symptomatic) were acquired immediately prior to and following completion of a common eccentric rehabilitation exercise protocol [8] and again 24 hours later. Participants with Achilles tendinopathy performed the testing protocol twice, such that symptomatic and asymptomatic tendons were exposed to isolated eccentric exercise on separate occasions. All images were obtained by a single operator experienced in musculoskeletal imaging using an 8 MHz linear-array transducer with standardised B-Mode settings. The orientation of lower limb segments throughout the eccentric exercise protocol was recorded using an eleven camera motion analysis system sampling at 200 Hz.

Sonographic images were post-processed using MATLAB software. The anterior and posterior edges of the Achilles tendon were manually digitised with the aid of a grey-scale profile at a standard reference point 40 mm proximal to the calcaneal insertion. True diametral strain was calculated using pre- and post-exercise tendon thickness. The 95% limits of agreement for repeated measures of diametral strain were ± 4.6%. Tendon echogenicity was estimated by calculating the mean grey-scale (arbitrary units, U) over an area encompassed by the anterior and posterior borders of the tendon and five pixels proximal and distal to the measurement site. Hyperechogenicity was denoted by high grey-scale values (white = 200), while tendon hypoechochogenicity was represented by low values (black = 0).

Kinematic data were exported from Vicon Nexus and segmented to isolate the 15 eccentric repetitions of each exercise set. The duration of loading, maximum and minimum sagittal ankle joint angles and ankle joint range of motion (ROM) were determined for each exercise repetition and a mean value was calculated for each of the six exercise sets.

The effect of tendon category (control, asymptomatic, symptomatic) on each of the dependent variables was investigated using a general linear modelling approach. The relationships between diametral strain and kinematic and kinetic variables were investigated via simple linear regression. Means and standard errors produced by the general linear models are presented in text.

RESULTS AND DISCUSSION
Table 1 summarises the sonographic appearance of tendons prior to eccentric exercise. Symptomatic tendons were thicker than asymptomatic tendons (p < .05) which, in turn, were thicker than control tendons (p < .05). Both symptomatic and asymptomatic tendons were hypoechochogenic compared to control tendons (p < .05).
This finding it is unclear if thickening and diametral strain collagen, soft tissue injuries systemic process and as symptomatic and as exercise. Error bars represent 95% confidence intervals.

**Figure 1**: Mean diametral strain in control (○), asymptomatic (▲) and symptomatic (■) Achilles tendon following eccentric exercise. Error bars represent 95% confidence intervals.

Thickening and hypoechogenicity changes were observed in both symptomatic and asymptomatic tendons. These sonographic findings which are typical of degenerative change [9] raise the possibility that Achilles tendinopathy may represent a systemic process, as has been suggested with other ‘overuse’ soft tissue injuries [10]. These findings are also consistent with observations that tendon degeneration may occur in the absence of clinical symptoms [11]. Due to the cross-sectional nature of the study, it is unclear if thickening and hypoechogenicity in asymptomatic tendons arose insidiously or secondary to an antalgic gait response.

While all tendons demonstrated an immediate decrease in tendon thickness in response to eccentric exercise, symptomatic tendons were characterised by a reduced diametral strain response compared to asymptomatic and control tendons. Although it is possible that this reduced strain reflects the altered loading pattern observed in the symptomatic limb, diametral strain was not related to any kinematic or kinetic parameter; suggesting that an altered movement pattern was not related to the aberrant response. Changes in tendon structure associated with tendinopathy, however, may provide an alternative explanation. Collagen fibril thinning and disorganisation and elevated GAG levels, which are commonly observed in tendinopathy [2, 7], may reduce realignment and extension of collagen fibrils under load and the amount of free water available to be moved by mechanical forces. In support of these concepts, previous research has shown that extension and realignment of collagen causes a decrease in the inter-fibril space, forcing fluid out of the tendon [5] and that removal of GAGs increases the amount of free water within tendon [12]. Although the asymptomatic tendon demonstrated sonographic signs of degenerative change, the diametral strain response did not differ to that of control tendon. Thus, it would appear that tendon degeneration may need to advance to a level associated with symptoms before the strain response is affected.

**CONCLUSIONS**

This is the first study to show that tendinopathic tendon demonstrates a reduced diametral strain response to eccentric exercise when compared to healthy tendon. This finding suggests that structural changes associated with tendinopathy may inhibit convective fluid movement within the tendon matrix and thereby impair molecular perfusion and tendon nutrition. The observation provides significant insight into potential pathological processes underlying tendinopathy and has important clinical implications for tendon rehabilitation programmes that employ eccentric loading regimes.

**REFERENCES**