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JSAMS-1760; No. of Pages 5

ARTICLE IN PRESS

Journal of Science and Medicine in Sport xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Journal of Science and Medicine in Sport

journal homepage: www.elsevier.com/locate/jsams

Original research

The effect of load on Achilles tendon structure in novice runners

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ARTICLE INFO

Article history:
Received 21 September 2016
Received in revised form
27 September 2017
Accepted 6 November 2017
Available online xxx

Keywords:
Tendinopathy
Achilles tendinopathy
Athletic injuries
Sports medicine
Ultrasonography
Ultrasonographic tissue characterisation

ABSTRACT

Objectives: To observe the changes in Achilles tendon structure in novice runners, with loading prescriptions of 100% body weight compared to 20% body weight.
Design: Randomised crossover.
Methods: Twenty novice runners participated in two separate running bouts spaced 14 days apart, one of high load at 100% body weight, and one of low load at 20% body weight. Tendon structure was measured by ultrasonographic tissue characterisation on 6 occasions; immediately prior to each run, 2 and 7 days after each run.
Results: The interaction effect of time and condition was not found to be significant for echotypes I–IV [Wald chi-square = 2.8, d.f. = 2, P = 0.247; Wald chi-square = 2.888, d.f. = 2, P = 0.236; Wald chi-square = 1.385, d.f. = 2, P = 0.5; Wald chi-square = 4.19, d.f. = 2, P = 0.123], respectively. A significant effect of time was found for echotypes III [Wald chi-square = 6.785, d.f. = 2, P = 0.0.034] and IV [Wald chi-square = 7.491, d.f. = 2, P = 0.0.024].
Conclusions: The decrease in echotypes III and IV suggest that moderate loads can be applied to the Achilles tendon without compromising tendon structure. Low to moderate loads may be beneficial in the management of Achilles tendinopathy. Further studies should focus on protocols with higher loading and/or repetitive loading in athletic populations with and without Achilles tendinopathy to assess any differences in tendon structure.

1. Introduction

Tendinopathy is a frequent overuse complaint that has been estimated to account for 30–50% of all sports related injuries.[1] A recent systematic review on running related musculoskeletal injuries found that Achilles tendinopathy presented as the second highest injury incidence at 9.1–10.9%.[2] The repetitive loading of a tendon during physical activity without adequate time for tendon recovery is assumed to be a major factor influencing the development of a tendinopathy.[3] There has been a model proposed in the literature that describes the continuum of tendon pathology and its relation to load.[3] Based on this model it is proposed that a normal healthy tendon with optimal levels of loading will adapt and strengthen. On the other hand, a healthy tendon that is loaded excessively and without adequate rest can degenerate through the stages of tendon pathology. Excessive tendon loading with poor management could ultimately lead to tendon rupture.[3]

Therefore, there may be a case for decreasing tendon load in order to restore a pathological tendon back to health. The Alter-G 'Antigravity' Treadmill (Alter-G Inc., Fremont, CA) is a tool that can be used to decrease load on the lower body using a technology called Lower Body Positive Pressure (LBPP).[4] Unloading of the original body weight can be adjusted from 100% down to 20% body weight with decrements of 1%.[5] Previous research has noted a decrease in ground reaction forces[6] and muscular activation[7] when comparing the Alter-G treadmill to standard treadmill use.

To assess tendon structure several imaging tools can be utilised such as ultrasonographic tissue characterisation (UTC). Four validated echotypes can be identified, based upon the stability of intensity and distribution on contiguous transverse images, and related to tendon integrity with UTC imaging. Echotypes I and II refer to more intact and organised tendon bundles. Echotype III refers to a more fibrillar and disorganised tissue structure; and echotype IV represents an amorphous matrix that is largely composed of fluid.[8] Load dependent tendon tissue structure changes

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https://doi.org/10.1016/j.jsams.2017.11.007
1440-2440/

Table 1
Participant characteristics at baseline.

Measure	Mean (n = 20)
Age (years) ± SD	22 ± 2.9
Gender (M/F)	12/8
Height (m) ± SD	1.76 ± 0.09
Weight (kg) ± SD	74 ± 13.4
BMI (kg/m^2) ± SD	24 ± 3

may be able to be monitored with UTC technology. Previous UTC imaging research[9,10] has observed acute (<72 h) transient changes in tendon structure where tendon responses to a maximal load (elite sporting match) were measured. Slightly disorganised echotype structures were observed two days after the loading bout which returned to baseline after four days.

Prior UTC research that has observed changes in Achilles tendon structure has been performed on trained subjects with maximal loads.[9,10] It is assumed that the Achilles tendons of novices will respond with similar changes in tendon structure as a result of sub-maximal loading due to the fact that untrained or novice exercisers respond well to most training protocols.[11,12] Therefore, acute tendon deformation/degeneration may be studied during loaded and unloaded treadmill running in novice runners with UTC technology.

The aim of this study was to observe the changes in Achilles tendon structure in novice runners, with loading prescriptions of high load (HL) at 100% body weight compared to low load (LL) at 20% body weight. The hypothesis was for a transient change in echotype II after the HL running bout, corresponding to an increase in echotype II two days after the HL run which would return to baseline at seven days post run. There was no change expected to be seen after the LL run.

2. Methods

Twelve male and eight female healthy novice runners were recruited to participate voluntarily in the study (Table 1). Participants were included if they had no more than limited previous experience with running. Limited experience was defined as a participant that had not followed a structured running programme in the past twelve months and had not run more than one time per week in the past three months. Participants were excluded if there was suspicion of lower limb musculoskeletal injuries or absolute contraindications to exercise testing according to the American College of Sports Medicine (ASCM) guidelines for exercise testing and prescription.[13] The protocol was approved by the Medical Ethical Committee of the University Medical Center Groningen (2016/039), all participants provided written informed consent.

The study employed a randomised crossover design. All participants participated in two separate running bouts and had six UTC scans taken. Running bouts consisted of one of high load (HL) on a standard treadmill (Technogym Excite, Gambettola, Italy) at 100% body weight, and one of low load (LL) on an Alter-G treadmill (Alter-G Inc., Fremont, CA) at 20% body weight. As the Alter-G treadmill is rarely used in practice with HL stimulus the standard treadmill was employed to approximate current best practice. The order of running bouts was randomised; half of the participants (group 1) performed the first running bout (RUN1) on the Alter-G treadmill and the second running bout (RUN2) on the standard treadmill. With the other half of the participants (group 2) the order was switched. UTC measurements were taken on both Achilles tendons of all participants on six occasions (UTC scan 1-UTC scan 6). These scans were performed immediately prior to RUN1 (day 0), 2 days post RUN1 (day 2), and 7 days post RUN1 (day 7). Participants then had seven rest days before participating in RUN2 (day 14) on the alternate treadmill. UTC measurements were again taken immediately prior to RUN2 (day 14), 2 days post RUN2 (day 16) and 7 days post RUN2 (day 21). This design was chosen due to the known physiological changes in tendon tissue structure post loading. There is an acute upregulation of collagen expression and an increase in synthesis of collagen protein, the degree of change is likely related to the amount of strain the resident fibroblasts experienced. The increased collagen development remains elevated for roughly 72 h post loading.[14] The UTC scan on day 2 was hypothesized to capture these changes and by day 7 the change was expected to have returned back to baseline levels. Minor changes in the testing protocol had to be made to accommodate to personal circumstances of some participants (UTC scan post running bout performed a day after the day it was originally scheduled). Training logs of all physical activities engaged in from day 0 to day 21 were completed. Participants were requested to refrain from running during the testing period.

The intervention consisted of a 20 min running bout on the prescribed treadmill after a 5 min walking warm-up. Male participants started the run at 8 km/h; female participants started the run at 6 km/h. Participants ran at an RPE of 3–5 on the modified BORG scale,[15] this was assessed every minute until the participant was within the desired range. Once participants were within this range RPE was assessed every 5 min to ensure participants stayed within the range. If RPE exceeded 5 then speed was decreased by 1 km/h; if RPE was lower than 3 then the speed was increased by 1 km/h.

Achilles tendon structure was quantified using the UTC imaging tool by a single experienced technician (LMR). Analysis of UTC output may incorporate a degree of subjectivity. To minimise this effect images were coded to identify subjects and time points, and analysed at a later date. A 7 MHz to 10 MHz linear ultrasound transducer (SmartProbe 12L5-V, Terason 2000+; Teratech; Burlington, Maryland, USA) was mounted in a tracking device (UTC Tracker, UTC Imaging, Stein, The Netherlands) that moved automatically along the Achilles tendons long axis over a distance of 12 cm recording regular images at intervals of 0.2 mm. The tracking device standardised transducer tilt, angle, gain, focus and depth.

Coupling gel was applied between the skin, an integrated stand-off pad of the tracking device and the transducer to optimise contact prior to scanning. Participants were positioned in a prone lying position on a treatment table with the ankle in maximal passive dorsiflexion.[16] The tracking device was placed on the posterior surface of the Achilles tendon parallel to the long axis of the tendon. The transducer was aligned with the Achilles insertion point at the calcaneus. Scan data was collected in a distal to proximal direction. The recorded images were stored and used to reconstruct a 3D ultrasound data block via the UTC software (UTC version 1.05, UTC Imaging). The UTC algorithm quantified echotypes across a rolling window of 25 continuous images (4.8 mm).

UTC is a tool which can quantify tendon structure based upon echotype stability.[17] Furthermore, it is able to discriminate between symptomatic and asymptomatic tendons of Achilles tendinopathy patients.[8] Symptomatic tendons have been shown to have higher percentages of echotypes III and IV, when compared to asymptomatic tendons.[8] High reproducibility and excellent intra-observer reliability has been reported with UTC (ICC > 0.92) in trained observers.[8]

Tendon structure was quantified by selecting a 2 cm section of the mid-portion of the Achilles tendon in the sagittal plane for analysis. This section was measured from 2 cm proximal to the upper border of the calcaneus in a proximal direction. This type of mid-portion Achilles tendon analysis has been performed in previous research.[9]

Generalised estimating equations were used to test for change of echotypes I–IV for UTC scans 1–3 and 4–6. Separate models were run for each of the four echotypes with the echotype as the dependant variable. Participant (ID number) and group were used