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Effects of Isokinetic Eccentric Training on the Human Achilles Tendon

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ABSTRACT

Gomes ARS, Campos TF, Beckenkamp PR, Diong J, Clarke E, Clarke JL, Herbert RD. Effects of Isokinetic Eccentric Training on the Human Achilles Tendon. **JEPonline** 2016;19(2):46-54. This study investigated the effects of isokinetic eccentric training on the cross-sectional area and thickness of the Achilles tendon. Thirty healthy adults were randomized into an Eccentric Training Group and a Control Group. Subjects in the Eccentric Training Group performed an isokinetic eccentric exercise of the gastrocnemius 3 times·wk^{-1} for 5 wks. Testing occurred at baseline and after training. Achilles tendon cross-sectional area and thickness were determined using ultrasound imaging. After training, there was no significant difference in the cross-sectional area or the tendon thickness between groups (mean difference in cross-sectional area 3.2 mm^2, 95% CI -3.3 to 9.7; thickness -0.2 mm, 95% CI -0.5 to 0.2). Thus, the findings indicate that short-term isokinetic eccentric training in healthy young men does not result in tendon hypertrophy.

Key Words*:* Exercise, Achilles Tendon, Adult, Skeletal Muscle

INTRODUCTION

Eccentric exercise has been used extensively in sports training and injury rehabilitation to improve skeletal muscle performance and facilitate recovery from musculoskeletal injuries (20). Mechanical loading induced by eccentric training can alter tendon morphology and increase tendon cross-sectional area (CSA). However, the mechanisms involved in tendon adaptation are still poorly understood. There is some evidence that tendon responds differently to long-term and short-term loading.

In humans, experienced long-distance runners (>5 yrs) were found to have greater Achilles tendon CSA (22%) than non-runners (19,9). Short-term loading in humans produces relatively small changes in CSA that appear to occur only in specific regions of the tendon (5). Short-term resistance training of 3 months produced marked changes in the material properties of human tendon in the apparent absence of tendon hypertrophy (18).

The effects of resistance training are not clear. Resistance training for 12 wks increased patellar tendon CSA in healthy young men (10). However, eccentric training performed 2 to 3 times·wk^{-1} for 14 wks did not change the CSA of the Achilles tendon or the collagen synthesis (4,13). While short-term eccentric training for 7 wks in healthy young men increased tendon stiffness compared to the control group, the effects of short-term eccentric training on tendon CSA are not known (3). Currently it is not clear if short-term eccentric training can induce tendon hypertrophy in humans. This is in contrast to the well-documented effects of training on muscle morphology (1). Thus, the purpose of this study was to determine the effects of 5 wks isokinetic eccentric training on tendon structure in healthy adults.

METHODS

Subjects

All subjects provided written consent to participate. Subjects, both genders, were included if they had no history of significant orthopedic problems in the lower limbs, and if they were not currently involved in a physical training program. Characteristics of subjects are shown in Table 1. This study was approved by the Human Research Ethics Committee of the University of Sydney (Protocol 12904) and conforms to the Declaration of Helsinki.

Procedures

Thirty subjects were randomized into 2 experimental groups: (a) an Eccentric Training Group (n=15); and (b) a Control Group (n=15). Subjects in the Eccentric Training Group performed left gastrocnemius isokinetic eccentric exercise according to a specified training protocol while the subjects in the Control Group did not perform the training. More details of the training protocol are provided below.

Subjects were asked not to perform any strenuous exercise other than the allocated exercise during the experimental period. The left leg of all subjects was tested before and after 5 wks. All subjects were familiarized with the testing and training procedures. During testing, the subjects were instructed to relax in the prone position on an examination bed with their feet hanging over the edge of the bed. A portable ultrasound unit (Esaote MyLab 25) was used to obtain

ultrasound images of the Achilles tendon of the left leg. Ultrasound images were obtained using a 7.5 to 12 MHz, 46 mm linear-array transducer (Esaote LA522E) positioned transversely over the Achilles tendon. The transducer was placed over the maximum anteroposterior diameter of the tendon at the level of the medial malleolus (22) and angled cranially and caudally until the scan plane produced an optimal image that showed maximal echogenicity of the Achilles tendon. To maintain optimal images, a marker was placed on the skin to preserve a constant orientation of the ultrasound head with respect to the tendon area. When the optimal image was obtained, it was recorded and two measurements of the CSA and thickness were made.

The CSA of the Achilles tendon was calculated by delineating manually the cross-sectional region of the Achilles tendon segmenting the ultrasound image. An example of these measurements is shown in Figure 1.

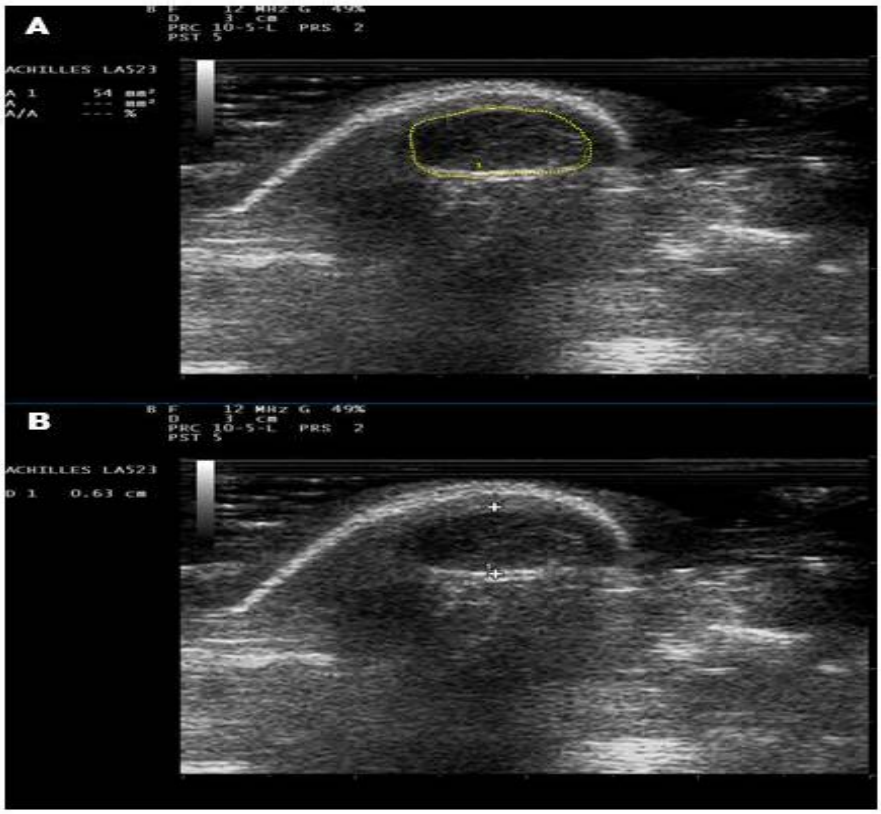

Figure 1. Measurement of Cross-Sectional Area and Thickness of the Achilles Tendon. A: Dashed yellow circle represents the CSA manually measured by area-ratio caliper. **B:** Thickness was manually measured in the transverse scan by distance between the calipers (white crosses).

Subjects in the Eccentric Training Group were instructed on the isokinetic eccentric calf-muscle training protocol. All training was supervised while the subjects were seated on the isokinetic dynamometer (Humac Norm) with the left ankle strapped securely in the footplate. Eccentric exercise was performed over an ankle range of motion of 15º plantarflexion to 5º dorsiflexion. Each subject performed 3 sets of 10 submaximal eccentric contractions at $45^{o} \cdot sec^{-1}$ for familiarization and, then, 3 sets of 10 maximal eccentric contractions at speed of $240^{o} \cdot sec^{-1}$ with

a 1 min rest between sets (2,11,17). The training sessions were separated by at least 1 day and performed 3 times·wk^{-1} for 5 wks.

Subjects in the Control Group attended the laboratory for the same duration and frequency, but listened to a tape-recording of the training instructions without performing the training. All training sessions for both groups were conducted using the following tape-recorded training instructions: “Get ready to produce a maximal contraction. Move to dorsiflexion and now, push as hard as you can, keep pushing as hard as you can, keep pushing … Now stop”) (6).

Subjects were asked to score their muscle soreness from the last 24 hrs at the beginning of each session using an 11-point visual analog scale on which a score of 0 indicated “No soreness” and 10 indicated “Worst soreness ever” (7).

Statistical Analyses

Between-group comparisons of Achilles tendon CSA and thickness were conducted using two-tailed independent samples *t*-tests. Statistical significance was set at P≤0.05. The sample size (n=30) is sufficient to detect an effect size of 1 with a power of 78%.

RESULTS

Baseline characteristics of the subjects are presented in Table 1. The two groups appeared similar at baseline.

Table 1. Subject Characteristics (Means ± SD).

Characteristics	Control Group	Eccentric Training Group
Gender	**(6 males; 9 females)**	**(8 males; 7 females)**
Age (yrs)	30 ± 6	33 ± 9
Weight (kg)	63 ± 13	68 ± 12
Height (cm)	170 ± 12	169 ± 7

The subjects in the Eccentric Training Group attended 90% of the training sessions (2 subjects attended all training sessions) and subjects in the Control Group attended 100% of the training sessions. All subjects were followed up and included in the intention to treat analysis.

There were no significant differences between groups in the tendon CSA, thickness, and muscle soreness score. The magnitudes of the between-group differences, which provide estimates of the effects of eccentric training, are presented in Figure 2 and Table 2.

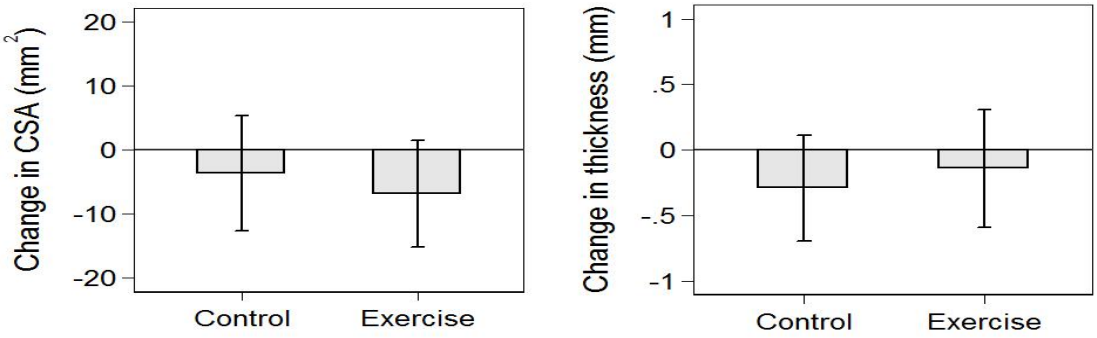

Figure 2: **Change in Achilles's Tendon Cross-Sectional Area and Thickness by Group.** Data are mean ± SD.

Table 2: Cross-Sectional Area, Thickness and Soreness Response to Training.

					Between-Group Differences (mean difference (95% CI, p)
	Week 0		**Week 5**		**Week 5 minus week 0**
	Control Group	**Eccentric Training Group**	**Control Group**	**Eccentric Training Group**	**Eccentric Training minus Control**
CSA (mm^2)	62.3	62.4	58.6	55.6	3.2
	(13.5)	(12.3)	(10.3)	(9.7)	(-3.3 to 9.7; 0.32)
Thickness (mm)	5.8	5.7	5.5	5.5	0.2
	(0.5)	(0.6)	(0.5)	(0.8)	(-0.5 to 0.2; 0.34)
Soreness	0.1	0.3	0.0	0.2	-0.3
	(0.5)	(0.8)	(0.3)	(0.6)	(-0.7 to 0.2; 0.20)

Data are means (±SD) (except where indicated).

DISCUSSION

Isokinetic eccentric calf-muscle training conducted 3 times·wk^{-1} for 5 wks does not appear to affect Achilles tendon CSA and thickness in healthy adults. The mean difference between the Eccentric Training Group and the Control Group in CSA change in the tendon was 3.2 mm^2, suggesting that training slightly increased CSA. However, this effect was not statistically significant and the 95% confidence interval extended from -3.3 mm^2 to 9.7 mm^2. The upper confidence limit of 9.7 mm^2 is large, about 16% of initial value, which implies that it is not possible to definitively rule out clinically important effects of eccentric exercise on CSA. Future studies will need to use larger sample sizes to investigate the clinical effect of eccentric training on tendon CSA.

It has been proposed that the period of adaptation to chronic loading is longer in tendon tissue compared with contractile elements of skeletal muscle, and only with very prolonged loading are significant changes in gross dimensions of the tendon observed (8). This could explain in part the lack of effect of the short period of eccentric training on tendon CSA in the present study.

Another study investigating the effects of 6 wks of eccentric training performed by recreational athletes found a decrease in the Achilles tendon stiffness without modification in the jump height (16). These findings might indicate that the tendon stiffness and performance could respond differently to the same period and type of training. Urlando and Hawkins (21) reported no change in the Achilles tendon strain during maximum plantar flexion efforts after 8 wks of isometric training. Thus, it might be hypothesized that the 1st 8 wks of ankle plantar flexion strength training in healthy adults is not sufficient to induce modification in the tendon morphology and performance.

Kubo and colleagues (12) reported that tendon stiffness did not change until after 2 months of training, but reached 50% tendon stiffness increase after 3 months. The authors suggested that the collagen synthesis, content, and structure of human tendons change after 2 months of training period, which could explain the absence of an effect on tendon CSA after 5 wks of eccentric training in the present study (12).

A morphometric analysis of collagen-fibrils in tendon tissue of treadmill-trained mice demonstrated that there was a disappearance of collagen fibrils and, then, a reappearance of thick instead of thin fibrils from the 3rd wk to the 5th wk (14). This finding could be explained by the instability of collagen fibrils caused by the rapid alteration in response to exercise. The authors proposed that between the 3rd and 5th wks collagen turnover is enhanced by mechanical stimuli. This hypothesis could explain apparent lack of the effect of eccentric training on tendon CSA in the present study.

Kjær et al. (8) suggested that tendon hypertrophy is more evident in the distal parts of the tendon than in the middle parts. This might explain why the eccentric training did not modify tendon CSA in the current study. It is possible that we failed to observe hypertrophy because the ultrasonography was performed on the middle part of the Achilles tendon, not on the distal part where there may have been a more pronounced tendon hypertrophy (8).

The mean effect of training on thickness was -0.2 mm (95% CI -0.5 to 0.2), meaning that the effect of training could have been to reduce thickness by as much as -0.5 mm or increase CSA

by as much as 0.2 mm, or anywhere in between. An increase of 0.2 mm is very small, about 3% of initial value, demonstrating that if 5 wks of eccentric training do not results in an increase tendon thickness the effect is very small. There could, therefore, be several reasons why we failed to detect tendon hypertrophy in the present study: (a) the eccentric training was performed for only a short period of 5 wks; (b) the subjects had healthy tendons without tendinosis; and (c) measurements were obtained in the middle portion of the tendon that might be less responsive to an eccentric exercise stimulus than the ends of the tendon.

Moreover, we did not evaluate cellular or molecular changes in the tendon to correlate the morphometric findings with possible changes in tendon biochemistry, nor did we investigate mechanotransduction processes (i.e., converting mechanical signals into electrical or chemical signals) thought to contribute to enhance muscle-tendon performance. Finally, we did not examine the mechanical properties of the human gastrocnemius tendon, which could be related to adaptations of tendon morphology. Future studies could monitor biochemical and functional outcomes to investigate the effect of eccentric training in healthy and pathological Achilles tendons.

CONCLUSIONS

This study found no evidence that short-term isokinetic eccentric training for 5 wks in healthy adults results in tendon hypertrophy.

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