Heavy Slow Resistance Versus Eccentric Training as Treatment for Achilles Tendinopathy

A Randomized Controlled Trial

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Background: Previous studies have shown that eccentric training has a positive effect on Achilles tendinopathy, but few randomized controlled trials have compared it with other loading-based treatment regimens.

Purpose: To evaluate the effectiveness of eccentric training (ECC) and heavy slow resistance training (HSR) among patients with midportion Achilles tendinopathy.

Study Design: Randomized controlled trial; Level of evidence, 1.

Methods: A total of 58 patients with chronic (>3 months) midportion Achilles tendinopathy were randomized to ECC or HSR for 12 weeks. Function and symptoms (Victorian Institute of Sports Assessment–Achilles), tendon pain during activity (visual analog scale), tendon swelling, tendon neovascularization, and treatment satisfaction were assessed at 0 and 12 weeks and at the 52-week follow-up. Analyses were performed on an intention-to-treat basis.

Results: Both groups showed significant ($P < .0001$) improvements in Victorian Institute of Sports Assessment–Achilles and visual analog scale from 0 to 12 weeks, and these improvements were maintained at the 52-week follow-up. Concomitant with the clinical improvement, there was a significant reduction in tendon thickness and neovascularization. None of these robust clinical and structural improvements differed between the ECC and HSR groups. However, patient satisfaction tended to be greater after 12 weeks with HSR (100%) than with ECC (80%; $P = .052$) but not after 52 weeks (HSR, 96%; ECC, 76%; $P = .10$), and the mean training session compliance rate was 78% in the ECC group and 92% in the HSR group, with a significant difference between groups ($P < .005$).

Conclusion: The results of this study show that both traditional ECC and HSR yield positive, equally good, lasting clinical results in patients with Achilles tendinopathy and that the latter tends to be associated with greater patient satisfaction after 12 weeks but not after 52 weeks.

Keywords: Achilles tendon; tendinopathy; eccentric training; heavy slow resistance training

Tendon tissue is uniquely designed to withstand considerable forces to produce joint movement, and it may at times see loads exceeding 9 kN.[8,14] However, when the tendon is exposed to repetitive high-magnitude loading, it can result in tendinopathy, which is a painful and disabling tendon injury that can persist for months to years.[13,18] The Achilles tendon is one of the largest and strongest tendons in the body,[11] yet it is frequently afflicted by tendinopathy. The incidence of tendon injuries has been estimated to be as high as 30% to 50% of all sports injuries, 50% among elite endurance runners, and 6% among sedentary people.[17,19] In fact, it has been reported that Achilles tendinopathy is the clinical diagnosis in 55% to 65% of all Achilles tendon disorders.[11]

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The exact cause of Achilles tendinopathy and other similar injuries remains elusive, which may be one reason for the lack of an apparent evidence-based best treatment practice. Histopathologic data and recent gene expression data indicate that chronic tendinopathy is not an inflammatory condition but rather a result of a failed healing process that causes degenerative changes of the hierarchical tendon structure, neovascularization, and nerve ingrowth.[22,30] The associated pain is due to the neovascularization and nerve ingrowth in the tendon[26,27] and is therefore a useful parameter in the diagnosis and subsequent clinical monitoring.

Research on the treatment of Achilles tendinopathy is somewhat scarce despite its prevalence and that it represents a major clinical problem. In the past decade, loading-based treatment in the form of eccentric training (ECC) has become the principal nonsurgical choice of treatment for Achilles tendinopathy,[3] although there is no convincing evidence that it is the most effective exercise regimen. In fact, a recent systematic review concluded that there is little clinical or mechanistic evidence that supports using the eccentric component alone and that well-conducted studies comparing different loading programs are largely lacking.[21] Nevertheless, it seems that loading itself yields positive clinical, structural, and biochemical effects with respect to tendinopathy.[1,15,16,20,39] However, Achilles tendinopathy remains challenging to manage successfully, and as many as 45% may not respond to eccentric exercises,[36] which may be related to lack of knowledge about the effect of loading parameters: load progressions, load magnitude, frequency (sets and repetitions), and restitution between treatment sessions. New loading-based exercise regimens—such as isolated concentric training,[20] heavy slow resistance training (HSR),[15] and eccentric-concentric progressing to ECC[37,39]—have been suggested but lack firm scientific evidence for their efficacy in Achilles tendinopathy. It was recently shown for patellar tendinopathy that HSR performed 3 times weekly yielded superior long-term results compared with the traditional eccentric loading regimen.[15] However, the effect of HSR in Achilles tendinopathy has never been investigated. On the basis of the aforementioned findings, we hypothesized that HSR would yield a more favorable clinical outcome compared with ECC. Therefore, we sought to investigate the effect of a 12-week HSR regimen compared with the traditional eccentric loading regimen in patients with midportion Achilles tendinopathy in a randomized controlled trial with a 52-week follow-up.

METHODS

Study Design

The study was designed as a prospective randomized single-blind controlled trial with a 12-week intervention period and a subsequent 52-week follow-up period from July 2009 through October 2012. A total of 58 recreational athletes (32 men, 15 women; age range, 18-60 years) with a diagnosed chronic unilateral midportion Achilles tendinopathy were included in the study. Patients were recruited from the Institute of Sports Medicine, Bispebjerg Hospital, Copenhagen, Denmark. An experienced sports medicine physician determined the diagnosis on the basis of defined clinical findings (Victorian Institute of Sports Assessment–Achilles [VISA-A] and visual analog scale [VAS]), physical examination, and pain duration of at least 3 months. In addition, the following ultrasonography findings needed to be present: local anterior-posterior (A-P) thickening of the midtendon level with a hypoechoic area and a color Doppler signal within the hypoechoic area.[15] Exclusion criteria were as follows: <4-week washout period from any other treatments, corticosteroid injections in the previous 12 months, bilateral Achilles tendinopathy, insertional Achilles tendinopathy, systemic disease (eg, rheumatoid arthritis, diabetes), any surgery, or any confounding lower limb and ankle injury.

TABLE 1
Patient Characteristics at Baseline[a]

Variable	ECC (n = 25)	HSR (n = 22)
Sex, n (male:female)	18:7	14:8
Age, y	48 ± 2 (31-60)	48 ± 2 (31-60)
Height, cm	179 ± 2 (164-196)	178 ± 2 (164-195)
Weight, kg	81 ± 2 (62-96)	81 ± 3 (65-112)
Body mass index, kg/m^2	25 ± 1 (21-35)	26 ± 1 (18-40)
Symptom duration, mo	19 ± 5 (3-120)	17 ± 3 (3-80)
Activity level before injury, h/wk	5 ± 1 (0-16)	5 ± 1 (2-11)

[a]Values are reported as mean ± SEM (range) unless otherwise indicated. There were no differences between groups for any parameter at baseline. ECC, eccentric training; HSR, heavy slow resistance training.

A sample size calculation was performed a priori on the basis of the primary outcome of VISA-A. A total of 18 patients was needed in each group to establish a clinically significant mean difference of 10 points (maximum score, 100 points) in the VISA-A score, with 80% power and an alpha level of .05. To account for dropouts, we sought to include a total of 25 patients in each group. The total of 58 patients was randomly allocated into 1 of the 2 intervention groups—ECC (n = 30) and HSR (n = 28)—using a computer-generated minimization randomization procedure.[12] The minimization procedure was based on activity level, symptom duration, and age. The subject characteristics are shown in Table 1, and there were no significant differences between the 2 groups (unpaired Student *t* tests). The study complied with the Declaration of Helsinki, was approved by the local human ethics committee for medical research (KF256131), and was registered at ClinicalTrials.gov (NCT00952042). All patients gave their informed consent before experiment.

Treatment Intervention

The eccentric loading program (ECC) was performed according to the protocol previously described,[3] and it included 3 sets of 15 slow repetitions of eccentric unilateral loading while standing on the step of a staircase. One

Figure 1. Depiction of applied heavy slow resistance exercises: (A) heel rises with bended knee in the seated calf raise machine, (B) heel rises with straight knee standing on a disc weight with the forefoot with the barbell on shoulders, (C) heel rises with straight knee in the leg press machine. All exercises are performed bilateral with equal weight on both legs.

exercise is performed with straight knees and one with bent knees, twice a day (morning and evening), 7 days a week, for 12 consecutive weeks. Patients were instructed to spend approximately 3 seconds completing each repetition and to have a 2-minute rest period between sets and a 5-minute rest period between the 2 exercises. All patients were instructed by a trained physical therapist on how to perform the 2 exercises, and they were given instructions and a written manual on how to progress. Load was increased gradually using a loaded backpack as pain diminished.

The HSR program previously described[15] was performed 3 times per week using resistance equipment in a fitness center. Each session consisted of three 2-legged exercises: heel rises with bended knee in the seated calf raise machine, heel rises with straight knee in the leg press machine, and heel rises with straight knee standing on a disc weight with the forefoot with the barbell on shoulders (Figure 1). The patients completed 3 or 4 sets in each exercise with a 2- to 3-minute rest between sets and a 5-minute rest period between the 3 exercises. The number of repetitions decreased, and load gradually increased, every week as the tendon got stronger. The repetitions and loads were as follows: 3 times, 15-repetition maximum (15RM), in week 1; 3 times, 12RM, in weeks 2 to 3; 4 times, 10RM, in weeks 4 to 5; 4 times, 8RM, in weeks 6 to 8; and 4 times, 6RM, in weeks 9 to 12. All exercises were performed in the full range of motion of the ankle joint, and patients were instructed to spend 3 seconds completing each eccentric and concentric phase (ie, 6 seconds per repetition). All patients were instructed by a trained physical therapist on how to perform the 3 exercises, and they were given instructions and a written manual on how to progress.

The main difference between the 2 exercise regimens is the total loading time "seen" by the tendon and the calculated session time, which includes rest periods. The time of tendon loading was estimated to be approximately 63 min/wk for ECC and 41 min/wk for HSR. The session time was 308 min/wk for ECC and 107 min/wk for HSR. Note that the estimated time for the HSR regimen represents only the first week of the protocol since repetitions and sets decrease over the intervention period.

To improve compliance, information manuals were provided to all patients in both groups. Furthermore, a follow-up supervision session was carried out by a trained physical therapist for all patients 1 week after intervention start. All patients were required to keep a standardized training diary from weeks 0 to 12, in which they documented every training session. The training record included number of repetitions, sessions, and load, and it was used to assess compliance and training progression.

Patients in both groups were not allowed to engage in sporting activities in the initial 3 weeks of the intervention period, in an attempt to minimize their risk of symptom exacerbation while adjusting to the exercise regimen. Subsequently, the patients were allowed to engage in sporting activities throughout the intervention period, provided that these could be performed with a discomfort not exceeding 30 mm on the VAS. While performing the intervention exercises, the patients were allowed to reach 40 to 50 mm on the VAS, but pain should have subsided by the following training session. If pain in the tendon had not subsided, the patient was advised to adjust the load of the program and/or one's daily living or sporting activities. A similar approach to pain management was included successfully by other randomized controlled trials in the management of Achilles tendinopathy.[15,39] All patients were instructed to refrain from taking anti-inflammatory drugs during the intervention. When the intervention period ended, the patients did not receive any further treatment or guidelines but were encouraged to maintain the obtained activity level.

Clinical Evaluation

All patients completed a written VISA-A questionnaire to assess the symptoms, function, and pain during sporting activities. The questionnaire consists of 8 questions in which the patients rate the magnitude of pain during rest, function, and activity. The maximum score is 100 points, and a lower score indicates more symptoms and a greater limitation of function and activity. The VISA-A questionnaire has been shown to be a valid and reliable outcome measure for patients with Achilles tendinopathy.[33] Improvement on the VISA-A >10 points is considered clinically significant.[35] In addition, the pain level in the tendon was assessed during 5 heel rises on stairs (VAS_H) and during running (VAS_R) and indicated on a 100-mm VAS. Patients completed the VISA-A questionnaire and VAS with a trained physical therapist at weeks 0 and 12 and at the 52-week follow-up. The VISA-A score was the primary clinical outcome measure of this study. The activity level of sporting activities (h/wk) was documented: before injury, at weeks 0 and 12, and at the 52-week follow-up. At weeks 12 and 52, the patients indicated

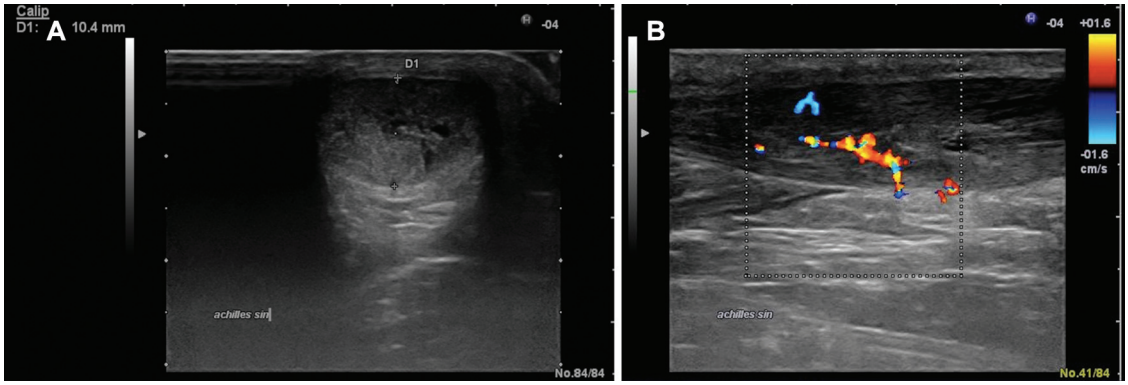

Figure 2. Illustration of ultrasonography assessments. (A) Assessment of anterior-posterior tendon thickness. (B) Color Doppler activity.

whether they were satisfied with the result of the treatment as part of the questionnaire.

Ultrasonography Measurements and Doppler Evaluation

Ultrasonography was performed on the injured Achilles tendon using a Hitachi Ascendus with a EUP-L75 18-MHz linear-array transducer (GE Medical Systems). Patients were examined in a prone position with the feet hanging free in a neutral position over the end of the table. All patients were instructed to avoid physical activity 24 hours before the examination. Grayscale and color Doppler settings (Figure 2) were identical for all examinations.

Grayscale examination was performed with a depth of 2.0 cm: auto optimizing [AO] = 100%, depth resolution = 84, and gain = 53). The tendon was scanned longitudinally and transversally to get a 3-dimensional impression of the tendon structure and its rotation. When the thickest point of the tendon was identified, the A-P distance was measured in a transversal scan, and the epitendon and paratendon were not included (Figure 2A). The measurement was standardized according to the method previously described.[9] The mean of 3 A-P thickness measurements of each image was used for analysis.

The color Doppler scans were obtained with a visual thin layer of gel between the transducer and the skin. The investigator applied minimum transducer pressure during scanning to demonstrate as much flow as possible. Color Doppler settings were optimized for low flow: frequency = 7.5 MHz (gain just below random noise level), AO = 100%, pulse repetition frequency = 0.4 kHz, and wall filters = 48 Hz. A standardized color box of 2.5 × 2.5 cm was positioned at the midtendon area that had the highest color Doppler activity (Figure 2B), according to the method previously described.[15] The scans were recorded as a 4-second sine loop in the sagittal plane with the highest color Doppler activity. Three 4-second sine loops were recorded, each containing 86 single images. From each sine loop, the image with the highest amount of Doppler activity was selected and saved for subsequent analysis. All analyses were conducted by the same researcher to avoid interindividual variations in the results; each sine loop was analyzed 3 times; and the image with the highest amount of Doppler activity was chosen for further statistical calculations. Activity was quantified as Doppler color fraction (ie, as the total number of colored pixels within the region of interest using a custom-made macro) in the software program ImageJ (v 1.48; National Institutes of Health). The Doppler color fraction measurement (%) was used for analysis. One investigator conducted all analyses in blinded fashion.

Data Reduction and Statistical Analysis

Forty-seven patients completed the intervention period (ECC, n = 25; HSR, n = 22). Five patients withdrew from the ECC group (1 with ankle pain, 2 with back pain, and 2 because of lack of time). Six patients withdrew from the HSR group (1 with ankle pain, 1 with back pain, 2 because of lack of time, and 2 who moved away). Forty-four patients attended the 1-year follow-up control (ECC, n = 24; HSR, n = 20). One patient in the ECC group sustained a partial Achilles tendon rupture during sports participation (badminton), and 2 patients did not show up for the 52-week follow-up. Four patients (2 in each group) did not return the training diary. The data were analyzed with the intention-to-treat approach, with the last observation carried forward.

Baseline characteristics were analyzed with unpaired Student t tests. Outcome measures were analyzed using 2-way analysis of variance (treatment × time) with repeated measures with Bonferroni-adjusted post hoc tests when appropriate. Results are reported as mean ± SEM and 95% CIs.

Patient satisfaction at 12 and 52 weeks and patient activity level at 0, 12, and 52 weeks were analyzed using Fisher exact tests. Patient compliance was analyzed with unpaired Student t tests. A Pearson correlation coefficient was employed to examine if changes in color Doppler activity over time were related to changes in VISA-A score over time.

RESULTS

All data are shown in Table 2. For VISA-A, there was a significant effect of time ($P < .0001$), but there was no

TABLE 2
Clinical and Sonographic Results[a]

	ECC					HSR				
	0 wk	12 wk	52 wk	Δ (%), 0-12 wk	Δ (%), 0-52 wk	0 wk	12 wk	52 wk	Δ (%), 0-12 wk	Δ (%), 0-52 wk
VAS–running[b]	49 ± 5.5 (38.3, 60.1)	20 ± 5.7 (9.3, 31.5)	12 ± 4.2 (3.2, 19.8)	29 ± 5.1 (18.9, 38.8)	38 ± 6.2 (25.6, 49.9)	54 ± 5.4 (43.3, 64.3)	17 ± 4.1 (9.3, 25.2)	5 ± 2.6 (–0.5, 9.8)	37 ± 6.7 (23.4, 49.8)	49 ± 7.0 (35.5, 62.8)
VAS–heel rises[b]	19 ± 5.0 (8.8, 28.6)	12 ± 3.6 (4.8, 18.9)	6 ± 2.6 (0.9, 11.0)	7 ± 3.9 (–0.8, 14.5)	13 ± 5.9 (1.3, 24.3)	29 ± 5.5 (17.7, 39.2)	7 ± 2.4 (2.1, 11.7)	5 ± 2.5 (–0.2, 9.4)	22 ± 5.5 (10.8, 32.3)	24 ± 5.7 (12.7, 35.0)
VISA-A[b]	58 ± 3.9 (50.6, 65.8)	72 ± 3.7 (64.7, 79.3)	84 ± 3.5 (78.0, 91.9)	–14 ± 2.5 (–18.8, –8.8)	–27 ± 4.5 (–35.6, –18.0)	54 ± 3.2 (48.6, 61.6)	76 ± 3.7 (70.5, 83.1)	89 ± 2.8 (83.6, 94.8)	–22 ± 2.7 (–26.9, –16.4)	–34 ± 3.9 (–41.8, –26.5)
A-P, mm[b]	8.3 ± 0.3 (7.7, 9.0)	8.1 ± 0.4 (7.4, 8.8)	7.3 ±0.3 (6.8, 7.9)	0 ± 0.1 (0, 0.5)	1.0 ± 0.3 (0.5, 1.5)	8.6 ± 0.5 (7.7, 9.5)	7.9 ± 0.4 (7.3, 8.8)	6.9 ± 0.3 (6.4, 7.4)	0.6 ± 0.2 (0.2, 0.9)	1.7 ± 0.3 (1.1, 2.4)
Doppler, %[c,d]	2.8 ± 0.6 (1.7, 3.7)	2.8 ± 0.5 (1.8, 3.8)	1.6 ± 0.5 (0.6, 2.6)	0 ± 0.4 (–0.9, 0.8)	4.0 ± 0.9 (2.7, 6.1)	4.0 ± 0.8 (2.5, 5.8)	2.0 ± 0.5 (1.0, 2.9)	1.0 ± 0.4 (0.1, 1.8)	2.3 ± 0.8 (0.8, 3.7)	1.1 ± 0.4 (0.2, 1.9)

[a]Values are presented as means ± SEM (95% CI). Significance based on 2-way analysis of variance; significant difference between groups set at $P < .01$. A-P, anterior-posterior thickness of the midtendon; Doppler, color Doppler fraction (ie, total number of colored pixels within the region of interest); ECC, eccentric training; HSR, heavy slow resistance training; VAS, visual analog scale; VISA-A, Victorian Institute of Sports Assessment–Achilles; 0 wk, baseline; 12 wk, postintervention; 52 wk, follow-up; Δ (%), relative change in time interval.
[b]Significant effect of time, $P < .0001$.
[c]Significant effect of time, $P < .005$.
[d]Significant treatment interaction, $P < .01$.

TABLE 3
Patient Activity Level at Weeks 0, 12, and 52[a]

Activity Level, h/wk	ECC (n = 25)	HSR (n = 22)
Wk 0	2 ± 1 (0-16)	2 ± 1 (0-8)
Wk 12	3 ± 1 (0-14)	4 ± 1 (1-10)
Wk 52	4 ± 1 (0-12)	5 ± 1 (2-20)

[a]Values are reported as mean ± SEM (range). There was a significant effect of time ($P < .05$) but no differences between groups or interaction. ECC, eccentric training; HSR, heavy slow resistance training.

significant interaction ($P = .26$) or difference between groups ($P = .62$), indicating that both treatments yielded similar improvements from 0 to 52 weeks. For VAS_H and VAS_R, there was a significant effect of time (VAS_H, $P < .0001$; VAS_R, $P < .0001$), but there was no significant interaction (VAS_H, $P = .08$; VAS_R, $P = .38$) or difference between groups (VAS_H, $P = .77$; VAS_R, $P = .71$), indicating that both treatments yielded similar improvements in pain from 0 to 52 weeks.

Tendon A-P thickness decreased significantly with time ($P < .0001$), but there was no difference between groups or treatment interaction. Tendon color Doppler area also decreased significantly with time ($P < .005$), and the interaction was significant ($P < .01$), but there was no difference found between groups (Table 2). The Doppler color fraction did not correlate significantly with the VISA-A score over time (0-12 weeks) in the HSR group ($r = 0.008$, $P = .95$) or the ECC group ($r = 0.14$, $P = .49$).

For activity level, there was a significant effect of time ($P < .05$), but there was no significant interaction ($P = .43$) or difference between groups ($P = .16$) (Table 3). The mean activity level during the 12-week intervention period was not different from the baseline level for either group.

The mean training session compliance rate was 78% in the ECC group and 92% in the HSR group, with a significant difference between groups ($P < .005$). The patient satisfaction with the clinical outcome at 12-week follow-up was 20 of 25 for ECC (80%) and 22 of 22 for HSR (100%; $P = .052$ between groups). At 52-week follow-up, 19 of 25 ECC patients (76%) and 21 of 22 HSR patients (96%) were satisfied ($P = .10$).

DISCUSSION

The main finding of the present study was that both the traditional ECC and the HSR yielded a positive clinical result in patients with Achilles tendinopathy in both the short- and long-term ranges. There was a pronounced improvement in physical activity level and pain during sporting activities (VAS_R, VAS_H, and VISA-A) in both groups. Concomitant with the clinical improvement, there was a reduction in A-P thickness and neovascularization as measured with color Doppler. None of these robust clinical and structural improvements differed between the ECC and HSR groups. However, patient satisfaction tended to be greater after 12 weeks with HSR (100%) than ECC (80%) but not after 52 weeks (HSR, 96%; ECC, 76%).

The effectiveness of a loading regimen for the treatment of Achilles tendinopathy is supported by the fact that there is often considerable improvement in pain and function.[3,20,23,35,39] In the current study, the patients had baseline VISA-A and VAS scores comparable with those previously reported in patients with Achilles tendinopathy.[6,20,39,40] Over the course of the 12-week intervention period, the VISA-A score improved by >10 points, and the VAS_R score was reduced by ≥30 points (mm) in both groups on average. These are clinically meaningful improvements and, moreover, corroborate previous reports of the effect of loading regimens on tendinopathy.[15,34,39-41]

After the 12-week intervention, the mean VISA-A score was 74 for all patients (ECC, 72; HSR, 77) after having undergone a loading-based exercise regimen alone, and this increased to 87 (ECC, 85; HSR, 89) after 52 weeks. So although clinical progress took place there, symptoms and decreased function remain 1 year after the end of intervention. A recent study by Silbernagel et al[38] demonstrated an average VISA-A score of 90 at a 5-year follow-up, with 20% of patients still having symptoms, which indicates that patients may not necessarily fully recover. The reason for the lack of complete recovery for patients is unknown. In the present study, it was not possible to obtain a tendon biopsy specimen as in other studies,[15] which may have shed light on the effect that the treatment may have had on the biochemical and structural composition of the tendon.

It was recently reported that both HSR and ECC yield good clinical effects in patients with patellar tendinopathy and that long-term patient satisfaction with HSR exceeded that of ECC.[15] We therefore sought to compare these loading regimens in patients with Achilles tendinopathy, which have not been examined before to the best of our knowledge. The results of the current study suggest that HSR and ECC improve symptoms and physical activity level equally well in patients with chronic midportion Achilles tendinopathy.

Eccentric loading regimens for tendinopathy have been widely accepted as the treatment of choice. However, the direction of the movement of the entire muscle-tendon unit at a given load and range of motion should have little or no differential effect on the tendon. In fact, peak forces and tendon length changes are similar during concentric and eccentric contractions.[31] Moreover, eccentric and concentric contractions yield a similar expression of collagen,[10] indicating that the fibroblast is similarly affected. Finally, habitual training with concentric and eccentric contractions appears to produce similar tendon growth.[7] Thus, it is not entirely clear why avoiding the concentric component should produce a more favorable clinical outcome. Studies have been designed to address the question,[20,23] but none have controlled carefully for magnitude of load (ie, tendon elongation). Although the present study was not designed to answer the effect of contraction mode per se, it appears that HSR, which includes a concentric as well as an eccentric component, produced similar results as the traditional ECC regimen.

Treatment satisfaction is an important clinical outcome and likely represents several components. In the present study, 80% of ECC patients and 100% of HSR patients were satisfied after the 12-week intervention, and the corresponding values were 76% and 96% at the 52-week follow-up, respectively. The clinical outcome was the primary study goal, and we did not chiefly aim to assess patient satisfaction. Nevertheless, we find it interesting that HSR tended to result in a higher satisfaction among patients than ECC did. The reason for this remains unknown, but it appears to corroborate the findings of an earlier investigation of patients with patellar tendinopathy.[15] Moreover, patient satisfaction of the ECC regimen in the current study is akin to that previously reported.[6,20] A possible reason for the difference in patient satisfaction between ECC and HSR could be the time necessary to complete the 2 regimens: ECC requires two 22-minute training sessions per day, 7 days a week, for a total of 308 min/wk. The corresponding session time for HSR patients is three 36-minute training sessions per week, for a total of 107 min/wk, and this is a considerable difference in time allotment. The actual reason for the reduced compliance rate in the ECC group (78% vs 92% in HSR) is unknown, but is one aspect that may be considered when loading regimes are offered to patients.

In contrast to our data, prior studies[3,6,20] showed that ECC patients resumed their previous activity levels at the end of the 12-week intervention period. It is difficult to reconcile these differences, since the same eccentric loading regimen was used in these studies. However, it was recently shown that mild pain can persist up to 5 years despite the use of the ECC regimen[41]; therefore, it is not surprising that patients in the present study did not completely regain their activity levels even at the 52-week follow-up.

Ultrasonography is commonly used to image tendinopathy, and color and power Doppler mode can be used to assess neovascularization.[27] It has been suggested that neovascularization is present in tendinopathy and that the associated nerve endings are the cause of the pain.[2] In the literature, there is conflicting evidence whether a tendinopathic Achilles tendon normalizes A-P thickness and color Doppler area after the ECC training regimen.[5,24-26,29,34,41] In the present study, tendon A-P thickness was reduced in both groups with time, which agrees well with some prior reports.[24,26,41] Tendon color Doppler area also decreased with time (Table 2), alongside the clinical symptoms, but it did not seem to be appreciably affected by the loading regimen. This decline in color Doppler area in response to a loading regimen corresponds with previous reports.[15,26,41] The absolute values for Doppler activity were quite low (1.0%-4.0%) and similar to that reported by Boesen.[4] There was a significant time $\times$ treatment interaction between the 2 exercise regimens, but this is likely a function of the coincidental dissimilarity at baseline (ECC, 2.8%; HSR, 4.0%). It has been suggested that ultrasound Doppler does not always reveal neovascularization in Achilles tendinopathy patients, and not all tendons with neovascularization are symptomatic.[28,42] In the present study, the change in Doppler color fraction did not relate to the change in the VISA-A score over time in the HSR group (r = 0.008, P = .95) or ECC group (r = 0.14, P = .49). The lack of relationship between color Doppler activity and clinical symptoms is supported by some[28] authors but not all.[32]

There are some inherent limitations associated with the current study. As previously mentioned, it would have been desirable to obtain a tendon biopsy specimen to examine if the interventions influenced the collagen content, cross-link composition, and fibril composition, but this was not possible within the confines of the study. It could

also be argued that strength testing would provide some information about the effect of the intervention. However, it is challenging to strength test a person with a painful condition, since the pain or injury itself would likely influence the result. An alternative method to examine the effect of the intervention on the muscular tissue would be to obtain magnetic resonance imaging to determine muscle hypertrophy, but this was not possible in the present study. Another drawback was the lack of registration regarding to what extent the patients continued the training program after the 12-week intervention period.

In conclusion, the results of this study do not support our hypothesis that HSR would yield a more favorable clinical outcome compared with the traditional ECC. The data show that ECC and HSR are effective in the treatment of chronic midportion Achilles tendinopathy and that the improvement achieved after 12 weeks of training lasts for 1 year, irrespective of exercise strength mode.

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