Continued Sports Activity, Using a Pain-Monitoring Model, During Rehabilitation in Patients With Achilles Tendinopathy: A Randomized Controlled Study

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Continued Sports Activity, Using a Pain-Monitoring Model, During Rehabilitation in Patients With Achilles Tendinopathy

A Randomized Controlled Study

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Background: Achilles tendinopathy is a common overuse injury, especially among athletes involved in activities that include running and jumping. Often an initial period of rest from the pain-provoking activity is recommended.

Purpose: To prospectively evaluate if continued running and jumping during treatment with an Achilles tendon-loading strengthening program has an effect on the outcome.

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

Methods: Thirty-eight patients with Achilles tendinopathy were randomly allocated to 2 different treatment groups. The exercise training group (n = 19) was allowed, with the use of a pain-monitoring model, to continue Achilles tendon-loading activity, such as running and jumping, whereas the active rest group (n = 19) had to stop such activities during the first 6 weeks. All patients were rehabilitated according to an identical rehabilitation program. The primary outcome measures were the Swedish version of the Victorian Institute of Sports Assessment–Achilles questionnaire (VISA-A-S) and the pain level during tendon-loading activity.

Results: No significant differences in the rate of improvements were found between the groups. Both groups showed, however, significant ($P < .01$) improvements, compared with baseline, on the primary outcome measure at all the evaluations. The exercise training group had a mean (standard deviation) VISA-A-S score of 57 (15.8) at baseline and 85 (12.7) at the 12-month follow-up ($P < .01$). The active rest group had a mean (standard deviation) VISA-A-S score of 57 (15.7) at baseline and 91 (8.2) at the 12-month follow-up ($P < .01$).

Conclusions: No negative effects could be demonstrated from continuing Achilles tendon-loading activity, such as running and jumping, with the use of a pain-monitoring model, during treatment. Our treatment protocol for patients with Achilles tendinopathy, which gradually increases the load on the Achilles tendon and calf muscle, demonstrated significant improvements. A training regimen of continued, pain-monitored, tendon-loading physical activity might therefore represent a valuable option for patients with Achilles tendinopathy.

Keywords: Achilles tendon; Victorian Institute of Sports Assessment–Achilles questionnaire; functional evaluation; pain-monitoring model

Achilles tendinopathy is a common overuse injury, especially among athletes involved in activities that include running and jumping.[10,15,30,42] Achilles tendinopathy causes many patients to decrease their physical activity level, with a potentially negative effect on their overall health and general well-being.[10,15,28]

The literature describes various types of treatment for patients with Achilles tendinopathy, including rest, heat, ultrasound, electrical stimulation, anti-inflammatory medications, exercise, and surgery.[1,10,11,28] Despite the high incidence of Achilles tendon disorder and the various recommended treatment protocols, there are, to the best of our knowledge, only 9 randomized trials on various treatments in the

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published literature.[4,19,21,23,26,32,33,36,41] It is also unclear which type of treatment is most effective for patients with Achilles tendinopathy and what criteria to use when choosing treatment.[1,10,11,28] The effects of exercise training appear to be promising, and the consensus today seems to be that all patients should be treated with an exercise program for 3 to 6 months.[1,3,5,7,11,21,26,36,41] Even with other types of treatments such as surgery, sclerosing injections, heat, ultrasound, electrical stimulation, and medications, some type of exercise is recommended as a complement to the treatment.[2,23,29,31,38,43]

Historically, a period of rest from the pain-provoking physical activity (usually running and jumping) has been recommended when initiating treatment.[7,30,42] Nichols[25] recommends that the rest period should depend on the severity and duration of injury. The literature is, however, generally vague when recommending some type of modified rest in which the pain-provoking activity should be limited or avoided.[11,28,42] Because these patients are generally very physically active people, an over-long period of rest or decrease in physical activity may have a negative effect on their quality of life and sporting performance.[8] Furthermore, an interesting and unanswered question is whether a rest period has a negative or a positive effect on the healing process. Likewise, is it harmful to continue the pain-provoking activity, or could it even be beneficial with an adjusted physical activity?

To our knowledge, the effect of continued tendon-loading activity (such as running and jumping) on treatment in patients with Achilles tendinopathy has not been studied.

We have previously used a pain-monitoring model, originally described by Thomeé,[44] as a guideline for the patient and clinician during treatment.[41]

The purpose of this study was to prospectively evaluate if continued running and jumping during treatment with an Achilles tendon-loading strengthening program would have an effect on the outcome.

MATERIALS AND METHODS

Study Design

This was a prospective, randomized, controlled study to assess the outcome of 2 different rehabilitation protocols in patients with Achilles tendinopathy. Patients who fulfilled the entry criteria as defined by the study protocol were randomized into the 2 different treatment groups—exercise training group and active rest group—during the first 6 weeks of rehabilitation. All patients were rehabilitated according to an identical rehabilitation program: a progressive Achilles tendon-loading strengthening program for 12 weeks to 6 months.

The randomization list was generated by a computer that was run by an independent statistician. The randomization list was not known to anyone in the study. The specific treatment was indicated in numbered opaque envelopes given to patients in the order of inclusion. The treating physical therapist opened the envelopes at the start of treatment and at that time informed the patients of their treatment group.

TABLE 1
Physical Activity Level Scale[a]

Level	Activity Description
1	Hardly any physical activity
2	Mostly sitting, sometimes a walk, easy gardening, or similar tasks
3	Light physical exercise ~2-4 h/wk, eg, walks (including to and from shops), fishing, dancing, ordinary gardening
4	Moderate exercise 1-2 h/wk, eg, jogging, swimming, gymnastics, heavier gardening, home repair, or easier physical activities >4 h/wk
5	Moderate exercise at least 3 h/wk, eg, tennis, swimming, jogging
6	Hard or very hard exercise regularly (several times a week), in which the physical exertion is great, eg, jogging, skiing

[a]Adapted with permission from Grimby G. Physical activity and muscle training in the elderly. *Acta Med Scand Suppl*. 1986;711:233-237.

The outcome was evaluated by patient-administered questionnaires for symptoms with physical activity and by muscle-tendon functional evaluations at baseline and 6 weeks, 3, 6, and 12 months after initiation of the treatment. The classification system of physical activity used was that of Grimby[9] (Table 1). All the evaluations were blinded and performed by 1 physical therapist who was not involved in the rehabilitation of the patients and was unaware of which treatment group the patients belonged to. Instructions for the exercise program and criteria for the treatment groups were provided by physical therapists working at the SportRehab physical therapy clinic in Göteborg, Sweden. The patients were in contact with the physical therapists on average once a week for the first 6 weeks and then as often as the physical therapist and patient deemed necessary.

All patients received oral and written information about the purpose and procedure of the study, and written informed consent was obtained. Ethics approval was obtained from the Human Ethics Committee at the Medical Faculty, Göteborg University, Sweden.

Inclusion and Exclusion Criteria

The patients were recruited through mailings to hospitals, orthopaedic surgeons, physical therapy clinics, and orthopaedic technicians in the Göteborg area. They were referred by their physician or initiated contact themselves. Initially, the patients were examined by an experienced licensed physical therapist who determined if the patients met the required criteria to participate in the study. Men and women 20 to 60 years of age with Achilles tendinopathy and duration of pain for more than 2 months were included. The definition of Achilles tendinopathy used was the clinical diagnosis, which is a combination of Achilles tendon pain, swelling, and impaired performance, as

recommended in the literature.[11,20,28] Ultrasonography evaluation was not used to determine inclusion or exclusion criteria. The exclusion criteria were injury to the foot, knee, hip, or back and/or history of rheumatoid arthritis or any other illness or injury thought to interfere with the participation in the study. Patients with insertional tendinopathy were also excluded.

Patients

From January 2004 to December 2004, 42 patients with a total of 57 injured tendons were included in the study. Two of the patients included in the exercise training group were excluded after the initial evaluation. One was excluded because he was not able to attend any of the other evaluations or physical therapy visits because of illness in the family, and the other patient developed pain in the ankle and knee that hindered participation in the study. Two patients included in the active rest group were also excluded after the initial evaluation. One subject requested exclusion because of self-reported noncompliance and difficulty with attending the evaluations and physical therapy sessions because of work conflicts. The other patient was excluded because of illness that did not allow him to start treatment or attend the 6-week and 3-month evaluations.

The final study group thus consisted of 38 patients (18 women, 20 men) with a total of 51 injured tendons (Table 2). The exercise training group consisted of 19 patients (7 women, 12 men) with a total of 26 injured tendons. The active rest group consisted of 19 patients (11 women, 8 men) with a total of 25 injured tendons. There were no significant differences between the groups with respect to age, height, weight, gender, number of patients with bilateral symptoms, duration of symptoms, and physical activity level.[9] The majority of the patients reported the injury to be due to overuse (87%) and were injured doing physical activity (84%).

TABLE 2
Patient Demographics[a]

Parameter	Exercise Training Group	Active Rest Group
Total included (women + men)	19 (7 + 12)	19 (11 + 8)
Involved side		
Right	5	6
Left	7	7
Both	7	6
Involved tendons	26	25
Age (y)		
Mean	44	48
SD	8.8	6.8
Range	30-58	38-58
Height (cm)		
Mean	179	177
SD	9	8
Range	158.5-193	163.5-194.5
Weight (kg)		
Mean	80.7	78.7
SD	15	11.6
Range	59.7-113.2	61.7-102.6
Duration of symptoms (mo)		
Mean	48	24.4
SD	84.5	40.8
Range	3-360	3-168
How injured		
Overuse	16	17
Acute injury	3	2
Injured doing		
Exercise	17	15
Leisure	0	1
Work	1	1
Other	1	2
Physical activity level before injury		
Mean	4.3	4.6
SD	1.3	0.6
Range	1-6	3-5

[a]No significant differences were found between the groups. SD, standard deviation.

Physical Activity Criteria for the 2 Groups

The exercise training group was allowed to continue Achilles tendon-loading activity for the first 6 weeks of rehabilitation. The patients used the pain-monitoring model, described by Thomeé[44] and modified by Silbernagel et al,[41] as a guide to the level of physical activity. According to the pain-monitoring model, the pain was allowed to reach level 5 on the visual analog scale (VAS), where 0 is no pain and 10 is the worst pain imaginable, during the exercise training. The pain after the exercise program was allowed to reach 5 on the VAS but should have subsided by the following morning. Pain and stiffness in the Achilles tendon were not allowed to increase from week to week.

The active rest group was not allowed to perform the physical activity that caused the symptoms or any other Achilles tendon-loading activity involving running or jumping during the first 6 weeks of rehabilitation. If they wanted to, they were allowed to swim, run in deep water using a buoyancy vest, bike, or walk as daily activity (but not to walk for exercise).

Training Diaries

Both groups kept a training diary for 0 to 12 weeks, in which they documented their rehabilitation exercises, other physical activities, symptoms, or other comments. The training diary was used by the treating physical therapists to assess compliance to treatment group.

Treatment Protocol

All patients were rehabilitated according to an identical rehabilitation program—a progressive Achilles tendon-loading strengthening program for 12 weeks to 6 months. The Achilles tendon and calf muscle strengthening protocol was based on our previous study,[41] but it has been modified in the clinic over the years (Table 3). The exercises were performed once a day, and the intensity and number of repetitions were based on the patients' status.

The exercises consisted mainly of 2-legged, 1-legged, eccentric, and fast-rebounding toe raises. The intensity was increased successively by increasing the range of motion (starting standing on the floor and then performing the exercise standing on stairs), increasing the number of repetitions (starting at 3 sets of maximum amount tolerated, up to 15 repetitions maximum per set), and increasing the load (with use of either a backpack or weight machine and by increasing the speed of loading). In phase 3 of the rehabilitation program, the patients started plyometric training. Phase 1 was continued for 1 to 2 weeks, phase 2 for 2 to 5 weeks, and phase 3 for 3 to 12 weeks, or longer if needed to achieve the patient status required for phase 4. Phase 4 was continued from 12 weeks to 6 months from the start of the treatment or longer if needed, until the patient had no symptoms. The progression of the exercise program was monitored by the treating physical therapists, and both groups followed the treatment protocol (Table 3).

TABLE 3
Treatment Protocol

Phase 1: Weeks 1-2
Patient status: Pain and difficulty with all activities, difficulty performing ten 1-legged toe raises
Goal: Start to exercise, gain understanding of their injury and of pain-monitoring model
Treatment program: Perform exercises every day
- Pain-monitoring model information and advice on exercise activity
- Circulation exercises (moving foot up/down)
- 2-legged toe raises standing on the floor (3 sets × 10-15 repetitions/set)
- 1-legged toe raises standing on the floor (3 × 10)
- Sitting toe raises (3 × 10)
- Eccentric toe raises standing on the floor (3 × 10)

Phase 2: Weeks 2-5
Patient status: Pain with exercise, morning stiffness, pain when performing toe raises
Goal: Start strengthening
Treatment program: Perform exercises every day
- 2-legged toe raises standing on edge of stair (3 × 15)
- 1-legged toe raises standing on edge of stair (3 × 15)
- Sitting toe raises (3 × 15)
- Eccentric toe raises standing on edge of stair (3 × 15)
- Quick-rebounding toe raises (3 × 20)

Phase 3: Weeks 3–12 (longer if needed)
Patient status: Handled the phase 2 exercise program, no pain distally in tendon insertion, possibly decreased or increased morning stiffness
Goal: Heavier strength training, increase or start running and/or jumping activity
Treatment program: Perform exercises every day and with heavier load 2-3 times/week
- 1-legged toe raises standing on edge of stair with added weight (3 × 15)
- Sitting toe raises (3 × 15)
- Eccentric toe raises standing on edge of stair with added weight (3 × 15)
- Quick-rebounding toe raises (3 × 20)
- Plyometric training

Phase 4: Week 12–6 months (longer if needed)
Patient status: Minimal symptoms, morning stiffness not every day, can participate in sports without difficulty
Goal: Maintenance exercise, no symptoms
Treatment program: Perform exercises 2-3 times/week
- 1-legged toe raises standing on edge of stair with added weight (3 × 15)
- Eccentric toe raises standing on edge of stair with added weight (3 × 15)
- Quick-rebounding toe raises (3 × 20)

Outcome Measures

The primary outcome measures were the Swedish version of the Victorian Institute of Sports Assessment–Achilles questionnaire (VISA-A-S)[35,40] and pain level during tendon-loading activity (hopping). For pain documentation, the VAS was used, where 0 is equal to no pain and 10 is the worst pain imaginable.

Functional Evaluations

The secondary outcome measures were the functional evaluations. The functional evaluations consisted of ankle dorsiflexion range of motion and a test battery developed to evaluate lower leg function in patients with Achilles tendinopathy.[39] The test battery consisted of 3 different jump tests, 2 different strength tests, and 1 endurance test. The jump tests were a countermovement jump (CMJ), a drop CMJ, and hopping. The CMJ was a vertical jump in which the starting position was an upright posture with hands placed behind the back. For the drop CMJ, the patients started by standing on 1 leg on a 20-cm-high wooden box. The patients were instructed to "fall" down onto the floor and, directly on landing, to perform a maximum vertical 1-legged jump. The strength tests were a concentric toe raise and an eccentric-concentric toe raise, and the endurance test was a standing toe raise test with 10% of the body weight added with a weight belt. The test battery was done exactly as described in the original article.[39] The functional tests have previously been shown to have good reliability in healthy subjects.[39] The functional tests have also been shown to have good validity for patients with Achilles tendinopathy and the ability to detect clinically relevant differences in function between the injured and healthy leg as well as between the more symptomatic and less symptomatic leg.[39]

Ultrasonography Measures

To establish a diagnosis of Achilles tendon injury, ultrasonography was performed using a real-time scanner, with a 7.5-MHz linear array probe. Both tendons were scanned in all patients, in the longitudinal as well as the axial plane. The tendon injury was registered as heterogeneity and/or hypoechoic areas in the tendon. Tendon edema and tendon thickening were also documented.

TABLE 4
VISA-A-S Scores and Hopping Pain Changes Between Baseline Evaluation and 6-Week, 3-Month, and 6-Month Evaluations[a]

Score Change	0-6 Weeks		0-3 Months		0-6 Months		0-12 Months	
Group	Exercise Training	Active Rest	Exercise Training	Active Rest	Exercise Training	Active Rest	Exercise Training	Active Rest
VISA-A-S score								
n	26	23	25	24	26	23	26	24
Mean	13	16	18	20	23	25	28	34
SD	17	12	18	20	20	17	17	17
95% CI	6-20	10-21	10-25	12-28	15-31	17-32	21-34	27-41
Median	10.5	16	16	19	20.5	21	26.5	31.5
IQR	18	11	20	26.5	21.5	26	20	29.5
Hopping pain (VAS)								
n	26	23	25	24	25	23	22	23
Mean	–1.3	–2.3	–2.2	–2.6	–2.8	–3.0	–3.2	–3.4
SD	2.1	2.0	2.6	2.5	2.7	2.3	2.7	2.7
95% CI	–2.2 to –0.5	–3.2 to –1.4	–3.3 to –1.1	–3.7 to –1.6	–3.9 to –1.6	–3.9 to –1.6	–4.4 to –2.0	–4.6 to –2.3
Median	–1.0	–2.5	–2.0	–2.7	–2.0	–3.0	–3.5	–4.0
IQR	3.0	4.0	4.2	5.0	4.0	5.0	4.0	5.0

[a]Mean, standard deviation (SD), 95% confidence interval (CI), median, and interquartile range (IQR) are provided. There were no significant differences ($P < .05$) between the groups on any of the occasions. VISA-A-S, Swedish version of the Victorian Institute of Sports Assessment -Achilles questionnaire; VAS, visual analog scale.

Statistical Analysis

A power analysis was carried out before the study. It was determined that a total of 40 patients were needed to detect a clinically significant mean score difference of 10 points in the VISA-A-S score with 80% power and at $P = .05$. All the evaluations were performed based on intention-to-treat analysis. This was done to safely deal with noncompliance in the groups. Nonparametric statistics were used in cases where we could not be sure that the data were normally distributed. To compare the groups, the differences in results of the injured tendons between the initial evaluation and the results on the 6-week, 3-, 6-, and 12-month evaluations were used. The groups were then compared using the Mann-Whitney U test. The Mann-Whitney U test was also used to compare the groups at baseline. To evaluate improvements from baseline, the Wilcoxon signed rank test was used. A Spearman rank correlation coefficient was used to evaluate the correlation between improvement and severity of symptoms and duration of symptoms. Values are reported as mean ± standard deviation (SD).

RESULTS

The exercise training group had a mean (SD) VISA-A-S score of 57 (15.8) at baseline and 85 (12.7) at the 12-month follow-up ($P < .01$). The active rest group had a mean (SD) VISA-A-S score of 57 (15.7) at baseline and 91 (8.2) at the 12-month follow-up ($P < .01$).

The ultrasonography revealed pathologic changes in 39 of 51 tendons, while 12 of 51 tendons were judged to have minimal or no changes. Similar pathological changes, that is, heterogeneity and/or hypoechoic areas within the tendon, were found in 7 contralateral symptom-free tendons.

Furthermore, there were no significant differences between the groups in baseline characteristics for any of the measured parameters.

Comparison Between Groups

For the primary outcomes, VISA-A-S score and pain during hopping, there were no significant differences in the change in scores/pain level compared with baseline between the groups at any of the follow-ups (Table 4). There were, moreover, no significant differences in the rate of improvement between the groups in any of the functional evaluations.

Change Over Time Within Groups

Both groups showed significant ($P < .01$) improvements on the VISA-A-S score (Table 5 and Figure 1) and decrease in pain during hopping (Table 6) at 6 weeks and at 3-, 6-, and 12-month evaluations. Both groups improved significantly ($P < .05$) in the total amount of work (in joules) performed during the toe-raise test performed at all follow-ups compared with baseline (Table 7). The active rest group had significant ($P < .05$) improvement in the eccentric-concentric toe-raise power at 6 weeks, but the exercise training group had significant improvements at the other follow-ups (Table 7). The exercise training group showed significant ($P < .05$) improvements in drop CMJ height and hopping quotient at the 6-month follow-up not seen in the active rest group (Table 7). Neither group had any significant improvements in CMJ height and concentric toe-raise power at any of the 4 evaluations (Table 7). There was no increase in range of motion of dorsiflexion in either group; instead, the exercise training group had a significant ($P < .05$) decrease in range of motion at 6 weeks and 6 months (Table 7).

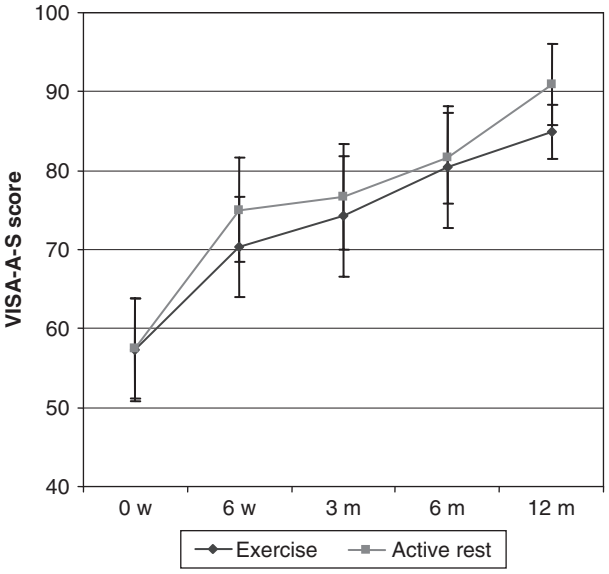

Figure 1. Mean VISA-A-S scores with 95% confidence interval, at 0 and 6 weeks and at 3-, 6-, and 12-month evaluations. VISA-A-S, Swedish version of the Victorian Institute of Sports Assessment–Achilles questionnaire.

There were significant ($P < .05$) correlations between the initial VISA-A-S score and the improvements in VISA-A-S score seen at the subsequent evaluations: 0 to 6 weeks, $r = –.292$; 0 to 3 months, $r = –.470$; 0 to 6 months, $r = –.459$; and 0 to 12 months, $r = –.756$.

The same significant ($P < .05$) correlations were seen when comparing the initial pain level with hopping and the improvements seen in pain level at the subsequent evaluations: 0 to 6 weeks, $r = –.498$; 0 to 3 months, $r = –.591$; 0 to 6 months, $r = –.681$; and 0 to 12 months, $r = –.823$.

There were no significant correlations between the duration of symptoms and the change in VISA-A-S score or change in pain level with hopping at any of the evaluations.

DISCUSSION

This randomized study could not demonstrate any negative effects from allowing the patients to continue Achilles tendon-loading activity (such as running and jumping) when using the pain-monitoring model during rehabilitation for Achilles tendinopathy.

Furthermore, this randomized treatment study confirms earlier results that strengthening exercises of the Achilles tendon, gastrocnemius, and soleus muscle complex cause significant improvements in symptoms and muscle-tendon function in patients with Achilles tendinopathy.[5,21,26,36,41]

Historically, in the literature, initial rest from pain-provoking activity has been recommended for Achilles tendinopathy,[7,30,42] but it appears that this might not be necessary. The patients in this study could safely continue with their activity of choice as long as they followed the pain-monitoring model. The pain-monitoring model states that exercise activity that does not cause pain above 5 of 10 on a VAS is safe. Because most of the patients with Achilles tendinopathy are middle-aged, physically active individuals, the allowance of continued exercise activity may have positive effects on their general health and quality of life. Also, athletes with Achilles tendinopathy would potentially benefit from being able to continue their sports activity in order to avoid significant deterioration in sporting performance. As in the present study, Visnes et al[45] also allowed continued physical activity during treatment in their study on athletes with patellar tendinopathy. They could not, however, show any positive effect of eccentric training when elite volleyball players with patellar tendinopathy continued their normal in-season training. No physical activity-monitoring model, such as the pain-monitoring model used in the present study, was used by Visnes et al[45]; this might explain the lack of improvement.

It cannot be excluded in the present study that the lack of treatment differences found between the 2 treatment groups for the functional secondary outcome evaluations represents a type II error. The power calculation made was for the primary and not for the secondary outcomes. Thus, no definite conclusions can be drawn from the results for the functional evaluations.

The literature states that Achilles tendinopathy mostly occurs in middle-aged men. In our study, as well in others, it can be seen that there is a change over the years in the percentage of women included. In the often-cited study by Kvist,[14] it was reported that 89% of the patients with Achilles tendinopathy were men. In a review of several more recent treatment studies, the percentage of women was between 14% and 55%, with the higher percentages seen in the later studies.[4-7,21,24,27,29-31,38] Because previous studies on Achilles tendinopathy include both men and women, we also included both men and women in the present study. At the time we planned the study, we did not expect to have as high as 50% women and did not expect that there would be a need for controlling the ratio between men and women in each group to get an equal number. Even though there are 7 women in the exercise training group and 11 women in the active rest group, there is no significant difference in the number of women in the 2 treatment groups. However, we recognize that the numbers are low and the chance to detect a difference with statistics is small. Further, statistical analysis comparing the 4 groups (women and exercise training, women and active rest, men and exercise training, men and active rest) on the main outcome (change in VISA-A-S score) using the Kruskal-Wallis test did not show any statistical differences between the groups. We acknowledge that gender could be a confounding factor; however, we have no indication that this factor has affected the outcome of the present study. Therefore, we do not believe that the validity of our results is affected by the ratio of men and women in the different treatment groups.

Even though our results appear similar to earlier studies on the effect of exercise on Achilles tendinopathy, direct comparisons between treatment studies are difficult to make because of variations in outcome measures.[5,21,26,36,41] The VISA-A-S questionnaire, used in the present study, measures important aspects of the

TABLE 5
VISA-A-S Scores at Testing Occasions[a]

VISA-A-S Scores	0 Weeks	6 Weeks	3 Months	6 Months	12 Months
Exercise training group					
n	26	26	25	26	26
Mean	57	70[b]	74[b]	80[b]	85[b]
SD	15.8	16.3	16.3	14.2	12.7
95% CI	51-64	64-77	68-81	75-86	80-90
Median	59	66	77	82	86
IQR	20.2	27.8	22.0	25.5	21.5
Active rest group					
n	25	23	24	23	24
Mean	58	75[b]	77[b]	82[b]	91[b]
SD	15.7	14.7	18.2	17.9	8.2
95% CI	51-64	69-81	69-84	74-89	87-94
Median	59	75	83.5	87	94
IQR	32	17	23	18	12.7

[a]Mean, standard deviation (SD), 95% confidence interval (CI), median, and interquartile range (IQR) are provided for the different test occasions. VISA-A-S, Swedish version of the Victorian Institute of Sports Assessment–Achilles questionnaire.
[b]Indicates a significant improvement ($P < .01$) compared with the baseline evaluation.

TABLE 6
Pain Level With Hopping[a]

VAS Pain Level With Hopping	0 Weeks	6 Weeks	3 Months	6 Months	12 Months
Exercise training group					
n	26	26	25	25	22
Mean	3.9	2.6[b]	1.7[b]	1.2[b]	0.9[b]
SD	2.5	2.5	0.7	1.9	1.7
95% CI	2.9-4.9	1.6-3.6	1.4-2.0	0.4-2.0	0.2-1.6
Median	5	2	1	0	0
IQR	4.1	5	3	2	1
Active rest group					
n	25	23	24	23	23
Mean	4.1	2.0[b]	1.7[b]	1.3[b]	0.7[b]
SD	2.8	2.2	2.6	2.1	1.3
95% CI	3.0-5.3	1.0-3.0	0.6-2.8	0.4-2.2	0.2-1.3
Median	5	2	0	0	0
IQR	5	4	2.7	3	1

[a]Mean, standard deviation (SD), 95% confidence interval (CI), median, and interquartile range (IQR) are provided for the different test occasions. VAS, visual analog scale.
[b]Indicates a significant improvement ($P < .01$) compared with the baseline evaluation.

patients' symptoms and the effect of their injuries on their physical activity.[40] In this study, the VISA-A-S questionnaire showed good responsiveness; that is, it was sensitive for clinically important changes over time with treatment, easy for the patients to fill out, and the data were easily handled. We therefore recommend the use of the VISA-A questionnaire in future studies for evaluating the effect of treatment on patients with Achilles tendinopathy. The results from different studies using the VISA-A questionnaire can then easily be compared with each other.

The treatment protocol used in the present study caused significant improvements in patients' symptoms at the 6-week evaluation, with continued improvement up to the 12-month evaluation. This strengthens earlier recommendations that the treatment of Achilles tendinopathy should be exercise-based.[1,3,5,7,11,21,26,36,41] The treatment protocol in this study was a strengthening program including both

TABLE 7
Results of the Functional Evaluations[a]

Measurement	Before	6 Weeks	3 Months	6 Months	12 Months
Endurance toe-raise test (work, J)					
Exercise training group					
n	25	23	25	25	23
Mean ± SD	1909 ± 942	2427 ± 1154[b]	2455 ± 1228[b]	2471 ± 1133[b]	2431 ± 1170[b]
Active rest group					
n	25	23	24	23	22
Mean ± SD	1716 ± 1021	2146 ± 1049[b]	2051 ± 1020	2122 ± 1041[b]	2058 ± 914[b]
Eccentric-concentric toe raise (power)					
Exercise training group					
n	26	26	25	25	23
Mean ± SD	313 ± 126	350 ± 157	393 ± 178[b]	390 ± 178[b]	366 ± 179[b]
Active rest group					
n	21	21	24	23	23
Mean ± SD	277 ± 144	336 ± 128[b]	303 ± 183	308 ± 153	289 ± 143
Concentric toe raise (power)					
Exercise training group					
n	26	26	25	25	23
Mean ± SD	227 ± 90	251 ± 117	244 ± 99	249 ± 124	229 ± 104
Active rest group					
n	25	23	24	23	23
Mean ± SD	202 ± 108	205 ± 93	204 ± 98	203 ± 88	193 ± 88
Drop CMJ (height, cm)					
Exercise training group					
n	26	26	25	25	22
Mean ± SD	10.63 ± 4.17	10.40 ± 3.96	11.03 ± 4.73	11.77 ± 4.18[b]	11.17 ± 4.31
Active rest group					
n	25	23	24	23	23
Mean ± SD	9.86 ± 5.23	11.12 ± 4.63	10.28 ± 5.14	10.30 ± 4.54	10.13 ± 4.63
Hopping (quotient)					
Exercise training group					
n	26	26	25	25	21
Mean ± SD	0.403 ± 0.136	0.437 ± 0.092	0.447 ± 0.112	0.512 ± 0.129[b]	0.475 ± 0.112
Active rest group					
n	25	23	24	23	23
Mean ± SD	0.419 ± 0.232	0.492 ± 0.166	0.419 ± 0.234	0.447 ± 0.144	0.470 ± 0.175
CMJ (height, cm)					
Exercise training group					
n	26	26	25	25	22
Mean ± SD	11.60 ± 4.88	11.64 ± 4.76	11.58 ± 5.05	11.69 ± 4.96	11.74 ± 4.55
Active rest group					
n	25	23	24	23	23
Mean ± SD	10.31 ± 5.07	11.28 ± 4.71	10.33 ± 4.57	10.48 ± 4.99	10.39 ± 4.74
Range of motion dorsiflexion					
Exercise training group					
n	26	22	21	21	23
Mean ± SD	35 ± 4.2	33.5 ± 3.8[b]	34 ± 3.7	33 ± 3.0[b]	35 ± 3.5
Active rest group					
n	23	22	24	23	23
Mean ± SD	34 ± 5.3	34 ± 4.8	33 ± 5.4	34 ± 4.6	34.5 ± 3.8

[a]SD, standard deviation; CMJ, countermovement jump.
[b]Indicates a significant ($P < .05$) difference compared with before treatment.

concentric and eccentric types of exercises. We believe the improvements seen were due to the high level of intensity of training, with daily exercises and a gradual increase of the load creating positive effects on both the muscle and tendon.

Mafi et al[21] compared concentric and eccentric calf muscle training in patients with Achilles tendinopathy and found similar improvements in symptoms (pain level with physical activity on VAS) in their eccentric training group, as seen in both the exercise training and active rest groups in the present study. There appear to be no negative effects from performing strengthening both concentrically and eccentrically. Mafi et al[21] seem to have used a lower intensity in the concentric group, not starting strengthening with body weight until week 3 and never increasing the load beyond the body weight. The lower load used by Mafi et al[21] might be the reason for their inferior result in the concentric training group. We believe that important key factors in improvement are both the intensity and type of loading. The underlying effects of exercise are not fully known, but mechanical loading on tendons appears to be important in both the healing process and in improving strength of the tendons.[12,34,37] In several studies, Langberg et al[16-18] have shown that exercise activity on tendons in healthy individuals produces an acute increase in the tendon collagen synthesis. It has also been shown convincingly that immobilization causes negative effects on tendons.[12,13] Greater strength of the triceps surae musculature has also been reported to be related to a greater ability of the Achilles tendon to store elastic energy.[22] Mechanical loading through exercise in patients with Achilles tendinopathy appears, therefore, to be important. Exactly how the exercise program should be designed and progressed, however, needs to be investigated further. To improve muscle-tendon function and prevent reinjury, it is suggested that aspects of motor control, proprioception, strength, malalignment, and flexibility all have to be addressed.

CONCLUSION

There was no significant difference between the treatment groups concerning the main outcome variables. No negative effects could be demonstrated from continuing Achilles tendon-loading activity, such as running and jumping, with the use of a pain-monitoring model during treatment. Our treatment protocol for patients with Achilles tendinopathy, which gradually increases the load on the Achilles tendon and calf muscle, monitored by a pain-monitoring model, demonstrated significant symptomatic improvements.

A training regimen of continued, pain-monitored, tendon-loading physical activity might therefore represent a valuable option for patients with Achilles tendinopathy.

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REFERENCES

1. Alfredson H. Chronic midportion Achilles tendinopathy: an update on research and treatment. *Clin Sports Med.* 2003;22:727-741.
2. Alfredson H. The chronic painful Achilles and patellar tendon: research on basic biology and treatment. *Scand J Med Sci Sports.* 2005;15:252-259.
3. Alfredson H, Lorentzon R. Chronic Achilles tendinosis: recommendations for treatment and prevention. *Sports Med.* 2000;29:135-146.
4. Alfredson H, Öhberg L. Sclerosing injections to areas of neo-vascularisation reduce pain in chronic Achilles tendinopathy: a double-blind randomised controlled trial. *Knee Surg Sports Traumatol Arthrosc.* 2005; 13:338-344.
5. Alfredson H, Pietilä T, Jonsson P, Lorentzon R. Heavy-load eccentric calf muscle training for the treatment of chronic Achilles tendinosis. *Am J Sports Med.* 1998;26:360-366.
6. Alfredson H, Pietilä T, Öhberg L, Lorentzon R. Achilles tendinosis and calf muscle strength. The effect of short-term immobilization after surgical treatment. *Am J Sports Med.* 1998;26:166-171.
7. Angermann P, Hovgaard D. Chronic Achilles tendinopathy in athletic individuals: results of nonsurgical treatment. *Foot Ankle Int.* 1999;20:304-306.
8. Ekblom B, Nilsson J. *Aktivt liv: Vetenskap och Praktik*. Farsta Malmö: SISU idrottsböcker; 2000.
9. Grimby G. Physical activity and muscle training in the elderly. *Acta Med Scand Suppl.* 1986;711:233-237.
10. Józsa L, Kannus P. *Human Tendons: Anatomy, Physiology, and Pathology*. Champaign, Ill: Human Kinetics; 1997.
11. Kader D, Saxena A, Movin T, Maffulli N. Achilles tendinopathy: some aspects of basic science and clinical management. *Br J Sports Med.* 2002;36:239-249.
12. Kannus P, Jozsa L, Natri A, Järvinen M. Effects of training, immobilization and remobilization on tendons. *Scand J Med Sci Sports.* 1997;7:67-71.
13. Kubo K, Akima H, Kouzaki M, et al. Changes in the elastic properties of tendon structures following 20 days bed-rest in humans. *Eur J Appl Physiol.* 2000;83:463-468.
14. Kvist M. Achilles tendon injuries in athletes. *Ann Chir Gynaecol.* 1991;80:188-201.
15. Kvist M. Achilles tendon injuries in athletes. *Sports Med.* 1994;18:173-201.
16. Langberg H, Rosendal L, Kjaer M. Training-induced changes in peritendinous type I collagen turnover determined by microdialysis in humans. *J Physiol.* 2001;534(Pt 1):297-302.
17. Langberg H, Skovgaard D, Asp S, Kjaer M. Time pattern of exercise-induced changes in type I collagen turnover after prolonged endurance exercise in humans. *Calcif Tissue Int.* 2000;67:41-44.
18. Langberg H, Skovgaard D, Petersen LJ, Bulow J, Kjaer M. Type I collagen synthesis and degradation in peritendinous tissue after exercise determined by microdialysis in humans. *J Physiol.* 1999;521(Pt 1):299-306.
19. Lowdon A, Bader DL, Mowat AG. The effect of heel pads on the treatment of Achilles tendinitis: a double blind trial. *Am J Sports Med.* 1984;12:431-435.
20. Maffulli N, Kenward MG, Testa V, Capasso G, Regine R, King JB. Clinical diagnosis of Achilles tendinopathy with tendinosis. *Clin J Sport Med.* 2003;13:11-15.
21. Mafi N, Lorentzon R, Alfredson H. Superior short-term results with eccentric calf muscle training compared to concentric training in a randomized prospective multicenter study on patients with chronic Achilles tendinosis. *Knee Surg Sports Traumatol Arthrosc.* 2001;9:42-47.
22. Muraoka T, Muramatsu T, Fukunaga T, Kanehisa H. Elastic properties of human Achilles tendon are correlated to muscle strength. *J Appl Physiol.* 2005;99:665-669.

23. Neeter C, Thomeé R, Silbernagel KG, Thomeé P, Karlsson J. Iontophoresis with or without dexamethazone in the treatment of acute Achilles tendon pain. *Scand J Med Sci Sports.* 2003;13:376-382.
24. Nelen G, Martens M, Burssens A. Surgical treatment of chronic Achilles tendinitis. *Am J Sports Med.* 1989;17:754-759.
25. Nichols AW. Achilles tendinitis in running athletes. *J Am Board Fam Pract.* 1989;2:196-203.
26. Niesen-Vertommen S, Taunton J, Clement D, Mosher R. The effect of eccentric versus concentric exercise in the management of Achilles tendonitis. *Clin J Sport Med.* 1992;2:109-113.
27. Öhberg L, Alfredson H. Ultrasound guided sclerosis of neovessels in painful chronic Achilles tendinosis: pilot study of a new treatment. *Br J Sports Med.* 2002;36:173-177.
28. Paavola M, Kannus P, Järvinen TA, Khan K, Jozsa L, Järvinen M. Achilles tendinopathy. *J Bone Joint Surg Am.* 2002;84:2062-2076.
29. Paavola M, Kannus P, Orava S, Pasanen M, Järvinen M. Surgical treatment for chronic Achilles tendinopathy: a prospective seven month follow up study. *Br J Sports Med.* 2002;36:178-182.
30. Paavola M, Kannus P, Paakkala T, Pasanen M, Järvinen M. Long-term prognosis of patients with Achilles tendinopathy. An observational 8-year follow-up study. *Am J Sports Med.* 2000;28:634-642.
31. Paavola M, Orava S, Leppilahti J, Kannus P, Järvinen M. Chronic Achilles tendon overuse injury: complications after surgical treatment. An analysis of 432 consecutive patients. *Am J Sports Med.* 2000;28:77-82.
32. Paoloni JA, Appleyard RC, Nelson J, Murrell GA. Topical glyceryl trinitrate treatment of chronic noninsertional achilles tendinopathy. A randomized, double-blind, placebo-controlled trial. *J Bone Joint Surg Am.* 2004;86:916-922.
33. Peers K. *Extracorporeal Shock Wave Therapy in Chronic Achilles and Patellar Tendinopathy* [Dissertation]. Leuven, Belgium: Leuven University Press, Leuven University; 2003.
34. Riley GP. Gene expression and matrix turnover in overused and damaged tendons. *Scand J Med Sci Sports.* 2005;15:241-251.
35. Robinson JM, Cook JL, Purdam C, et al. The VISA-A questionnaire: a valid and reliable index of the clinical severity of Achilles tendinopathy. *Br J Sports Med.* 2001;35:335-341.
36. Roos EM, Engström M, Lagerquist A, Söderberg B. Clinical improvement after 6 weeks of eccentric exercise in patients with mid-portion Achilles tendinopathy—a randomized trial with 1-year follow-up. *Scand J Med Sci Sports.* 2004;14:286-295.
37. Sarasa-Renedo A, Chiquet M. Mechanical signals regulating extracellular matrix gene expression in fibroblasts. *Scand J Med Sci Sports.* 2005;15:223-230.
38. Schepsis AA, Wagner C, Leach RE. Surgical management of Achilles tendon overuse injuries. A long-term follow-up study. *Am J Sports Med.* 1994;22:611-619.
39. Silbernagel KG, Gustavsson A, Thomeé R, Karlsson J. Evaluation of lower leg function in patients with Achilles tendinopathy. *Knee Surg Sports Traumatol Arthrosc.* 2006;14:1207-1217.
40. Silbernagel KG, Thomeé R, Karlsson J. Cross-cultural adaptation of the VISA-A questionnaire, an index of clinical severity for patients with Achilles tendinopathy, with reliability, validity and structure evaluations. *BMC Musculoskelet Disord.* 2005;6:12.
41. Silbernagel KG, Thomeé R, Thomeé P, Karlsson J. Eccentric overload training for patients with chronic Achilles tendon pain—a randomised controlled study with reliability testing of the evaluation methods. *Scand J Med Sci Sports.* 2001;11:197-206.
42. Stanish WD, Curwin S, Mandell S. *Tendinitis: Its Etiology and Treatment*. New York: Oxford University Press; 2000.
43. Testa V, Capasso G, Benazzo F, Maffulli N. Management of Achilles tendinopathy by ultrasound-guided percutaneous tenotomy. *Med Sci Sports Exerc.* 2002;34:573-580.
44. Thomeé R. A comprehensive treatment approach for patellofemoral pain syndrome in young women. *Phys Ther.* 1997;77:1690-1703.
45. Visnes H, Hoksrud A, Cook J, Bahr R. No effect of eccentric training on jumper's knee in volleyball players during the competitive season: a randomized clinical trial. *Clin J Sport Med.* 2005;15:227-234.