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Heavy-Load Eccentric Calf Muscle Training For the Treatment of Chronic Achilles Tendinosis

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ABSTRACT

We prospectively studied the effect of heavy-load eccentric calf muscle training in 15 recreational athletes (12 men and 3 women; mean age, 44.3 ± 7.0 years) who had the diagnosis of chronic Achilles tendinosis (degenerative changes) with a long duration of symptoms despite conventional nonsurgical treatment. Calf muscle strength and the amount of pain during activity (recorded on a visual analog scale) were measured before onset of training and after 12 weeks of eccentric training. At week 0, all patients had Achilles tendon pain not allowing running activity, and there was significantly lower eccentric and concentric calf muscle strength on the injured compared with the noninjured side. After the 12-week training period, all 15 patients were back at their preinjury levels with full running activity. There was a significant decrease in pain during activity, and the calf muscle strength on the injured side had increased significantly and did not differ significantly from that of the noninjured side. A comparison group of 15 recreational athletes with the same diagnosis and a long duration of symptoms had been treated conventionally, i.e., rest, nonsteroidal antiinflammatory drugs, changes of shoes or orthoses, physical therapy, and in all cases also with ordinary training programs. In no case was the conventional treatment successful, and all patients were ultimately treated surgically. Our treatment model with heavy-load eccentric calf muscle training has a very good short-term effect on athletes in their early forties.

Overuse injuries involving the Achilles tendon are common, especially among runners.[5,8,19,20] The majority of Achilles tendon overuse injuries occur in men, and they occur at a higher rate in middle-aged athletes than do most other overuse injuries.[3,10] Nonsurgical treatment is not always successful, and surgery is required in about 25% of these patients.[10] Frequency of surgery increases with patient age, duration of symptoms, and occurrence of tendinopathic changes.[10]

There are only a few studies on calf muscle strength in patients with Achilles tendon disorders. Calf muscle strength has been measured after rehabilitation in patients with surgically treated complete Achilles tendon ruptures[4,14,15,17] and in patients with complete Achilles tendon ruptures treated either surgically or nonsurgically.[7,18] We have recently, in two prospective studies on middle-aged recreational athletes with chronic Achilles tendinitis/tendinosis, reported the results of surgical treatment followed by 6 weeks of immobilization and of surgical treatment followed by 2 weeks of immobilization.[1,2] The results showed that it took a long time to recover concentric and eccentric calf muscle strength, despite a controlled postoperative rehabilitation including eccentric calf muscle training. The postoperative immobilization time, 6 weeks compared with 2 weeks, did not seem to have any influence on the time to recovery of calf muscle strength or on the time to resumption of previous activity levels.

A literature review indicated that there are no prospective studies on eccentric calf muscle training in patients with Achilles tendinopathies. Stanish et al.[16] have reported good results with an eccentric training regimen in patients with chronic tendinitis. However, to the best of our knowledge, no scientific data on these patients have been reported.

At our clinic, we have surgically treated patients with chronic Achilles tendinosis who do not respond to conventional nonsurgical treatment. The aim of this study was to

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prospectively study the short-term effect of heavy-load eccentric calf muscle training on tendon pain during activity and on calf muscle strength in patients with chronic Achilles tendinosis who were selected for surgical treatment.

MATERIALS AND METHODS

Fifteen consecutive recreational athletes (12 men and 3 women; mean age, 44.3 ± 7.0 years) with the diagnosis of Achilles tendinosis and a long duration of symptoms (18.3 months; range, 3 to 100) had pain during running and had tried conventional treatment (rest, nonsteroidal antiinflammatory drugs, changes of shoes or orthoses, physical therapy, and ordinary training programs) with no effect on the Achilles tendon pain. This group of patients was contacted during the years 1995 to 1996 and selected for preoperative heavy-load eccentric calf muscle training.

A control group of 15 consecutive recreational athletes (11 men and 4 women; mean age, 39.6 ± 7.9 years) with the same diagnosis and a long duration of symptoms (33.5 months; range, 6 to 88) was also contacted during the years 1993 to 1995.[1,2] The patients in this group had pain during running and had tried the same conventional treatments as the study group with no effect on the Achilles tendon pain. This group of patients underwent surgical treatment.[1,2] During the last 3 months before surgery, the patients in this group were resting and were not on any training regimen.

All patients in both groups had degenerative changes (tendinosis) in the tendon 2 to 6 cm above the Achilles tendon insertion on the calcaneus. The diagnosis was based on pain located in the Achilles tendon for at least 3 months. In all patients, localized degenerative changes in the tendon, corresponding to the painful area, were seen on ultrasonographs. All ultrasonography examinations were done by the same radiologist, and the degenerative changes were described as local thickening of the tendon, irregular tendon structure and fiber orientation, and separated tendon fibers. All patients in both groups had morning stiffness in the Achilles tendon and pain during running.

Patients with bilateral symptoms or with restricted ankle joint motion due to other injuries or diseases were excluded.

Muscle Strength

Isokinetic calf muscle strength was measured in newton-meters with a Biodex isokinetic dynamometer (Biodex Co., Shirley, New York). Peak torque and total work were evaluated in the experimental group before (week 0) and after (week 12) the eccentric training regimen. Peak torque was evaluated in the group that underwent surgery before (week 0) and after (week 24) surgery. In the results, total work is presented as “average work” (work per repetition). Peak torque is presented as the highest torque measurement from one repetition.

Concentric plantar flexion peak torque and total work were measured at 90 deg/sec (5 repetitions) and 225 deg/sec (10 repetitions) of angular velocity. Eccentric plantar flexion peak torque and total work were measured at 90 deg/sec (3 repetitions). All tests in all patients were done at about the same time of the day (between 9 AM and noon). The warm-up procedure consisted of 10 minutes of bicycling. For testing, the patients were seated with the knee positioned at 40° of flexion and with a hip angle of 110°. The axis of rotation in neutral position passes through the body of the talus, the fibular malleolus, and through or just below the tibial malleolus. Strength was measured between 20° of dorsal flexion and 30° of plantar flexion. The strength of the injured side was compared with the strength of the noninjured side. All tests were performed by the same physical therapist.

To our knowledge, there are no studies on the test-retest reliability of the Biodex dynamometer for ankle plantar flexion and dorsiflexion. Therefore, in our laboratory we determined the test-retest reliability for ankle plantar flexion and dorsiflexion peak torque using six healthy and noninjured subjects (4 men and 2 women; mean age, 34.4 ± 7.6 years). Statistical analysis of the data showed the following intraclass correlation coefficients: eccentric plantar flexion at 90 deg/sec, $r = 0.98$; concentric plantar flexion at 90 deg/sec, $r = 0.89$; concentric plantar flexion at 225 deg/sec, $r = 0.55$; concentric dorsiflexion at 90 deg/sec, $r = 0.59$; and dorsiflexion at 225 deg/sec, $r = 0.77$.

Pain Score

The amount of pain during activity (running) was evaluated by the patients on a 100-mm visual analog scale. On the visual analog scale, the amount of pain is recorded from 0 to 100 mm, where no pain is recorded as 0 and severe pain is recorded as 100. In the training group, evaluation was done before (week 0) and after (week 12) the eccentric training regimen. In the control group, evaluation was done before (week 0) and after (week 24) surgical treatment.

Eccentric Training Model

All patients were instructed on how to perform the eccentric training by either of two physical therapists (TP or PJ). They were given practice instructions and a written manual on how to progress. A control on how the patients did their exercises was done by the physical therapist after 6 weeks. The patients were instructed to do their eccentric exercises 2 times daily, 7 days/week, for 12 weeks. During the 12-week training regimen, running activity was allowed if it could be performed with only mild discomfort and no pain.

Two types of eccentric exercises were used (Fig. 1). The calf muscle was eccentrically loaded both with the knee straight (Figs. 1, A and B) and, to maximize the activation of the soleus muscle, also with the knee bent (Fig. 1C). Each of the two exercises included 15 repetitions done in 3 sets (3 × 15 repetitions). The patients were told that muscle soreness during the first 1 to 2 weeks of training was to be expected.

In the beginning, the loading consisted of the body

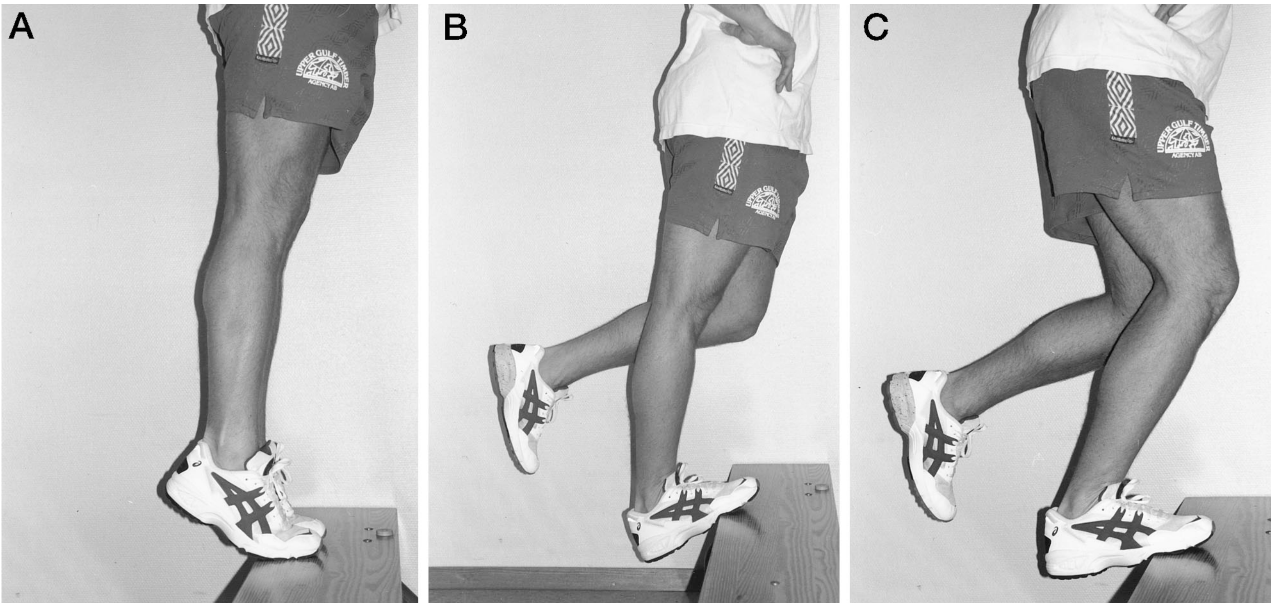

Figure 1. From an upright body position and standing with all body weight on the forefoot and the ankle joint in plantar flexion lifted by the noninjured leg (A), the calf muscle was loaded eccentrically by having the patient lower the heel with the knee straight (B) and with the knee bent (C).

weight, and the patients were standing with all their body weight on the injured leg. From an upright body position and standing with all body weight on the forefoot and the ankle joint in plantar flexion, the calf muscle was loaded by having the patient lower the heel beneath the forefoot (Fig. 1). They were only loading the calf muscle eccentrically, no following concentric loading was done. Instead, the noninjured leg was used to get back to the start position. The patients were told to go ahead with the exercise even if they experienced pain. However, they were told to stop the exercise if the pain became disabling. When they could perform the eccentric loading exercise without experiencing any minor pain or discomfort, they were instructed to increase the load by adding weight. This could easily be done by using a backpack that was successively loaded with weight (Fig. 2). In this way the eccentric calf muscle loading was gradually increased. If very high weights were needed, the patients were told to use a weight machine (Fig. 3).

Postoperative Rehabilitation

In the surgically treated group, all patients were treated postoperatively by the same physical therapist (TP). They followed a special stepwise training regimen and were seen regularly (every other week initially, and then monthly for 6 months, and finally at 1 year after surgery). The details of this postoperative training program have been previously published.[2]

Statistical Evaluation

The Wilcoxon signed rank test was used to evaluate differences between the injured and noninjured sides and

Figure 2. Increasing the load by adding weight in a backpack.

TABLE 1
Basic Data on 30 Patients with Chronic Achilles Tendinosis

Variable	Eccentric training group (N = 15)	Surgical treatment group (N = 15)
Sport (No. of patients)		
Jogging	15	14
Soccer		1
Symptom (No. of patients)		
Morning stiffness	15	15
Pain during walking	12	9
Pain preventing running	15	15
Earlier treatment (No. of patients)		
Previous ordinary training program	15	15
NSAID[a]	13	12
Local cortisone injection	3	5
Biomechanical faults (No. of patients)		
Cavus feet	6	5
Body characteristics		
Age (years)	44.3 ± 7.0	39.6 ± 7.9
Height (cm)	176.3 ± 9.4	175.5 ± 9.4
Weight (kg)	77.4 ± 10.1	75.5 ± 11.7
Duration of symptoms (months)	18.3 (3 – 100)	33.5 (6 – 88)

[a] Nonsteroidal antiinflammatory drug.

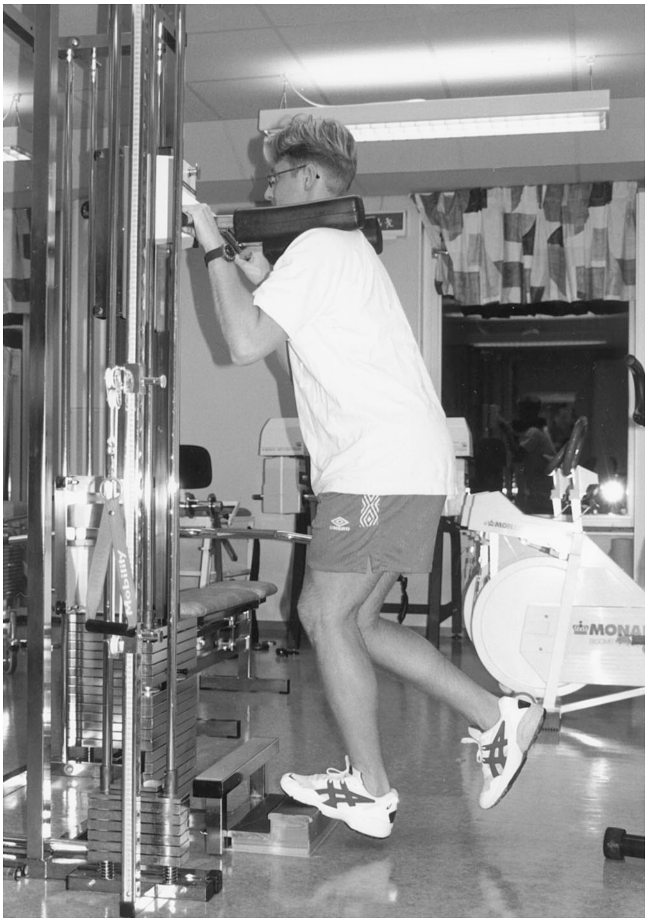

Figure 3. Increasing the load by adding weight with a weight machine.

between the different testing periods for the injured side. A P value of less than 0.05 was considered significant.

RESULTS

The group that underwent eccentric training included 12 men and 3 women with a mean age of 44.3 ± 7.0 years, and the group that underwent surgical treatment included 11 men and 4 women with a mean age of 39.6 ± 7.9 years (Table 1). The mean duration of symptoms was higher for the control group because of the wait for surgery, which can be 6 months to 1 year at our clinic. Sports activities, characteristic symptoms, earlier treatment, and biomechanical faults for all 30 patients with chronic Achilles tendinosis are shown in Table 1.

Isokinetic Peak Torque

Calf muscle strength in the injured and noninjured legs in the control group that underwent surgery is shown in Table 2. Preoperatively, the injured side had significantly lower concentric plantar flexion strength at 90 and 225 deg/sec (18.7% and 23.7%, respectively) and lower eccentric plantar flexion strength (13.6%) than the noninjured side. At week 24 postoperatively, the injured side had significantly lower concentric plantar flexion strength at 90 and 225 deg/sec (14.5% and 15.2%, respectively) and lower eccentric plantar flexion strength (15.7%) than the noninjured side.

In the group that was on the eccentric training regimen, before onset of training (week 0) the injured side had significantly lower concentric plantar flexion strength at 90 and 225 deg/sec (12.1% and 18.0%, respectively) and lower eccentric plantar flexion strength (11.2%) than the noninjured side (Table 3). After training (week 12), the concentric plantar flexion strength at 90 and 225 deg/sec and eccentric plantar flexion strength on the injured side had increased significantly (Table 3). There were no sig-

TABLE 2
Isokinetic Concentric and Eccentric Peak Torque (in Newton-meters) in 15 Patients with Chronic Achilles Tendinosis and Selected to Receive Surgical Treatment

Test condition	Preoperative (Week 0)		Postoperative (Week 24)	
	Injured[a]	Noninjured	Injured[a]	Noninjured
Concentric plantar flexion				
90 deg/sec	70.8 ± 24.4	87.1 ± 21.6	73.6 ± 23.8	86.1 ± 22.5
225 deg/sec	34.4 ± 15.3	45.1 ± 12.3	36.7 ± 14.4	43.3 ± 12.8
Eccentric plantar flexion				
90 deg/sec	146.3 ± 56.3	169.4 ± 48.0	144.3 ± 50.7	171.2 ± 63.7

[a] The injured side had significantly lower strength than the noninjured side for all test conditions ($P < 0.01$).

TABLE 3
Isokinetic Concentric and Eccentric Peak Torque (in Newton-meters) in 15 Patients with Chronic Achilles Tendinosis Who Underwent a 12-Week Calf Muscle Strengthening Regimen

Test condition	Week 0		Week 12	
	Injured	Noninjured	Injured	Noninjured
Concentric plantar flexion				
90 deg/sec	69.1 ± 24.6[a]	78.6 ± 20.8	76.9 ± 20.6[b]	80.4 ± 18.6
225 deg/sec	30.9 ± 10.4[a]	37.7 ± 10.3	35.5 ± 11.3[b]	37.5 ± 11.8
Eccentric plantar flexion				
90 deg/sec	152.0 ± 57.4[c]	171.1 ± 48.6	179.2 ± 56.9[d]	181.9 ± 43.8

[a] Concentric plantar flexion strength was significantly less ($P < 0.01$) in the injured leg compared with the noninjured leg.
[b] Concentric plantar flexion strength in the injured leg increased significantly ($P < 0.05$) compared with pretraining strength.
[c] Eccentric plantar flexion strength was significantly less ($P < 0.05$) in the injured leg compared with the noninjured leg.
[d] Eccentric plantar flexion strength in the injured leg increased significantly ($P < 0.01$) compared with pretraining strength.

TABLE 4
Isokinetic Concentric and Eccentric Average Work (in Joules) in 15 Patients With Chronic Achilles Tendinosis Who Underwent a 12-Week Calf Muscle Strengthening Regimen

Test condition	Week 0		Week 12	
	Injured	Noninjured	Injured	Noninjured
Concentric plantar flexion				
90 deg/sec	32.8 ± 13.3[a]	38.5 ± 10.6	37.5 ± 13.0[b]	40.5 ± 12.7
225 deg/sec	11.8 ± 5.4[a]	15.1 ± 4.8	14.0 ± 7.1	16.3 ± 6.8
Eccentric plantar flexion				
90 deg/sec	104.6 ± 45.7	115.4 ± 44.5	107.1 ± 38.2	106.4 ± 32.8

[a] Concentric plantar flexion strength was significantly less ($P < 0.01$) in the injured leg compared with the noninjured leg.
[b] Concentric plantar flexion strength in the injured leg at 90 deg/sec increased significantly ($P < 0.05$) compared with the pretraining strength.

nificant differences in concentric and eccentric plantar flexion strength between the injured and noninjured sides. On the noninjured side, there were no significant differences in concentric and eccentric plantar flexion strength between weeks 0 and 12.

Isokinetic Average Work

Before the onset of eccentric calf muscle training (week 0) the injured side showed significantly lower concentric plantar flexion average work at 90 and 225 deg/sec (14.8% and 21.9%, respectively), but not lower eccentric plantar flexion average work, than the noninjured side (Table 4). After training (week 12), the concentric plantar flexion average work at 90 deg/sec, but not at 225 deg/sec, had increased significantly on the injured side. There was no significant difference in eccentric plantar flexion average work on the injured side between weeks 0 and 12. After training (week 12), there were no significant differences in concentric and eccentric plantar flexion strength between the injured and noninjured sides (Table 4). On the noninjured side, there were no significant differences in concentric and eccentric plantar flexion strength between weeks 0 and 12.

Pain Scale

The effect of eccentric calf muscle training and surgical treatment was evaluated on a 100-mm visual analog scale, on which the patients described the amount of pain during activity (running) before (week 0) and after the eccentric training regimen (week 12) or surgical treatment (week 24). In the group that had eccentric calf muscle training, there was a significant decrease ($P < 0.001$) in the pain score (from 81.2 ± 18.0 to 4.8 ± 6.5) from week 0 to week 12. In the control group (surgical treatment), there was a significant decrease ($P < 0.01$) in the pain score (from 71.8 ± 17.9 to 21.2 ± 11.4) from week 0 to week 24. All patients were satisfied and back at their preinjury levels at week 12 and week 24, respectively.

DISCUSSION

Achilles tendinopathy with disabling pain is a common overuse injury, most frequently seen among middle-aged male runners.[5,8,10,19] Nonsurgical treatment is not always successful and surgery is required in about 25% of these patients.[10] The occurrence of tendinopathic changes, a high age, and a long period of symptoms, increases the need for surgical treatment.[10–13]

In this study, 15 middle-aged recreational runners (12 men and 3 women) with the diagnosis of chronic Achilles tendinosis who were selected for surgical treatment underwent a specially designed eccentric calf muscle training program preoperatively that resulted in excellent results and no need for surgical treatment. We also evaluated a group of 15 middle-aged recreational runners (11 men and 4 women) recruited with the same diagnostic criteria and selected for surgical treatment who had stopped nonsurgical treatment to prepare for surgery. There were no major differences between the two groups of patients. All patients in both groups had tendinopathic changes that were seen on ultrasonographs, had had persistent symptoms for a long period, and had tried conventional treatment with no effect. The group that underwent surgical treatment had a longer duration of symptoms than the eccentric training group, and this difference is explained by the fact that this group was on the waiting list for operation while the training group started their eccentric training regimen immediately after the diagnosis had been settled. At our clinic the waiting time for such a surgical intervention is around 6 months to 1 year.

Stanish et al.[16] suggested in 1986 that eccentric muscle strength training should be included in the rehabilitation of tendon injuries, and they showed promising results with an eccentric training model in patients with chronic tendinitis. In our study, after 12 weeks of eccentric calf muscle training, all patients were back at their preinjury levels with full running activity. There were no significant side-to-side differences in concentric and eccentric plantar flexion strength between the injured and noninjured sides. All patients were satisfied and no patient had to be surgically treated. In the group that was resting before surgery, all patients had remaining Achilles tendon pain and underwent surgical treatment. After surgical treatment, all patients came back to their preinjury levels with running activity, but the time needed for recovery was 6 months, compared with 3 months for the group treated with the eccentric training regimen. It appears that the eccentric calf muscle training had a good effect on the painful condition in the Achilles tendon. However, whether this is an effect of the higher eccentric calf muscle strength after training or other mechanisms associated with eccentric loading of the tendon we do not know. As in other studies on eccentric training,[9] an improvement in concentric muscle strength was also seen after training was completed.

The maximal load is placed on a tendon during the eccentric phase, and it is likely that tendon injuries occur during eccentric loading.[6,16] All patients in our study were recreational runners, and theoretically their Achilles tendon injuries may have been a result of repetitive microtrauma during eccentric loading when running. They were found to have significantly lower concentric and eccentric plantar flexion strength on the injured side compared with the noninjured side before the eccentric training program was instituted. This strength deficit might possibly predispose the tendon to injury. However, this strength deficit might also be acquired during the period of inactivity before the examination, but one could assume that during that period both extremities would be affected. A possible explanation might also have been that the strength deficit was associated with the pain in the tendon during the test situation. Therefore, the angle in the joint was between 20° of dorsiflexion and 30° of plantar flexion during the test, and all patients could perform the test without any disabling pain in the tendon. Another theoretical explanation for the strength differences recorded might be that there is a neuromuscular disturbance on the injured side caused by the initial injury.

It has been proposed that possible explanations for the positive effects of eccentric training on tendinitis might be either an effect of stretching, with a "lengthening" of the muscle-tendon unit and consequently less strain during ankle joint motion, or effects of loading within the muscle-tendon unit, with hypertrophy and increased tensile strength in the tendon.[16] Thus, remodeling of the tendon is induced from eccentric loading. Therefore, to try to find structural changes in the tendon related to the eccentric training, we are observing this group of patients regularly with ultrasound examinations.

In prospective training studies there is always a risk of noncompliance, and patient cooperation is important. In our model for eccentric calf muscle training, we used only two exercises that are easy to perform in a correct manner. The exercises can be done at home, and no special training machines are needed. We had no dropouts in this study.

The velocity-specific effects of eccentric training have not been extensively investigated but, based on current knowledge, eccentric exercise does not appear to be velocity-specific.[9] In our training model, only eccentric loading of the muscle tendon unit was applied, and the loading was applied at a slow speed at every training session. In the training model proposed by Stanish et al.,[16] the eccentric loading phase is followed by a concentric loading phase, and the eccentric loading is applied with increasing speed day by day on a weekly basis.

A literature review indicated that there were no studies on calf muscle strength in patients with the diagnosis Achilles tendinitis or tendinosis, and only a few on calf muscle strength in patients treated for Achilles tendon ruptures.[4,7,14,15,17,18] In these studies, calf muscle strength has been measured postoperatively in patients with total Achilles tendon ruptures. We have recently, in two prospective studies on patients with chronic Achilles tendinitis/tendinosis, reported the results of surgical treatment followed by 6 weeks of immobilization or followed by 2 weeks of immobilization.[1,2] The results showed that it took a long time to recover concentric and eccentric calf muscle strength, despite a controlled postoperative rehabilitation including eccentric calf muscle training. The results of these two studies showed that the patients were back at their preinjury activity levels around 6 months postoperatively. In this study, including the same type of patients (same inclusion criteria) as in our two studies with surgical treatment, all patients were back at their preinjury level after 3 months of eccentric calf muscle training.

Based on our short-term results, there are several beneficial effects with this treatment model. It seems to be a safe training model. No new injuries associated with the type of calf muscle and joint loading (ankle, knee, and hip) were noticed. The risks associated with surgical treatment and immobilization are not involved. The cost of this treatment is low. Sick leave from work is not needed unless the patient's work includes heavy loading of the lower leg.

This was a short-term study, as the patients have been observed for an average of 6 months (range, 4 to 12), but all patients are back at their preinjury levels with full running activity. A few patients have had short periods of minor Achilles tendon pain that have disappeared with continued eccentric training. Therefore, after the 12-week training period, all patients have been instructed to continue their eccentric training 1 to 2 times per week. We do not know whether eccentric calf muscle training is a definite cure for chronic Achilles tendinosis, and these patients are being regularly observed.

CONCLUSIONS

Our model for eccentric calf muscle training in patients with chronic Achilles tendinosis is easy to perform and provides a good treatment model that has resulted in a fast recovery in concentric and eccentric calf muscle strength and resumption of previous running activity in 15 consecutive patients. It seems that there is little place for surgery in the treatment of chronic Achilles tendinosis located at the 2- to 6-cm level in the tendon. At the least, we strongly suggest that this training model be properly tried before surgical intervention is instituted. Further studies on the possible mechanisms that can explain the effects of eccentric calf muscle training on Achilles tendon pain are needed.

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