

SURGICAL TREATMENT COMPARED WITH ECCENTRIC TRAINING FOR PATELLAR TENDINOPATHY (JUMPER'S KNEE)

A RANDOMIZED, CONTROLLED TRIAL

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Background: Although the surgical treatment of patellar tendinopathy (jumper's knee) is a common procedure, there have been no randomized, controlled trials comparing this treatment with forms of nonoperative treatment. The purpose of the present study was to compare the outcome of open patellar tenotomy with that of eccentric strength training in patients with patellar tendinopathy.

Methods: Thirty-five patients (forty knees) who had been referred for the treatment of grade-IIIB patellar tendinopathy were randomized to surgical treatment (twenty knees) or eccentric strength training (twenty knees). The eccentric training group performed squats on a 25° decline board as a home exercise program (with three sets of fifteen repetitions being performed twice daily) for a twelve-week intervention period. In the surgical treatment group, the abnormal tissue was removed by means of a wedge-shaped full-thickness excision, followed by a structured rehabilitation program with gradual progression to eccentric training. The primary outcome measure was the VISA (Victorian Institute of Sport Assessment) score (possible range, 0 to 100), which was calculated on the basis of answers to a symptom-based questionnaire that was developed specifically for patellar tendinopathy. The patients were evaluated after three, six, and twelve months of follow-up.

Results: There was no difference between the groups with regard to the VISA score during the twelve-month follow-up period, but both groups had improvement ($p < 0.001$). The mean combined VISA score for the two groups increased from 30 (95% confidence interval, 25 to 35) before the start of treatment to 49 (95% confidence interval, 42 to 55) at three months, 58 (95% confidence interval, 51 to 65) at six months, and 70 (95% confidence interval, 62 to 78) at twelve months. In the surgical treatment group, five knees had no symptoms, twelve had improvement but were still symptomatic, two were unchanged, and one was worse after twelve months ($p = 0.49$ compared with the eccentric training group). In the eccentric training group, five knees did not respond to treatment and underwent secondary surgery after three to six months. Of the remaining fifteen knees in the eccentric training group, seven had no symptoms and eight had improvement but were still symptomatic after twelve months.

Conclusions: No advantage was demonstrated for surgical treatment compared with eccentric strength training. Eccentric training should be tried for twelve weeks before open tenotomy is considered for the treatment of patellar tendinopathy.

Level of Evidence: Therapeutic Level I. See Instructions to Authors for a complete description of levels of evidence.

Patellar tendinopathy (jumper's knee) can severely limit or even end an athletic career. This condition affects athletes in many sports, particularly elite athletes in jumping sports¹. The prevalence of jumper's knee has been estimated to range between 40% and 50% among high-level volleyball players¹⁻⁴ and between 35% and 40% among elite basketball players¹. A recent epidemiological study showed that the average duration of substantial pain problems and re-

duced function is nearly three years¹. The high prevalence, low function scores, and chronic nature that are characteristic of the condition mean that patellar tendinopathy may impair athletic performance in some jumping sports as much as acute knee injuries do¹.

Jumper's knee is an insertional tendinopathy that most commonly affects the patellar tendon origin on the inferior pole of the patella⁵⁻⁷; it is not an inflammatory condition⁸⁻¹¹.

The initial treatment of jumper's knee typically includes rest, ice, electrotherapy, massage, taping, anti-inflammatory medication, or corticosteroid injections. However, these treatment regimes have not been demonstrated to be effective, and thus they have no evidence-based support^{7,12}.

Surgery has been recommended if nonoperative treatment fails. Open patellar tenotomy has been the most widely described procedure and remains the technique against which others are compared¹³. In 2000, Coleman et al. reviewed twenty-five surgical outcome studies and assessed their quality with use of a newly developed methodology score⁵. They found that the quality of studies was generally low: only two prospective studies, both of which were nonrandomized, had been performed at that time^{14,15}. Interestingly, they also found that the reported success rate was inversely related to the methodological quality of the studies (that is, low-quality studies demonstrated high success rates, and vice versa).

We are not aware of any randomized clinical trials on the surgical treatment of patellar tendinopathy. One reason may be a lack of alternative nonsurgical treatment options to which patients can be randomized. However, eccentric training was suggested as a treatment modality for jumper's knee as early as 1984 by Curwin and Stanish¹⁶. Recently, eccentric training has been found to be effective in pilot studies of patients with patellar tendinopathy¹⁷⁻¹⁹ as well as in larger randomized studies of patients with Achilles tendinopathy²⁰⁻²³.

Therefore, we undertook a randomized trial to compare the outcome of open patellar tenotomy with that of eccentric strength training in a group of patients with patellar tendinopathy.

Materials and Methods

Design

This randomized clinical study involved the use of a two-group repeated-measures design in which patients were

followed for twelve months (Fig. 1). From March 2001 to September 2004, patients with patellar tendinopathy who had volunteered for the study were randomly allocated to a surgical treatment group or an eccentric training group. In addition, patients who reported that eccentric training had had no effect were offered surgical treatment and were also followed for twelve months after surgery; these patients constituted the secondary surgical treatment group. The study was approved by the Regional Committee for Medical Research Ethics, Helse Øst.

Patient Recruitment

Physicians and physical therapists in the Oslo region were informed of the purposes and procedures of the study by mail and were asked to refer patients who fulfilled the inclusion criteria to the Health Department at the Olympic Training Center. The center normally only serves athletes on the national team level, but a broader range of patients was accepted for the present study. After receiving information about the study, patients were invited to take part in a clinical screening examination, which included a full knee examination and an evaluation with use of a questionnaire detailing age, height, weight, gender, history of knee pain, treatment received, sporting profile, and activity level. All patients were screened by the same physician (R.B.).

Inclusion Criteria

The diagnostic criteria that were used to identify jumper's knee included a history of exercise-related pain in the proximal part of the patellar tendon or the patellar insertion and tenderness to palpation corresponding to the painful area⁴. In addition, a magnetic resonance imaging investigation was done. To be included in the study, the patient had to have a clinical diagnosis of jumper's knee as well as grade-IIIB symp-

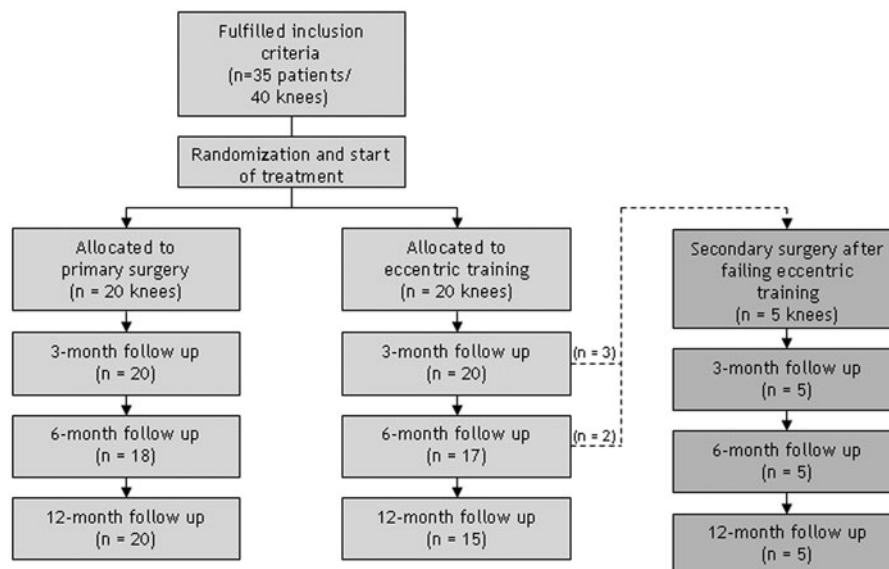


Fig. 1

Flowchart depicting the patient randomization procedure, treatment groups, and follow-up.

toms on the scale originally described by Blazina et al.²⁴ and later modified by Lian et al.⁴ (that is, the patient had to have pain during and after activity and had to be unable to participate in sports at the same level as before the onset of pain). In addition, the patient had to have thickening and increased signal intensity changes corresponding to the painful area as seen on the magnetic resonance imaging scan, had to have had symptoms for a minimum of three months, and had to be willing to undergo surgery. The subject was excluded if he or she had a history of knee or patellar tendon surgery or had an inflammatory or degenerative joint condition. Both knees were included if the patient had bilateral involvement. The subject had to be at least eighteen years old and had to be able to understand oral and written Norwegian. Patients who fulfilled the selection criteria were asked to sign a written consent form. During the recruitment period, all but five eligible patients were included. The main reason for noninclusion was an unwillingness to undergo surgery.

Randomization and Blinding

A randomization sequence to surgical treatment or eccentric training (in blocks of four) was created by our statistician prior to the start of the study. Numbered, sealed envelopes were used to reveal the group allocation to the investigator and the patient after inclusion in the study. Patients with bilateral involvement were allocated to have one knee in each group; in these cases, the envelope was used to allocate the treatment for the right knee. Patients in both groups were allowed to take pain medication freely, including nonsteroidal antiinflammation medication. Neither the patients nor the investigators were blinded with regard to the group allocation.

Eccentric Training Protocol

The patients in the eccentric training group were followed weekly for twelve weeks by a physical therapist (B.F. or one of two other individuals who were not authors of the study) from the Olympic Training Center to ensure proper execution of the program and exercises. The patients were asked to perform the eccentric training program on a 25° decline board at home. Each training session was to be completed twice daily, with three sets of fifteen repetitions being performed at each session. The exercises were done without warming up. The downward (eccentric) component was performed with the affected leg, and the upward (concentric) component was performed with the asymptomatic leg. If both knees were affected, the patient was instructed to use the arms to assist during the concentric phase. The patient was instructed to take two seconds for each eccentric component of each exercise. The squat was performed with the back in a vertical position and with the knee flexed to 90°; this ensured that the knee was flexed beyond 60°, which is the joint angle that is thought to place maximal load on the patellar tendon¹⁸. This protocol adapts Alfredson's Achilles tendon exercise program²⁰ to the patellar tendon.

The patient was instructed to exercise despite pain dur-

ing exercise and to stop only if the pain became disabling. The training group was recommended to have a pain value of 4 or 5 on a visual analog scale (with 0 representing no pain and 10 representing the worst pain possible) during the eccentric training sessions. When pain decreased to <3, the participant added load in a backpack in 5-kg increments. If pain increased to >5, the participant was instructed to perform the exercise with less weight.

The patients in the eccentric training group were asked to train for a minimum of twelve weeks and were encouraged to continue the eccentric training twice weekly thereafter. During the first eight weeks of treatment, the patients were not allowed to take part in sports-specific training. After four weeks, they were allowed to cycle, to jog on a flat surface, or to exercise in water if these activities could be done without pain. After eight weeks, the patients were allowed to gradually return to their sport if there was no or minimal pain.

Surgical Treatment

Under sterile conditions, 25 mL of local anesthetic (Xylocaine [lidocaine; 10 mg/mL] with adrenaline) was infiltrated subcutaneously anterior to the patellar tendon. Surgery was performed by two experienced orthopaedic surgeons (L.E. and S.L.). A 5-cm longitudinal midline incision was made from the inferior patellar pole distally. A tourniquet was not used. Bleeding vessels were electrocauterized. The paratenon was split longitudinally, any pathologic paratenon tissue was removed, and the tendon was fully exposed. The tendon was split longitudinally in the midline to expose the deeper layers. Tendon tissue was excised with use of a full-thickness wedge-shaped incision, which was widest at the patellar pole and narrowed distally. All abnormal-appearing tissue was removed. If clearly abnormal tissue was not seen macroscopically, the excision was based on the magnetic resonance imaging signal changes. Typically, the wedge had a proximal base that was 1 cm wide and extended to an apex located 2 to 3 cm distal to the patellar pole. No osseous procedures were performed. No sutures were placed in the tendon, but the subcuticular tissue was closed with resorbable sutures and the skin was closed with cutaneous sutures. The cutaneous sutures were removed after two weeks.

Postoperatively, the patients were provided with crutches and were referred to the same physical therapists as those in the eccentric training group, who followed the patients on a weekly basis for at least twelve weeks. During the first six weeks, the patients participated in a rehabilitation program that involved a gradual increase in the number of training sessions and repetitions. In Week 1, the patient performed isometric quadriceps exercises focusing on the vastus medialis obliquus, non-weight-bearing pain-free range-of-motion exercises, and weight transfer while standing. In Week 2, the patient added walking, with gradual reduction of the use of crutches. In Week 3, the patient added cycle ergometry with light loads and gradually increasing duration as well as high squats with arm support. In Week 4, the patient added step-ups to a low (5 to 6-cm) step. In Week 5, the patient added

step-downs from a low (5 to 6-cm) step. In Week 6, the patient added eccentric squat training with use of the same program as that used for the eccentric training group, starting without load. However, in contrast to the eccentric training group, no or minimal pain was tolerated during the eccentric training for the surgically treated group. Other training was permitted according to the same guidelines as were used for the eccentric training group.

Secondary Surgical Treatment Group

Patients in the eccentric training group who reported no improvement after a minimum of twelve weeks of training were offered secondary surgical treatment. The surgical procedure and rehabilitation program for this group were the same as those for the primary surgical treatment group. The patients in the secondary surgical treatment group were followed for an additional twelve months after surgery.

Treatment Evaluation

Weekly training logs were kept by both groups for the first twelve weeks of rehabilitation. The patients were scheduled for follow-up visits in the clinic after three, six, and twelve months. At each evaluation, the patients underwent functional testing and completed a VISA (Victorian Institute of Sport Assessment) form and a form assessing their global satisfaction with treatment. The forms were completed by the patients themselves with minimal assistance from the investigators. The primary outcome that was measured over the study period was knee function according to the self-reported VISA score. The VISA score²⁵ is calculated on the basis of the answers to eight questions assessing symptoms, simple tests of function, and the ability to play sports. The VISA score can range from 0 to 100, with the maximum score of 100 representing full, pain-free function. Competing athletes with patellar tendinopathy commonly have a score in the 50 to 80-point range. The VISA score was designed specifically to quantify knee function in subjects with patellar tendinopathy and has been shown to be a reliable and valid measure^{25,26}. Secondary outcomes were a global evaluation score, treatment satisfaction, and functional tests of strength and jumping performance. Both groups evaluated the intervention by answering the question "How is your knee now as compared with before treatment?" by marking an 11-point visual numerical scale, with +5 representing maximum improvement (no symptoms), 0 representing no change, and -5 representing maximum worsening (severe symptoms). Overall treatment satisfaction was rated with use of a 4-grade scale as "no symptoms," "improved, but still symptomatic," "no change," or "worse."

Functional Tests

Jumping performance and strength were tested before the start of treatment and again after six and twelve months by a tester who was unaware of the purpose of the study. The order of the tests was always the same: standing jumps were tested first, counter-movement jumps were tested next, and

leg extension strength was tested last. After each effort, the patient rated the pain by marking an 11-point visual numerical scale, with 0 representing no pain and 10 representing maximum pain. The jump tests were performed on a force platform (Model LG6-4-2000; AMTI, Watertown, Massachusetts), and jump height (in centimeters) was calculated on the basis of the force-time curve (net impulse). Two types of jumps were tested: a standing jump and a counter-movement jump. Each jump was done nine times, first on both legs and then on each leg (on both sides, whether affected by patellar tendinopathy or not). Standing jumps were performed with the subject starting from a stationary semisquatting position with 90° of knee flexion and with both hands kept fixed on the hips. No counter-movement was allowed with any body segment. Counter-movement jumps were done with the subject starting the movement from a stationary erect position with the knees fully extended. The subject was then allowed to bend down to approximately 90° of knee flexion before starting the upward motion of the jump. Both hands were kept fixed on the hips. The patient was not vocally encouraged during the jumps, and the tester watched carefully to ensure that the proper technique was used. The best of three technically correct jumps on the affected leg or legs was used for the final calculations. Strength was recorded as the one-repetition maximum load (in kilograms) that the patient could lift in a closed-chain exercise with use of a leg-press machine (C-line B14 Angled Leg Press; David Fitness and Medical, Vantaa, Finland).

Statistical Methods

To test the principal null hypothesis that there was no difference between the groups with regard to VISA scores, the groups were compared with use of analysis of variance for repeated measures, with treatment group (surgery or eccentric training) as the between-subjects factor and time (baseline, three, six, or twelve months) as the within-subjects factor. An intention-to-treat analysis was used, which means that for patients in the eccentric training group who opted for secondary surgery, the final score before surgery was carried forward to the twelve-month follow-up. Within-group comparisons were performed with use of the paired t test, and between-group comparisons were performed with use of the unpaired t test. The level of significance was set at 5%, and the results are presented as the mean and the 95% confidence interval unless otherwise stated.

The sample size was calculated on the basis of the primary outcome measure, the VISA score, with use of a significance level of 5% and a test power of 90%. A mean baseline score (and standard deviation) of 55 ± 12 points in symptomatic athletes and of 95 ± 8 points in athletes without patellar tendinopathy was expected^{25,26}. The difference between symptomatic and nonsymptomatic athletes (40 points) was assumed to represent the maximum potential treatment benefit. To detect a group difference of thirteen points (equivalent to 33% of the maximal potential effect), it was determined that we would need to include fifteen patients in each group. The calculations also assumed a standard deviation for the change

TABLE I Subject Characteristics at Baseline

	Eccentric Training Group	Primary Surgery Group
Age* (yr)	31 ± 8 (19-45)	30 ± 8 (19-49)
Height* (cm)	180 ± 9 (161-196)	178 ± 8 (161-191)
Weight* (kg)	81 ± 12 (57-100)	76 ± 10 (57-95)
No. of female patients	2	3
VISA score* (points)	29 ± 16 (9-57)	31 ± 15 (4-54)
Participation in organized sports training* (yr)	16 ± 7 (6-28)	17 ± 8 (5-37)
Duration of symptoms* (mo)	33 ± 28 (6-100)	35 ± 30 (6-120)
Specific sport activity training* (hr/wk)	7.6 ± 6.4 (0-30)	6.5 ± 3.9 (0-14)
Weight training* (hr/wk)	2.0 ± 2.0 (0-6)	2.9 ± 2.9 (0-10)
Jump training* (hr/wk)	0.2 ± 0.6 (0-2)	0.4 ± 0.7 (0-2)
Other training* (hr/wk)	1.4 ± 2.4 (0-10)	2.5 ± 3.9 (0-15)
Total training volume* (hr/wk)	11.2 ± 7.2 (3-30)	12.2 ± 7.3 (0-30)

*The values are given as the mean and the standard deviation, with the range in parentheses.

of 11 based on a correlation between the baseline and final VISA scores of 0.5.

Results

Patient Characteristics

The study group included thirty-five patients (four women and thirty-one men) with forty tendons with patellar tendi-

nopathy; five patients had bilateral symptoms. The results of randomization and follow-up are illustrated in Figure 1. The patients had participated mainly in running/fitness training (thirteen patients), soccer (seven), team handball (six), and martial arts (four). The baseline characteristics and training history of the two groups are shown in Table I. There were no differences in baseline characteristics between groups ($p = 0.15$ to 0.85).

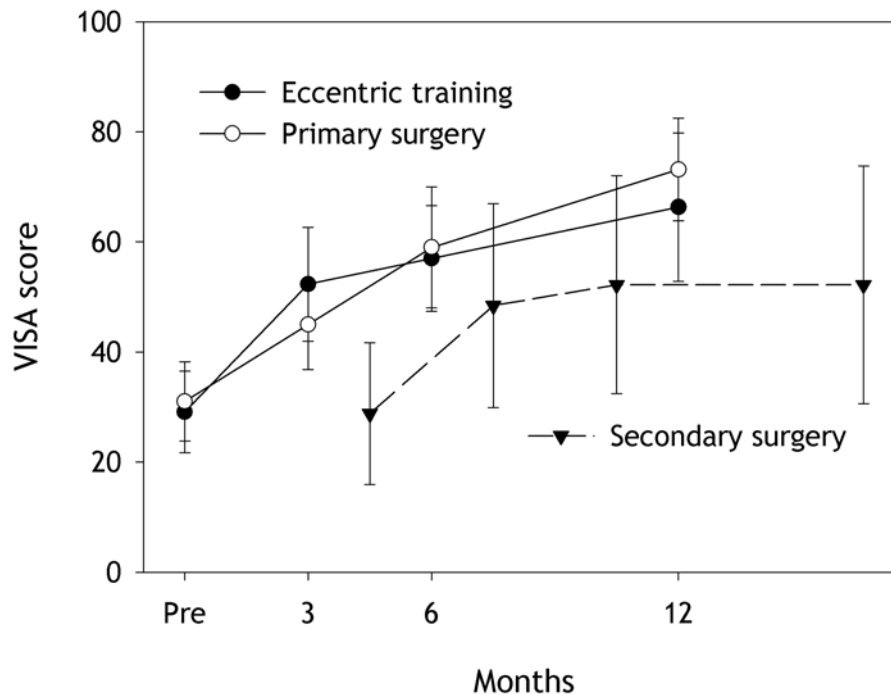


Fig. 2

Illustration showing the mean VISA scores (with 95% confidence intervals) for the primary surgical treatment group (open circles) and the eccentric training group (closed circles) after three, six, and twelve months of follow-up. In addition, the results are shown after secondary surgery for the subgroup in which eccentric training failed (closed triangles, dashed line).

TABLE II Pain Scores for Functional Tests at Baseline and After Twelve Months*

	Primary Surgery Group		Eccentric Training Group	
	Baseline	After 12 Months	Baseline	After 12 Months
Standing jump	4.3 (3.3 to 5.3)	1.3 (1.0 to 1.7)	3.9 (2.7 to 5.1)	1.7 (0.9 to 2.5)
Counter-movement jump	4.8 (3.8 to 5.8)	1.7 (0.7 to 2.7)	3.9 (2.7 to 5.1)	1.8 (1.0 to 2.6)
Leg press	4.1 (2.9 to 6.2)	1.2 (0.4 to 2.0)	4.0 (2.6 to 5.4)	1.3 (0.5 to 2.1)

*The values are given as the group mean, with the 95% confidence interval in parentheses.

The patients in the eccentric training group completed an average of 9.3 ± 4.1 training sessions per week (66% of the prescribed dose) during the initial twelve-week follow-up period, whereas the patients in the primary surgery group completed 10.1 ± 4.3 weekly training sessions (72% of the prescribed dose) during the twelve-week postoperative rehabilitation period.

VISA Score

When the two main treatment groups were compared, there was no difference between the groups with regard to the VISA scores during the twelve-month follow-up period ($F = 0.26$; $p = 0.87$, analysis of variance) but there was a strong time effect ($F = 55.9$; $p < 0.001$). Thus, there was no difference between the groups in terms of the VISA scores at three months (-7 ; 95% confidence interval, -20 to 6), six months (2 ; 95% confidence interval, -12 to 16), or twelve

months (7 ; 95% confidence interval, -9 to 22) (Fig. 2). However, the mean combined VISA score for the two groups increased from 30 (95% confidence interval, 25 to 35) before the start of treatment to 49 (95% confidence interval, 42 to 55) at three months, 58 (95% confidence interval, 51 to 65) at six months, and 70 (95% confidence interval, 62 to 78) at twelve months (Fig. 2). Five patients in the eccentric training group experienced no improvement after at least twelve weeks of training and underwent surgery after the three or six-month follow-up (Fig. 1). In this subgroup, with the numbers available, we did not detect any significant improvement in the VISA score during the twelve-month period (Fig. 2).

Global Evaluation Score

When the two main treatment groups were compared, there was a significant difference between the groups with regard

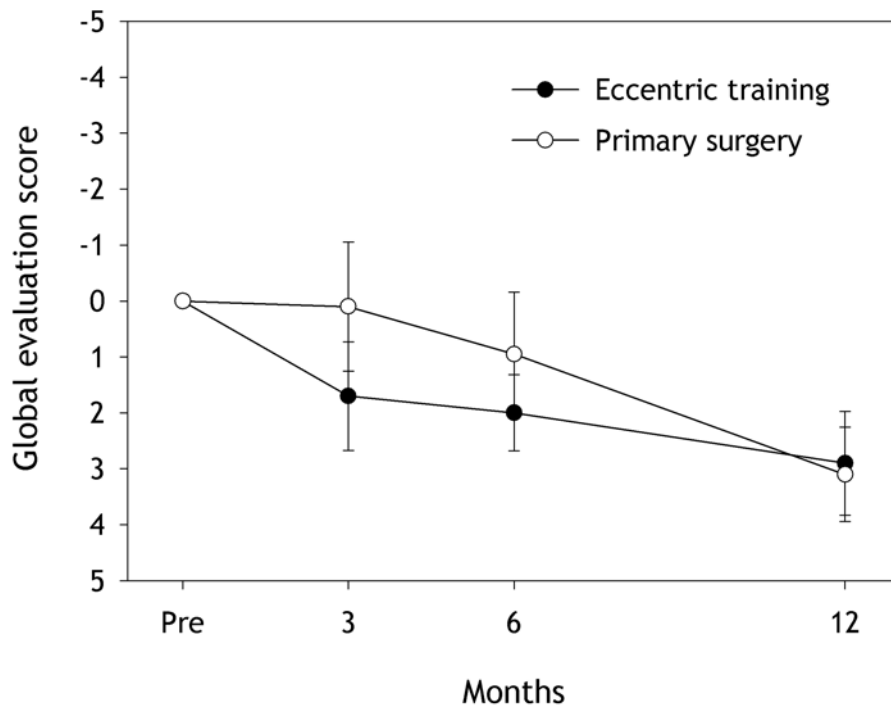


Fig. 3

Illustration showing the mean global evaluation scores (with 95% confidence intervals) for the primary surgical treatment group (open circles) and the eccentric training group (closed circles) after three, six, and twelve months of follow-up.

to the global evaluation scores during the twelve-month follow-up period ($F = 5.65$; $p = 0.007$, analysis of variance). Furthermore, a strong time effect was seen ($F = 13.8$; $p < 0.001$) (Fig. 3). Post hoc tests revealed that the global evaluation score had improved more in the eccentric training group than in the primary surgery group after three months (1.6; 0.1 to 3.0), while there was no group difference after six months (1.1; -0.2 to 2.3) or twelve months (-0.2; 95% confidence interval, -1.4 to 1.0). The mean combined score at the twelve-month follow-up was 3.0 (95% confidence interval, 2.4 to 3.6).

Functional Tests

There was no difference between or within the groups with regard to jump height on either the standing jump test or the counter-movement jump test (Fig. 4). On the leg-press strength test, there was significant improvement when the baseline values were compared with the six and twelve-month values in both groups, although no differences in strength were noted between the groups with the numbers studied (Fig. 4). There was no change in either group with respect to pain scores when the baseline values were compared with the six-month values for any test (standing jump, $p = 0.23$ for both groups combined; counter-movement jump, $p = 0.092$; leg-press strength test, $p = 0.057$), but there was significant improvement in both groups when the baseline values were compared with the twelve-month values for all three tests (standing jump, $p = 0.002$; counter-movement jump, 0.001; leg-press strength test, $p = 0.019$) (Table II).

Overall Treatment Satisfaction and Complications

After twelve months, there was no difference in overall treatment satisfaction between the surgical treatment group and the eccentric training group ($p = 0.49$). Five knees in the surgical treatment group had no symptoms, twelve had improvement but were still symptomatic, two were unchanged, and one was worse. The latter knee had development of a chronic pain condition in the quadriceps (primarily the vastus medialis obliquus) of unknown origin postoperatively. As mentioned previously, five knees in the eccentric training group did not respond to treatment and underwent secondary surgery. In this subgroup, three knees had improvement but were still symptomatic and two were unchanged at twelve months after surgery. Of the remaining fifteen knees in the eccentric training group, seven had no symptoms and eight had improvement but were still symptomatic after twelve months.

Return to Sports

After twelve months, five patients in the surgical treatment group were training fully and had no symptoms, four were training fully but had mild or moderate symptoms, eight were training at a reduced level, and three could not train at all because of the knee problem. Of the fifteen patients in the eccentric training group who did not undergo secondary surgery, six were training fully and had no symptoms, five were train-

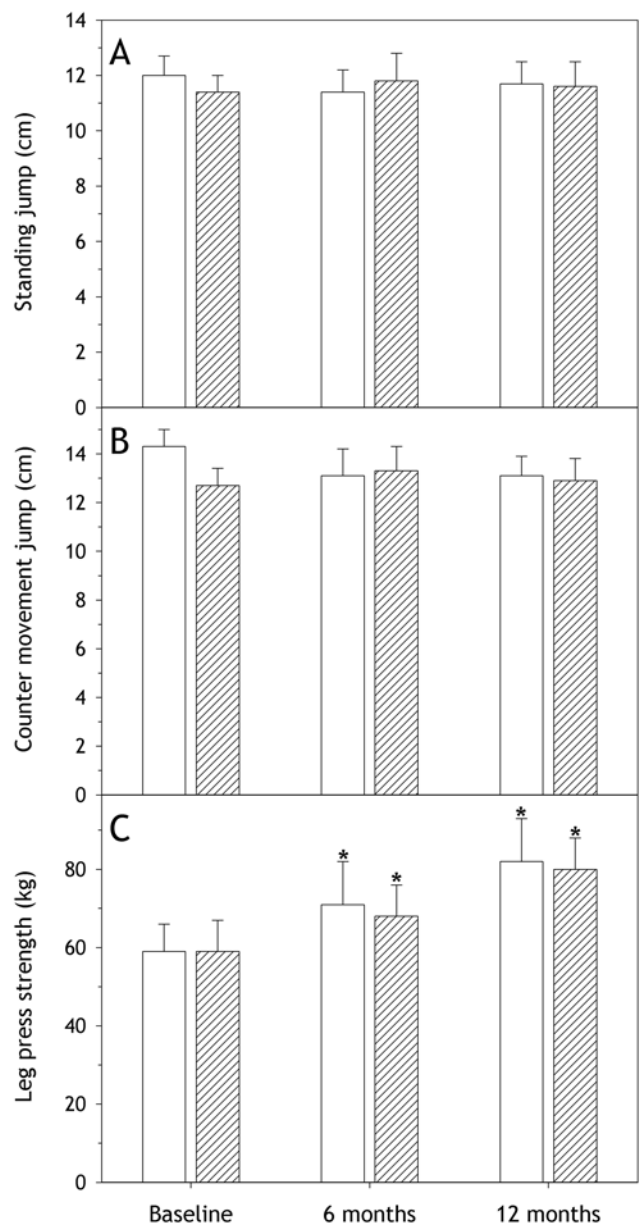


Fig. 4

Illustration showing the rise of the center of gravity (in centimeters) for the standing jump test (A) and the counter-movement jump test (B) on the affected leg as well as the one-repetition maximum (in kilograms) for the leg-press test with both legs (C) in the primary surgical treatment group (white columns) and the eccentric training group (hatched columns) at baseline and after six and twelve months of follow-up. * $p < 0.05$ as compared with the baseline value. All values are shown as the mean and the 95% confidence interval.

ing fully but had mild or moderate symptoms, two were training at a reduced level, and two could not train at all after twelve months. Of the five patients in the secondary surgery group, one was training fully but had mild or moderate symptoms, three were training at a reduced level, and one could not train because of the knee problem.

Discussion

The main finding of the present study was that although both treatment options (open tenotomy and eccentric strength training) resulted in a definite improvement in knee function in patients with long-standing and severe symptoms of patellar tendinopathy, there was no measurable difference between the groups. If anything, there was a trend favoring the eccentric training group after three months. An early delay in recovery may be expected after any surgical procedure, but the results of the present study also clearly indicate that surgery for patellar tendinopathy cannot be considered to be a "quick fix." It also should be noted that since the surgically treated group followed the same eccentric training program as the training group did, albeit with a slower progression, it is not possible to ascribe the improvement in the surgical group to surgery alone. It could just as well have been that the postsurgical rehabilitation protocol, which eventually included the same eccentric program as that followed by the other group, was responsible for the observed effects.

In fact, the results of treatment were not overly impressive in either group. In the eccentric training group, fifteen of twenty knees had improvement, but only seven of these knees were free of symptoms after one year. In the surgical treatment group, seventeen of twenty knees had improvement but only five of these knees became symptom-free. If applying the success criteria described by Coleman et al.⁵, with the success rate being defined as the percentage of patients with excellent results ("return to preinjury activity level without pain") or good results ("return to preinjury activity level with mild or moderate pain"), our results correspond to a success rate of 55% in the eccentric training group and of 45% in the surgical treatment group.

In their 2000 review of twenty-five surgical outcome studies, Coleman et al.⁵ reported success rates ranging from 54% to 100% after open patellar tenotomy, with an "overall" success rate of 83%. However, they also found that study quality was generally low; the reviewed studies were mainly retrospective case series with a mean overall methodology score of as low as 37 (range, 15 to 66) of a maximum of 100 points. They reported major concerns with all aspects of the research methodology, including design, subject selection, and outcome measures. Moreover, the success rate was inversely related to the methodological quality of the studies.

Therefore, the present study was planned on the basis of the guidelines developed by Coleman et al.⁵ for future studies of patellar tendon surgery. According to their criteria, we estimate that the Coleman Methodology Score for the present study exceeds 90 points. The study was performed as a prospective trial with use of predefined patient selection criteria, standardized protocols for surgery and rehabilitation, and a sensitive and reliable outcome measure that was completed by the patients themselves with minimal investigator assistance. The assignment of patients to treatment groups was randomized with use of concealed lists, and the

groups were similar at the start of the trial. Every attempt was made to treat the two patient groups equally apart from the treatment allocation, and all patients were analyzed in the groups to which they had been assigned (that is, we followed an intention-to-treat procedure). On the basis of the results, it appears that, when examined with use of a rigorous study protocol, the success rate of surgery for patellar tendinopathy is considerably lower than the rates reported by most previous research groups⁵.

Nevertheless, there are some factors that need to be addressed when interpreting the results of the current study. First, the majority of patients were recreational or subelite athletes. From a recent epidemiological study, we know that jumper's knee is a common condition at the elite level in jumping sports, such as basketball, volleyball, and soccer¹. However, none of the patients in the present study were elite basketball, volleyball, or soccer players. The explanation may be that, in order to be included in the study, patients had to be unable to participate in sports and had to be willing to undergo surgery as a treatment option. This level of disability is also reflected by the mean baseline VISA score of 30, which was much lower than that reported for symptomatic athletes competing at the elite level (mean, 64 points)¹ or that for a group of active volleyball players who were enrolled in a study on the effect of eccentric training (mean, 63 points)²⁷. In other words, the patients who were included in the present study represented a subgroup with severe and recalcitrant symptoms, and we do not know whether the results would be different for individuals with less severe symptoms.

Second, open tenotomy was chosen as the surgical method because this is the technique that has been favored in most studies. However, other techniques also have been described in the literature, either alone or in combination with open tenotomy. These include curettage of the patella at the tendon-bone junction^{28,29}, drilling of the inferior patellar pole^{30,31}, ultrasound-guided percutaneous longitudinal tenotomy¹⁵, and arthroscopic patellar tenotomy^{5,32}. To our knowledge, the outcomes associated with these techniques have not been examined with use of adequate methodology in prospective trials.

Finally, we were not able to blind the patients to the treatment group to which they had been assigned. Blinding is only possible if sham surgery is included, and perhaps not even then. However, every effort was made to keep the information that was given to the subjects neutral. The forms that were used to collect outcomes data were completed by the patients themselves with minimal investigator assistance, and the functional testing was done by a tester who was unaware of the purpose of the study. We therefore have no reason to believe that the reporting of outcomes was biased.

In recent years, eccentric exercises have been validated as an appropriate treatment program for patients with Achilles tendinopathy^{20-23,33}. Alfredson et al.²⁰ reported a substantial reduction in pain and improved strength in

patients with Achilles tendinopathy who participated in an exercise program involving slow, painful eccentric loading. All of those subjects returned to their previous level of athletic activity. However, less is known about the results of treatment of patellar tendinopathy with eccentric training¹⁹. Pilot studies have suggested that exercising with a decline board will increase the load on the extensor mechanism more than is the case with a traditional squat and may result in greater improvement in knee function¹⁸. A pilot study involving the use of a 25° decline board showed a decrease in pain after a treatment period of twelve weeks¹⁸. Another pilot study comparing decline board exercise with a traditional squat showed decreased pain and improved sporting function after twelve weeks in both groups, and this effect was maintained over a twelve-month period¹⁷. In contrast, a recent study of volleyball players who continued to train and compete as normal during the intervention period did not show any effect of a twelve-week eccentric training program²⁷. However, the present study is the first study to examine the effect of an eccentric training program in a group of patients with severe symptoms of patellar tendinopathy.

In conclusion, although surgical treatment and eccentric strength training can produce significant improvement in terms of pain and function scores, it appears that only about half of all patients will be able to return to sport within one year after treatment with each option, and fewer still will have relief of all symptoms. In the absence of other validated treatment options, we believe that eccentric train-

ing, a low-risk and low-cost option, should be tried before surgery is considered. ■

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References

- Lian OB, Engebretsen L, Bahr R. Prevalence of jumper's knee among elite athletes from different sports: a cross-sectional study. *Am J Sports Med.* 2005; 33:561-7.
- Ferretti A, Puddu G, Mariani PP, Neri M. Jumper's knee: an epidemiological study of volleyball players. *Physician Sportsmed.* 1984;12:97-103.
- Ferretti A. Epidemiology of jumper's knee. *Sports Med.* 1986;3:289-95.
- Lian O, Holen KJ, Engebretsen L, Bahr R. Relationship between symptoms of jumper's knee and the ultrasound characteristics of the patellar tendon among high level male volleyball players. *Scand J Med Sci Sports.* 1996;6: 291-6.
- Coleman BD, Khan KM, Maffulli N, Cook JL, Wark JD. Studies of surgical outcome after patellar tendinopathy: clinical significance of methodological deficiencies and guidelines for future studies. *Victorian Institute of Sport Tendon Study Group. Scand J Med Sci Sports.* 2000;10:2-11.
- Khan KM, Maffulli N, Coleman BD, Cook JL, Taunton JE. Patellar tendinopathy: some aspects of basic science and clinical management. *Br J Sports Med.* 1998;32:346-55.
- Fredberg U, Bolvig L. Jumper's knee. Review of the literature. *Scand J Med Sci Sports.* 1999;9:66-73.
- Alfredson H, Forsgren S, Thorsen K, Fahlstrom M, Johansson H, Lorentzon R. Glutamate NMDAR1 receptors localised to nerves in human Achilles tendons. Implications for treatment? *Knee Surg Sports Traumatol Arthrosc.* 2001;9: 123-6.
- Alfredson H, Thorsen K, Lorentzon R. In situ microdialysis in tendon tissue: high levels of glutamate, but not prostaglandin E2 in chronic Achilles tendon pain. *Knee Surg Sports Traumatol Arthrosc.* 1999;7:378-81.
- Khan KM, Cook JL, Kannus P, Maffulli N, Bonar SF. Time to abandon the "tendinitis" myth. *BMJ.* 2002;324:626-7.
- Cook JL, Feller JA, Bonar SF, Khan KM. Abnormal tenocyte morphology is more prevalent than collagen disruption in asymptomatic athletes' patellar tendons. *J Orthop Res.* 2004;22:334-8.
- Peers KH, Lysens RJ. Patellar tendinopathy in athletes: current diagnostic and therapeutic recommendations. *Sports Med.* 2005;35:71-87.
- Jozsa L, Kannus P. Human tendons: anatomy, physiology, and pathology. Champaign, IL: Human Kinetics; 1997.
- Khan KM, Visentini PJ, Kiss ZS, Desmond PM, Coleman BD, Cook JL, Tress BM, Wark JD, Forster BB. Correlation of ultrasound and magnetic resonance imaging with clinical outcome after patellar tenotomy: prospective and retrospective studies. *Victorian Institute of Sport Tendon Study Group. Clin J Sport Med.* 1999;9:129-37.
- Testa V, Capasso G, Maffulli N, Bifulco G. Ultrasound-guided percutaneous longitudinal tenotomy for the management of patellar tendinopathy. *Med Sci Sports Exerc.* 1999;31:1509-15.
- Curwin S, Stanish WD. *Tendinitis, its etiology and treatment.* Lexington, MA: Collamore Press; 1984.
- Young MA, Cook JL, Purdam CR, Kiss ZS, Alfredson H. Eccentric decline squat protocol offers superior results at 12 months compared with traditional eccentric protocol for patellar tendinopathy in volleyball players. *Br J Sports Med.* 2005;39:102-5. Erratum in: *Br J Sports Med.* 2005;39:246.
- Purdam CR, Jonsson P, Alfredson H, Lorentzon R, Cook JL, Khan KM. A pilot study of the eccentric decline squat in the management of painful chronic patellar tendinopathy. *Br J Sports Med.* 2004;38:395-7.
- Cannell LJ, Taunton JE, Clement DB, Smith C, Khan KM. A randomized clinical trial of the efficacy of drop squats or leg extension/leg curl exercises to treat clinically-diagnosed jumper's knee in athletes: pilot study. *Br J Sports Med.* 2001; 35:60-4.
- Alfredson H, Pietila T, Jonsson P, Lorentzon R. Heavy-load eccentric calf muscle training for the treatment of chronic Achilles tendinosis. *Am J Sports Med.* 1998;26:360-6.

- 21.** Silbernagel KG, Thomee R, Thomee 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.
- 22.** Fahlstrom M, Jonsson P, Lorentzon R, Alfredson H. Chronic Achilles tendon pain treated with eccentric calf-muscle training. *Knee Surg Sports Traumatol Arthrosc.* 2003;11:327-33.
- 23.** Roos EM, Engstrom M, Lagerquist A, Soderberg 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;14:286-95.
- 24.** Blazina ME, Kerlan RK, Jobe FW, Carter VS, Carlson GJ. Jumper's knee. *Orthop Clin North Am.* 1973;4:665-78.
- 25.** Visentini PJ, Khan KM, Cook JL, Kiss ZS, Harcourt PR, Wark JD. The VISA score: an index of severity of symptoms in patients with jumper's knee (patellar tendinosis). Victorian Institute of Sport Tendon Study Group. *J Sci Med Sport.* 1998;1:22-8.
- 26.** Cook JL, Khan KM, Kiss ZS, Griffiths L. Patellar tendinopathy in junior basketball players: a controlled clinical and ultrasonographic study of 268 patellar tendons in players aged 14-18 years. *Scand J Med Sci Sports.* 2000;10:216-20.
- 27.** 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;15:227-34.
- 28.** Karlsson J, Lundin O, Lossing IW, Peterson L. Partial rupture of the patellar ligament. Results after operative treatment. *Am J Sports Med.* 1991;19:403-8.
- 29.** Karlsson J, Kalebo P, Goksor LA, Thomee R, Sward L. Partial rupture of the patellar ligament. *Am J Sports Med.* 1992;20:390-5.
- 30.** Griffiths GP, Selesnick FH. Operative treatment and arthroscopic findings in chronic patellar tendinitis. *Arthroscopy.* 1998;14:836-9.
- 31.** Raatikainen T, Karpakka J, Puranen J, Orava S. Operative treatment of partial rupture of the patellar ligament. A study of 138 cases. *Int J Sports Med.* 1994;15:46-9.
- 32.** Coleman BD, Khan KM, Kiss ZS, Bartlett J, Young DA, Wark JD. Open and arthroscopic patellar tenotomy for chronic patellar tendinopathy. A retrospective outcome study. Victorian Institute of Sport Tendon Study Group. *Am J Sports Med.* 2000;28:183-90.
- 33.** Ohberg L, Lorentzon R, Alfredson H, Maffulli N. Eccentric training in patients with chronic Achilles tendinosis: normalised tendon structure and decreased thickness at follow up. *Br J Sports Med.* 2004;38:8-11.