No Effect of Eccentric Training on Jumper's Knee in Volleyball Players During the Competitive Season

A Randomized Clinical Trial

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Background: The effect of surgery on patellar tendinopathy (jumper's knee) is questionable, and conservative treatment protocols have not been properly documented.

Purpose: The aim of this study was to investigate the effect of a newly developed eccentric training program for patellar tendinopathy in volleyball players during the competitive season.

Study Design: Randomized clinical trial.

Methods: Patients were recruited from male and female elite volleyball teams in Norway, and the diagnosis was based on clinical examination alone. Of 51 players diagnosed with patellar tendinopathy, 29 could be included in the study. The training group (n = 13) performed squats on a 25° decline board as a home exercise program (3 × 15 repetitions twice daily) for a 12-week intervention period during the final half of the competitive season. The eccentric (downward) component was done on the affected leg. The control group (n = 16) trained as usual. The primary outcome was a symptom-based questionnaire developed specifically for patellar tendinopathy (Victorian Institute of Sport Assessment score), and patients were followed up before and after the intervention period, as well as after 6 and 30 weeks. All subjects self-recorded training to document their activity level (eccentric training, volleyball training, matches, other training).

Results: There was no change in Victorian Institute of Sport Assessment score during the intervention period in the training (pre, 71.1 ± 11.3; post, 70.2 ± 15.4) or control group (pre, 76.4 ± 12.1; post, 75.4 ± 16.7), nor was there any change during the follow-up period at 6 weeks or 6 months. The training group completed 8.2 ± 4.6 weekly sessions of eccentric training during the intervention period (59% of the recommended volume), and there was no difference between groups in training or competition load.

Conclusion: There was no effect on knee function from a 12-week program with eccentric training among a group of volleyball players with patellar tendinopathy who continued to train and compete during the treatment period. Whether the training would be effective if the patients did not participate in sports activity is not known.

Key Words: tendinopathy, patellar tendon, treatment, elite athletes

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Musculoskeletal health is a necessary component of overall health. Tendon disease interferes with exercise and sporting participation, thus affecting general health. Patellar tendinopathy (jumper's knee) can severely limit or even end an athletic career as it is a recurrent condition, and recovery from each episode may take up to 12 months.[1] Patellar tendinopathy affects athletes in many sports, and elite jumping athletes are the most susceptible.[1,2] The prevalence of patellar tendinopathy is 40% to 50% among high-level volleyball players.[3–5]

Patellar tendinopathy is an insertional tendinopathy most commonly affecting the patellar tendon's origin on the inferior pole of the patella[1,6–8] and is due to collagen fiber degeneration; it is not merely an inflammatory condition.[9] The treatment of patients with patellar tendinopathy is initially conservative and may include rest, ice, electrotherapy, massage, and taping. Surgery may also be indicated in recalcitrant cases, although the benefits of surgical treatment have not been tested in randomized studies.[6] However, neither conservative nor surgical treatments have evidence-based support, and these treatments have not been shown to return all athletes to their sport.[6,8]

In the last few years, eccentric exercises have been validated as an appropriate treatment program in the case of Achilles tendinopathy,[10–13] and recent treatment protocols based on eccentric exercise routines have shown promising results. Alfredson et al[10] reported a significant reduction in pain and improved strength in Achilles tendinopathy patients who participated in an exercise program using slow, painful eccentric loading. All of these subjects returned to their previous level of athletic activity.

However, much less is known about the treatment of patellar tendinopathy with eccentric training. Effective validated treatment regimens for patellar tendinopathy similar to the Achilles programs[10] are urgently needed, and the value of specific exercises needs investigation. Moreover, in most of the research on patellar tendinopathy to date, the patients have been recruited in a referral-based specialist care setting. This means that most patients included in these studies have serious

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problems, most often to the extent that they have had to stop sports participation entirely, or at least to reduce their level of sports participation significantly. Eccentric treatment programs have not been systematically tested on athletes with patellar tendon pain who are still able to train and compete at an elite level.

The eccentric exercise usually recommended for patellar tendon is the squat.[14] However, when performing a squat, it is possible to unload the knee extensors and, to a significant degree, reduce the load through the patellar tendon, particularly by using the gluteal and calf muscles. As the knee is an intermediate joint in a closed chain, loads through the extensor mechanism may be reduced by both proximal and distal compensations. Purdam[15] has suggested that this effect can be minimized and load on the patellar tendon maximized by performing squats on a decline board. Pilot studies and clinical experience suggest that exercising with a decline board will increase the load on the extensor mechanism more than a traditional squat and may result in greater improvement in knee function. Pilot studies and clinical experience suggest that exercising with a decline board will increase the load on the extensor mechanism more than a traditional squat and may result in greater improvement in knee function. A pilot study using a 25° decline board showed an improvement in pain levels from a training period (treatment period) of 12 weeks.[16] Another pilot study comparing the decline to the traditional squat showed improved pain and sporting function after 12 weeks in both groups, and this effect was main-tained over a 12-month period.[17]

Therefore, this study implemented a treatment protocol utilizing both the principles of the decline squat and the intensity of the Alfredson program[10–13] on high-level volleyball players with jumper's knee who were still able to train and compete despite their symptoms.

METHODS

Design

This randomized, controlled study used a 2-group repeated-measures design with a training period of 3 months and a 6-month follow-up. Patients were recruited from the clubs in the elite and 1st divisions for men and women in Norway during the fall (November to December, first half of the competitive season). The intervention period was the 3 first months of the following year (January to March, final half of the competitive season).

Players with patellar tendinopathy who volunteered for the study were randomly allocated to a treatment (eccentric squat training) or a control group (no special treatment). Pain and function were recorded at baseline and weekly during the 12-week treatment period. These measurements were also taken 6 weeks and 6 months after the end of the treatment period (at the start of the next indoor season). Jumping ability was tested before and after the 12-week treatment period. The final 3 months of the competitive season was chosen as the training period for several reasons. First, during this period, the training and competition load was the same for all players, and there was less chance of differences in load (other than the eccentric training program) between the 2 groups. Second, the recruitment period coincides with the time of the season when the prevalence of patellar tendinopathy is assumed to be at its maximum, and we were more likely to be able to recruit subjects for the study. Finally, it is clinically relevant to test whether it is possible to treat players with eccentric training during the competitive season, while they train and compete as much as symptoms allow. However, players who were not free of symptoms at the end of the season were asked to continue the program after the 12-week period until they were symptom-free.

Subjects

All teams in the elite division (9 male and 7 female) and 16 1st division teams (8 of 10 male and 8 of 12 female) were contacted during the fall competition season (November and December) and invited to take part in a clinical examination. The coach and the club were informed of the purposes and procedures of the study by letter. The study was approved by the Regional Committee for Medical Research Ethics, Helse Øst.

Each club was visited at a time convenient to them. After an oral presentation, players who thought they would be eligible were invited to take part in a clinical screening examination. If eligible for the study, they were asked to sign a written consent form before inclusion. They were also asked to complete a questionnaire reporting their anthropometric details, history of their knee pain, any treatment, sporting profile, and activity level.

Inclusion and Exclusion Criteria

The inclusion was based on a clinical examination, and the following diagnostic criteria were used to identify patients with patellar tendinopathy[5]: history of pain in the quadriceps or patellar tendons or their patellar or tibial insertions (localized on a knee map) in connection with training or competition, and tenderness to palpation corresponding to the painful area. Imaging studies were not done to confirm the clinical diagnosis.

To be included, patellar tendinopathy symptoms had to have been present for a minimum of 3 months, and the Victorian Institute of Sport Assessment (VISA) score[18] had to be less than 80 points. Data on both knees were recorded if the patient had bilateral problems, and the knee with the lowest VISA score at the time of inclusion was used in the final data analysis.

The subjects had to be between 18 and 35 years old. These age limits excluded the diagnoses of Osgood-Schlatter and Sinding-Larsen-Johansson disease in the adolescent athlete and significant osteoarthritis in the older athlete. Subjects were excluded if they had a history of knee problems caused by patellofemoral pain syndrome, inflammatory joint conditions, or degenerative conditions.

Randomization

Of the 510 players attending the team information meetings, 51 were diagnosed with jumper's knee and volunteered to take part in the study (Fig. 1). A total of 31 patients reported a VISA score of <80 and could be included in the study (Fig. 1). After inclusion, the subjects were randomized into treatment or

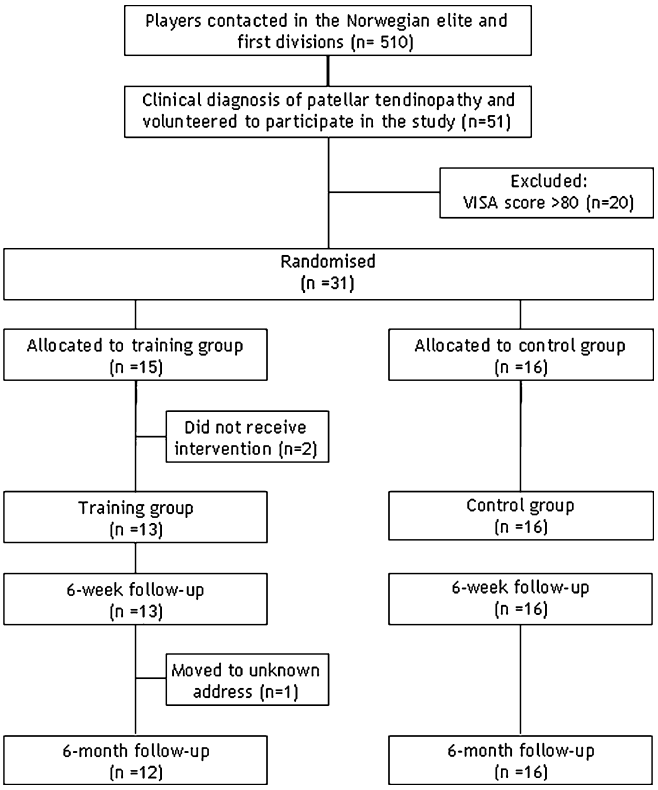

FIGURE 1. Flow chart depicting the recruitment, randomization procedure, and follow-up.

control groups by a statistician who was blinded to player identity. Players from the same teams were randomized in blocks to different groups. There were 2 dropouts in the training group after randomization; one left the study before the training period started for reasons unrelated to the study, and the other did not return any data (Fig. 1). Since an alternate exercise treatment program was not prescribed for the control group, blinding subjects to group allocation was not possible.

Training Protocol

Both groups received an information package including the assessment forms. The training group also received an instruction booklet and a 25° aluminium decline board. They were followed up by telephone when the training period started, and the training program was described and discussed in detail by 2 of the investigators (H.V. and A.H.). In addition, each player was instructed in person during the first half of the training period (2–6 weeks into the program) to ensure proper execution of the program and exercises.

The players in the treatment group 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 3 sets of 15 repetitions each session. The exercises could be done without warming up. The downward component (eccentric component) was on the affected leg and the upward component on the asymptomatic leg. If both legs were injured, the subjects were instructed to use their arms to assist during the concentric phase and train only 1 leg at the time. They were instructed to take 2 seconds for each eccentric component of each exercise. The squat went to 90° of knee flexion, which ensured that the subjects went past 60° of knee flexion, the joint angle thought to place maximal load on the patellar tendon.[15] This prescription adapts Alfredson's Achilles exercise program[10] to the patellar tendon.

The subjects were instructed to exercise despite pain during exercise, but to stop if the pain became disabling. The training group was recommended to have a pain value of 5 on a visual analogue scale during the eccentric training sessions (0 means no pain and 10 the worst pain ever). Load was increased as pain decreased, and they added load in a backpack in 5-kg increments. Those with less pain than 3 to 4, were recommended to increase the weight. Players with more pain than 6 to 7 during the exercises were recommended to do the exercise with less weight.

The clubs did not employ physical therapists to monitor their teams, and other physical therapy modalities were not provided during the treatment period. However, subjects were allowed to take prescribed pain medication, including NSAIDs, which was recorded in the training log.

The players in the training group were encouraged to continue the eccentric training if they still had knee pain at the end of the 12-week treatment period. The control group trained as usual.

Treatment Evaluation

The subjects in the treatment group self-recorded the exercise program (including the number of repetitions, sets, and load for each training session) as well as the pain level during the eccentric exercises by a 10-cm visual analogue scale from no pain (0) to worst pain (10). This scale has been investigated and shown to be a reliable and sensitive scale for pain, and has been used extensively in orthopedic investigations.[19] This diary was returned by mail on a weekly basis to the investigators. All subjects (including the control group) also self-recorded their activity level (volleyball training, games, other training) on a weekly basis. The investigators maintained weekly contact with the players by phone and e-mail, and the diaries were monitored continuously for possible aggravating activities that may have influenced the subject's ability to exercise.

The primary outcome measured over the study period was knee function using VISA score. The VISA score was designed specifically to quantify knee function in subjects with patellar tendinopathy and has also been shown to be a reliable and valid measure.[18,20,21]

Secondary outcomes were a global evaluation score (pain and function) and jumping performance. Both groups evaluated the intervention period by answering the question, "How is your knee now compared to when the study started in January?" by marking on a 11-point visual numerical scale, where +5 represented maximal improvement (no symptoms), 0 was marked as no change, and −5 maximal worsening (serious symptoms).

Jumping performance was tested before and after the 3-month treatment period in all subjects. The 29 players were pretested during the recruitment phase. The retesting started

2 weeks before the intervention period ended and was completed within 5 weeks after the intervention period ended.

The jump tests are based on a simple method to determine the height of rise of the center of gravity during jumping. The tests were performed using a contact mat connected to a digital timer. The equipment measures the flight time of each jump, and the height of rise of the center of gravity is calculated from this.[22]

Two types of jumps were tested: a standing jump and a counter movement jump. Each jump was first tested on both legs and then on each leg (both sides, whether affected by patellar tendinopathy or not). Standing jumps (SJs) were performed with the subject starting from a stationary semi-squatting position with 90° knee flexion and with both hands kept fixed on the hips. No counter movement was allowed with any body segment. Counter movement jumps (CMJ) were done with the subject starting the movement from a stationary erect position with knees fully extended, and they were allowed to bend down to approximately 90° knee flexion before starting the upward motion of the jump. Both hands were kept fixed on the hips.

The players were not vocally encouraged during the jumps, and the investigators watched carefully to ensure that the proper technique was used. In particular, care was taken to ensure that there was no counter movement in the standing jumps, and that the subjects landed with straight legs. The reliability of these methods in our laboratory (coefficient of variation) is 4.3% for SJ and 5.3% for CMJ (Gaasvaer, Personal communication). The best out of 3 technically correct jumps was used for the final calculations.

Statistics

Since no data were provided by 2 subjects in the training group, they could not be included in the analysis. Otherwise, an intention-to-treat analysis was done including all subjects regardless of their compliance with the training program. VISA scores were compared using analysis of variance for repeated measures, testing for group by time interactions (repeated-measures ANOVA). Paired *t* tests were used to compare VISA score during the first week of the intervention period with the inclusion score for the entire group of subjects. Also, unpaired *t* tests were used to compare VISA score between groups 6 weeks and 6 months after the treatment period.

The sample size was calculated based on VISA score as the principal outcome measure. From previous studies, a baseline score of 55 points in symptomatic players and 95 points without patellar tendinopathy was expected,[18] with a standard deviation among volleyball players of 17 points.[2] We estimated that we needed to include 15 players in each group, or a total of 30 players, to detect a 50% treatment effect (ie, a 20-point difference in VISA score) with a significance level of 5% and test power of 90%.

Results are reported as the means ± standard deviations unless otherwise noted.

RESULTS

Randomization

The baseline characteristics, symptom description, and training history for the control and training groups are shown in Table 1. Of the 31 patients included, 24 had patellar tendinopathy only (all of them with symptoms from the patellar insertion), 2 patients had quadriceps tendinopathy only, and 3 patients had both quadriceps and patellar tendinopathy (Table 1). Two clubs had 3 players each included in the study, 5 clubs 2 players each, and 15 clubs 1 player only.

Training

During the intervention period, the volume of volleyball training per week was 5.1 ± 2.9 hours for the training group and 6.1 ± 3.8 hours for the control group. Weight training and other types of physical training were done with 1.6 ± 2.7 hours in the training group and 2.0 ± 3.1 hours in the control group.

The training group was instructed to perform the eccentric training program twice a day (14 sessions per week), and the mean value reported was 8.2 ± 4.6 sessions per week (Fig. 2).

TABLE 1. Subject Characteristics At Baseline

	Training Group (n = 13)	Control (n = 16)
Age (y)	26.8 ± 4.6 (19–35)	26.4 ± 3.4 (20–31)
Height (cm)	183.9 ± 9.9 (168–198)	184.7 ± 8.1 (170–199)
Weight (kg)	83.8 ± 7.7 (68–96)	84.4 ± 16.4 (51–112)
Females	5/13	5/16
Bilateral symptoms (n)	6	6
Duration of symptoms (mo)	67 ± 44 (—)	79 ± 75 (—)
Quadriceps tendinopathy only (n)	0	2
Quadriceps and patellar tendinopathy (n)	2	1
Patellar tendinopathy only (n)	11	13
Volleyball training (h/wk)	5.8 ± 1.3 (—)	6.4 ± 2.6 (—)
Weight training (h/wk)	1.4 ± 1.5 (—)	1.9 ± 1.8 (—)
Seasons playing at elite level (n)	4.6 ± 2.9 (0.5–12.0)	5.5 ± 2.7 (1.0–12.0)
Seasons playing organised sports (n)	13.8 ± 4.5 (7–20)	14.1 ± 4.6 (4–20)

Values are presented as means ± SDs (range).

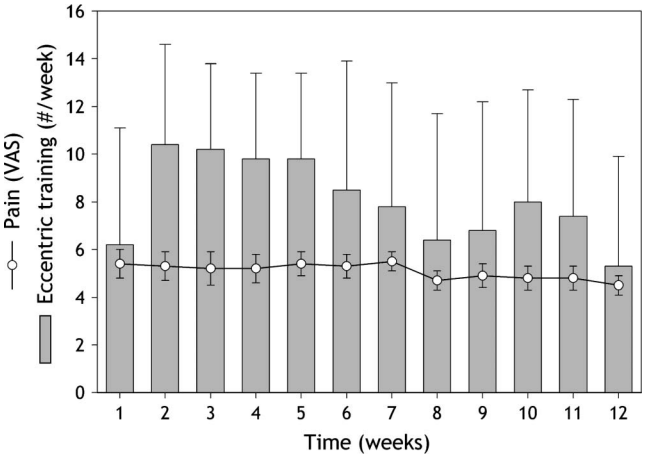

FIGURE 2. Pain level and volume of eccentric training of the training group. The reported weekly pain level (±SE) during eccentric training (shown as open circles) and the number of weekly reported sessions (±SD) with eccentric training (shown as shaded bars).

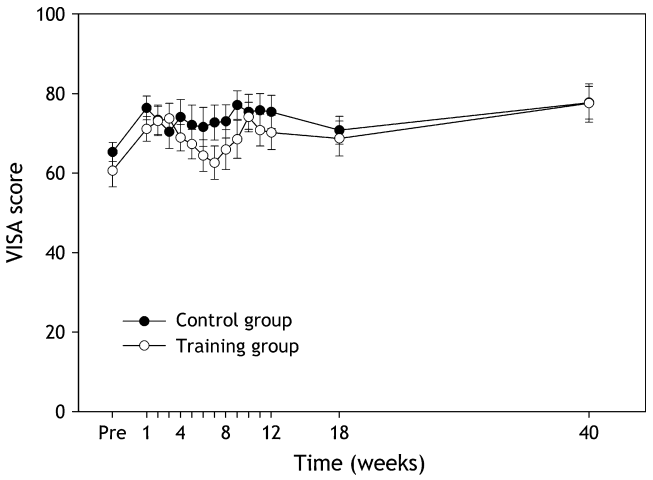

FIGURE 3. VISA score. The self-reported weekly VISA score (±SE) for the training and control groups before, during (weeks 1–12), and after the treatment period (6 weeks and 6 months after the end of the training period).

Only 6 of the 13 players in this group did exercises with an additional external load, and the final load these players reported having used was 4.2 ± 4.9 kg. The mean pain level reported by the players in the training group during the eccentric training was 5.1 ± 1.8 (Fig. 2). One of the players in the training group developed patellofemoral pain syndrome during the treatment period and reduced the eccentric training on the recommendation of the investigators. During the first 6 weeks of follow-up (after the 12 week intervention period), 4 of 13 players continued using the eccentric training program. Of these, 2 reported a higher and 2 a lower VISA score during the intervention period. Only 1 of these players reported having continued eccentric training after the first 6 weeks of follow-up. He reported a small improvement in his VISA score during the intervention period.

VISA Score

The training group was included with a VISA score of 61 ± 15 and the control group with a score of 65 ± 9. The VISA score before, during, and after the intervention period is shown in Figure 3. The players reported having less knee pain during the first week of the intervention period compared with their inclusion score ($P = 0.022$; paired t test). There were no significant differences in VISA score between the 2 groups during the intervention period ($P = 0.39$; $F_{11,17} = 1.14$; ANOVA time by group). There was no significant difference in the use of pain or anti-inflammatory medication between the 2 groups.

As shown in Figure 4, which shows the individual VISA score in the 2 groups, there was no difference in VISA score from pretreatment (week 1) to posttreatment (week 12; $F_{1,27} = 0.001$; $P = 0.98$). Also, there was no difference in VISA score between groups 6 weeks ($P = 0.71$; unpaired t test) or after 6 months after the treatment period ($P = 0.99$).

Global Knee Function Score

On the question, "How is your knee now compared to when the study started in January?" the training group reported a score of +0.7 ± 2.1 and the control group a score of +0.2 ± 1.1 ($P = 0.44$; Student t test).

Jumping Performance

The results from the jump tests before and after the intervention period are shown in Figure 5. There was a small improvement of 1.2 ± 2.9 cm in jumping performance for the counter movement jump (both legs) in the training group ($P = 0.046$; $F_{1,27} = 4.37$; ANOVA time by group), but there were no significant differences between the 2 groups for the other jump tests (SJ both legs, $P = 0.17$; CMJ affected leg, $P = 0.49$; SJ affected leg, $P = 0.67$).

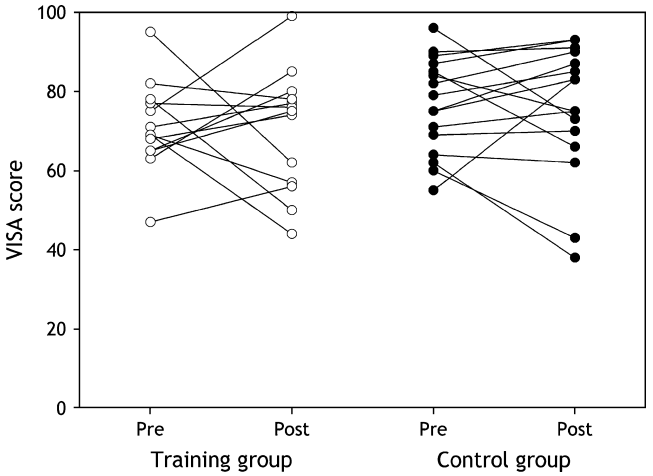

FIGURE 4. VISA score. The self-reported individual VISA scores in the training group and the control group before (week 1) and at the end of the treatment period (week 12).

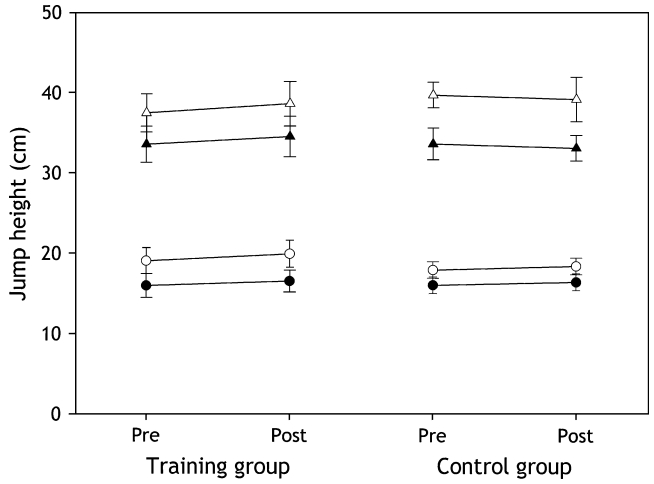

FIGURE 5. Jumping performance. Results (±SE) from the countermovement jump (open symbols) and standing jump (closed symbols) before and after the treatment period. Results are shown separately for tests on both legs (triangles) and on the affected leg (circles).

DISCUSSION

The main finding of this study was we could not detect any effect of a 12-week program of eccentric training during the competitive season on a group of elite amateur volleyball players with jumper's knee. This is in contrast to the results from recent studies on Achilles tendinopathy and 2 pilot studies on patellar tendinopathy.[10–14,16,17]

Although Stanish et al[23] first suggested eccentric strength training for the rehabilitation of tendon injuries in 1986, research into this area has been limited until recently. Alfredson et al[10] first described very good short-term effects with heavy-load eccentric calf muscle training in midportion Achilles tendinopathy. A randomized clinical trial showed eccentric exercise to be superior to concentric calf muscle training in midportion Achilles tendinopathy.[11,13] However, it should be noted that the same eccentric training program provided pain relief in only 10 of 31 tendons (32%) with chronic insertional Achilles tendon pain.[13] Silbernagel et al,[12] in the best-controlled study on Achilles tendinopathy to date, also reported good results from eccentric training. Compared with the control group, there were significantly more patients in the eccentric training group who were satisfied at the 1-year follow-up. Based on these studies,[24] they conclude that treatment with eccentric calf-muscle training produces good clinical results in patients with chronic painful midportion Achilles tendinopathy, but not in patients with chronic insertional Achilles tendon pain. However, it should be kept in mind that all of these studies have included a mixed patient group consisting mainly of recreational athletes with a mean age above 40 years, and that the long-term results are largely unknown.

Compared with midportion Achilles tendinopathy, there is limited research on patellar tendinopathy. Cannell et al[14] compared the efficacy of a 12-week drop squat program to leg extension and leg curl exercises to treat clinically diagnosed jumper's knee. They found a reduction in pain in both groups, and they found a high proportion of patients to return to sport, but no difference between groups. Purdam et al[16] compared the effect of the eccentric training performed on a decline board with eccentric squats on a flat floor in a pilot study. They found that there was an improved clinical outcome in the decline board group.

There are a number of methodological issues that need to be considered when interpreting the contrasting findings between the current study and previous studies on midportion Achilles tendinopathy, principally the recruitment and screening of subjects, the compliance with and quality of the training program, and the timing of the intervention. First, it should be noted that we recruited only players who actively volunteered to take part in the study. Only 10% of the 510 players who were present during the team meetings volunteered to take part, and 20 players with mild symptoms (VISA score above 80 points) had to be excluded. The cutoff of 80 points was chosen to eliminate players with a clinical diagnosis of jumper's knee but only minimal symptoms. It resulted in a mean VISA score at inclusion of 65 (control group) and 61 (intervention group). This means that the score in the intervention group was identical to that reported by Purdam et al[16] in their intervention study, but somewhat better than the patients in the original validation study of the VISA scale.[18] This is as expected, considering that the patients included in the present study were recruited among actively competing players, not sports medicine clinic patients. As the expected prevalence of symptomatic patellar tendinopathy among volleyball players is 40%,[4,25] we probably recruited less than 1/3 of the players who had jumper's knee. In other words, it seems that the recruitment and selection process resulted in the inclusion of a group of athletes with symptoms that were sufficiently serious to motivate them for eccentric training 2 times a day.

The second issue that must be considered is whether the training program was optimal and whether the athletes complied with the prescribed program. The program was considered optimal as it followed the Alfredson prescription with 2 daily sessions of training and slow, painful eccentric exercises.[10–13] It also matched the principles of Purdam et al[15] by performing the squats on a decline board to maximize the load on the patellar tendon, a program that has shown promising results in 2 pilot studies after a training period of 12 weeks.[16,17] However, a practical problem with the exercise prescription is that if both legs were injured, players were probably not able to unload fully during the concentric phase, even if they were instructed to use their arms to assist and train only 1 leg at a time. Whether this influenced the results, we do not know, but the problem is the same in all previous studies on patellar and Achilles tendinopathy. Nevertheless, the weekly reports show that compliance was very good. During the first full week of training, the mean number of training sessions the players reported having completed was >10 out of a target of 14 sessions (twice daily). The postintervention jump tests also showed a small improvement in the intervention group, even if some players could not be tested until several weeks after the end of the intervention period for practical reasons. This is another indication that they had been training as prescribed. Also, the mean level of pain reported during the eccentric training sessions was 5 on a 10-point visual analogue scale for the entire 12-week period (Fig. 2), which matches the prescribed

level. The training volume declined somewhat during the 12-week period, but the overall mean value reported was still as high as 8 sessions per week. Previous studies on eccentric training for tendinopathy have not recorded individual compliance, so we do not know whether the current figures are lower or higher than in previous studies that have reported a positive effect of eccentric training.[10–13]

One obvious potential explanation for the conflicting results between the present study and previous studies[10–13] is simply that eccentric training does not result in the same positive effects for insertional tendinopathies (patellar or quadriceps tendinopathy) as for midportion tendinopathy (Achilles tendon). However, similar eccentric exercise for insertional tendinopathies has been shown to be effective in adductor tendinopathy[26] and in the patellar tendon.[17] This suggests that another explanation for the apparent differences in efficacy may be the timing of the intervention. In contrast with previous studies, the aim of the present study was to see whether eccentric training could be used to treat players with jumper's knee who continued to train and compete at a high level. Previous studies have mainly recruited subjects in a hospital-based referral setting among patients who were no longer able to train and compete. In the current study, the intervention period was during the final half of the competitive season, and the patients followed the eccentric training program while participating in the usual team training and matches. It is possible that, in the present study, the training and competition schedule interfered with the potential effects of the eccentric training program in some way—the total load on the tendon may simply have become too high.

Some players in the training group reported that it was difficult to follow their regular training, play matches, and at the same time complete the eccentric training program twice daily, because they felt a responsibility to be at their best for the weekend matches. When they played more than 1 match per week or had important matches, they had to reduce the eccentric training load. It is our impression that this is the main explanation for the reduction reported in the volume of eccentric training observed during the 12-week period. This interpretation is supported by the pain scores reported, which remained high and constant throughout the entire 12-week training period. After the end of the competitive season, only 4 players continued the eccentric training program even if their volleyball training schedule was much less demanding. It may be that they were disappointed with the initial results from the eccentric training program during the competitive season and therefore were no longer motivated to continue the exercises.

It may be argued that the apparent lack of a treatment effect represents a type II error. The study size was determined to be able to detect a 50% treatment effect on VISA scores compared with the control group. Post hoc power calculations show that with a pooled standard deviation of 12 points, as found in the present study, the smallest detectable VISA score difference is 14 points (90% power at the 5% significance level). However, as clearly seen from Figures 3 and 4, there is no trend toward an improvement in knee function in the eccentric training group. As a matter of fact, VISA scores tended to decrease during the first half of the treatment period, when compliance was best.

In conclusion, we could detect no effect from the 12-week eccentric training program in a group of volleyball players with jumper's knee who still trained and competed as normal during the intervention period. However, a clinical trial with a start after the end of the season or in which the players are removed from regular sports participation during the treatment period may have completely different results. Nevertheless, the results indicate that there is no benefit from an eccentric training program without removing the athlete from regular training and competition during the treatment period.

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