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Exercise Protocol and Electrical Muscle Stimulation in the Prevention, Treatment and Readaptation of Jumper's Knee

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ABSTRACT

Jumper's knee (patellar tendinitis) is a condition characterised by the appearance of pain in the anterior part of the knee. It is associated with sports activities involving jumping that place a great demand for speed and force on the extensor muscles of the knee. To date many different treatments have been described but no effective protocol has yet been found. In this study six high-level athletes completed a six-month knee readaptation programme over two years consisting of eccentric, isometric, concentric exercises and electrical stimulation with the patellar tendon stretched to maximum tension. Pain was assessed prior to the protocol and at intervals six month using a visual analogue scale (VAS). A clear improvement was observed comparing the initial mean versus those at 18 and 24 months. Diminished pain during the 24 months suggests a direct benefit of this protocol. However, though this study produced hopeful results, the sample size was small and more research is needed.

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Introduction

Jumper's knee, also known as patellar tendonitis, is a condition characterised by the appearance of pain in the anterior part of the knee, usually located at the proximal insertion of the patellar tendon on the lower end of the patella. Pain may also appear in the distal insertion of the patella into the tibia as well as at the insertion of the quadriceps tendon on the upper end of the bone.

Jumper's knee is associated with sports activities involving jumping[1]. It occurs mainly in sports featuring a demand for speed and force in the extensor muscles of the knee, such as volleyball, basketball and athletics. With a prevalence of up to 45% in high-level sports[2] and 14.4% in recreational sports[3], patellar tendonitis is one of the most frequent causes of athlete withdrawal from training and competition. Clinical decisions about patellar tendonitis are difficult to make owing to the lack of knowledge about tendonitis due to overuse. Hence athletes may undergo long, frustrating periods of rehabilitation, with unpredictable results[4].

Different treatments have been described, but an effective protocol has not yet been found[5.6]. The literature suggests that treatment should be designed on the basis of training using eccentric muscle strengthening exercises, giving positive results in terms of the subjective perception of pain as well as improved functionality[-9]. However, the ability of physicians' to recommend a specific protocol is limited[10], especially in high-level sports, where the demands of tendon tension are much greater. No positive results have been found if treatment commences during the competition season, which suggests that protocols should be initiated in the preparation period.[11,]

It is believed that the efficacy of an exercise is in its ability to improve the isolation of the extensor muscles of the knee. This result may be achieved by subjecting the muscles to exercises involving direct tensions such as eccentric, concentric, isometric movements or isometric electrical stimulation with the tendon in a stretched position. This latter technique has proved to be beneficial for influencing muscle metabolism[13-15] through physiological adaptations. Although such adaptations are not directly related to tendon metabolism it has been observed that tendons respond to progressive, controlled stress by increasing their tensile strength, facilitating an increase in collagen aiding in their repair and remodeling[16].

Likewise, stress (mechanical load) is beneficial for the health of the tendon, influencing structure, chemical composition and mechanical properties[17,18]. If electrical stimulation is applied causing an isometric contraction, the tendon itself will be subjected to a longitudinal stress and tension, provided the muscle is stretched during the stimulation. The amount of stretch may be influenced by the placement of the limb in a flexed or extended position. The use of an electric stimulation machine with the muscle in a stretched position may prove to be beneficial for jumper's knee, and another tool for trainers and therapists.

A search of the literature has revealed no studies referring to the use of electrical stimulation for this pathology. This lack has prompted the design of the present study in order to analyse the effects of electrical stimulation in combination with eccentric, concentric and isometric exercises with regards to pain reduction during a tendon readaptation programme. This study specifically looked at various positions of the lower leg in order to generate an increased direct tension on the patellar tendon, via a stretch, for the treatment of high-level athletes with jumper's knee.

Methods

Subjects

Six high-level athletes (out of a possible 30) were chosen for the study after meeting rigorous inclusion/exclusion criteria (Table 1). All were males with a mean (±SD) age of 22.18 ± 2.14 years. Three of the athletes were high jumpers with the remainder competing in the triple jump. These athletes all competed at the international level for the Spanish athletics team.

All participants signed an informed consent form to participate in the study and to allow the use and publication of the results. The protocol was approved by the Ethics Committee of the Medical Services of the Royal Spanish Athletic Federation.

Study design

A two-year longitudinal retrospective case study was conducted with repeated measurements of pain every six months after pre-season interventions (12 weeks in the winter and a

Table 1: Inclusion and exclusion criteria

Inclusion criteria	• International athletes. • Diagnosed chronic patellar tendinopathy or jumper's knee by a specialist doctor in sports medicine, by means of ultrasound assessment and magnetic nuclear resonance. • Evolution of the condition over at least two years. • Failure during these two years of other medical and physiotherapeutic treatments, including surgery. • The application of the protocol of this study every six months for 24 months.
Exclusion criteria	• Other associated pathologies of the knee.

10 weeks in the summer). Assessments for the study were taken from the database of the Department of Physiotherapy of the Royal Spanish Athletic Federation. During the two years of the study, training remained the same as in the previous years, including jumps from the third week post start of the protocol.

The whole study was designed, implemented and supervised directly by the same physiotherapist at the sports facilities of the Madrid Sports Council Medical Centre.

Instruments

For the muscle tendon strengthening exercises by electrical stimulation, a Megasonic 313-Electromedicarin S.A. (Barcelona, Spain) device was used enabling the variation of current parameters for the study. According to the nomenclature for the device, the excite-motor current applied was of an asymmetric two-phase low-frequency[19] (Figure 1). Medicarin reusable electrodes were used (10 x 5cm and 5 x 5cm) placed in the following order ensuring maximum stimulation of the whole quadriceps muscle group (Figure 2)[20]: a) two 10 x 5cm proximal electrodes, to stimulate the exit of the femoral nerve; b) three 5 x 5cm electrodes placed over the motor points of the vastus medialis, rectus femoris and vastus lateralis. In order to complete the circuit, the two following channels were created: a) an inferior proximal electrode connected to the vastus medialis (Channel one), and b) a superior proximal electrode connected to the anterior rectus and vastus lateralis, joined at the same output with a bifurcated cable (Channel two).

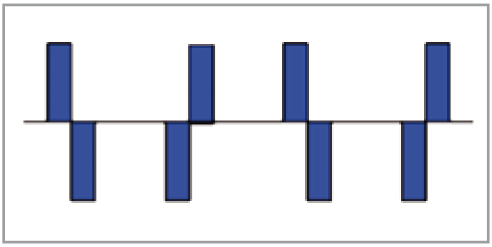

Figure 1: Graphic representation of the asymmetric equalised current. Nomenclature used by the company Electromedicarin S.A.

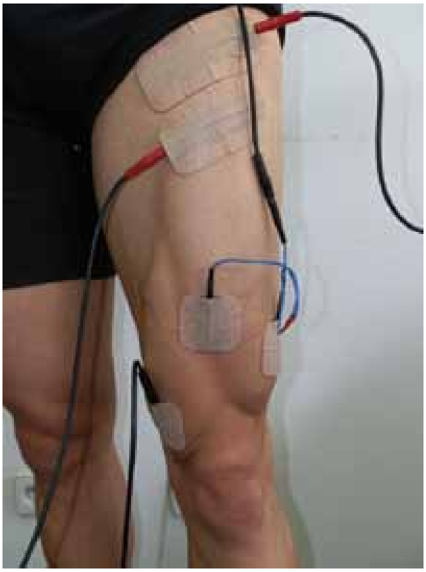

Figure 2: Electrical stimulation of the quadriceps muscle

For the eccentric, isometric and concentric exercises, inelastic bands were used, allowing the athlete to be placed in a fixed, semi-squat position with the centre of mass shifted backwards, as depicted in the exercises below (Figures 4.1 – 4.3).

Protocol

The protocol consisted of a combination of two muscle strengthening exercises progressively subjecting the tendon to a controlled stress from a low to a maximum load. The first exercise involved the use of electro-stimulation placing an isometric load on the quadriceps muscle during various stretched positions. The second exercise exposed the quadriceps muscle to either an eccentric, concentric or isometric load. All participants completed the 12-week (winter pre-season) and 10-week (summer pre-season) protocol of three sessions/week, except during weeks 3, 6, 9 and 12, in which they performed two sessions/weeks. The progression of the exercises and the parameters are shown in Table 2.

Description of the exercises

Exercise one (E1) refers to the isometric electro-stimulation of the quadriceps muscle under a stretch (Figure 3.1). With the athlete in a seated position and the knee locked at 90º, the athlete is asked to perform a voluntary contraction at an intensity indicated in Table 2, prior to the electrical stimulation. The intensity of the current is then increased until it surpasses the voluntary contraction, which is maintained by the athlete in order to conserve the neuromuscular connection from the brain. The intensities of the current are increased progressively on a weekly basis from a minimum to a maximum level, with the latter intensity being greater than the intensity of the maximum voluntary contraction of the athlete.

Exercise two (E2) refers to the electrical stimulation of the quadriceps muscle, during an increased stretch (Figure 3.2). With the athlete in the supine position and the knee locked at 90º, the rectus femoris is lengthened as the athlete lowers himself onto the plinth. This position increases the tension in the patellar tendon. The

Figure 3.1

Figure 3.2

Table 2: PATELLAR TENDON PROTOCOL. Exercises, electrical stimulation parameters and progression

WEEK	Electrical stimulation and eccentric training					Electrical stimulation parameters: Pulse width	Frequency	Time On	Ramp up	T.Off	Intensidad
1	E1: 4x12					350µ	40Hz	4s	0.25s	8	Low
	E3: 4x8										
2	E1: 2x12	E2: 2x12				340	45	4	0.20	8	Medium
	E3: 2x8	E3+: 2x8									
3	E1: 2x12	E2: 2x12				330	50	4	0.15	8	Medium
	E3: 1 x 8	E3+: 3x8									
4	E1: 2x10	E2: 2x10				320	55	4	0.10	8	Submaximum
	E3: 1x8	E3++: 3x8									
5	E1: 2x10	E2: 2x10				310	60	4	0.05	8	Submaximum
	E3: 1x8	E3++: 2x8	E4: 1x5								
6	E1: 2x10	E2: 2x10				300	65	4	0	8	Submaximum
	E3: 1x6	E3++: 2x6	E4: 2x5								
7	E1: 2x8	E2: 2x8				290	70	4	0	8	Maximum
	E3: 1x6	E3++: 2x6	E4: 1x5	E4+: 1x5							
8	E1: 2x8	E2: 2x8				280	75	3	0	8	Maximum
	E3: 1x6	E3++: 2x6	E4: 1x5	E4++:1x5							
9	E1: 2x8	E2: 2x8				270	80	3	0	8	Maximum
	E3: 1x6	E3++: 1x6	E4: 1x5	E4++:1x5	E5: 1x4						
10	E1: 2x6	E2: 2x6				260	85	2	0	8	Maximum
	E3: 1x6	E3++: 1x6	E4: 1x5	E4+: 1x5	E5: 1x4						
11	E1: 2x6	E2: 2x6				250	90	2	0	8	Maximum
	E3: 1x 6	E3++: 2x6	E4: 1x5	E4++:1x5	E5: 2x3						
12	E1: 2x6	E2: 2x6				240	95	2	0	8	Maximum
	E3: 1x 6	E3++: 2x6	E4: 1x5	E4++:1x5	E5: 2 x 3						

E1: Isometric electrical stimulation in stretched position Hip-knee 90º.
E2: Isometric electrical stimulation in stretched position Hip 0º-knee 90º.
E3: Eccentric + isometric bilateral. Hip-knee 90
E4: Eccentric + isometric bilateral. Hip 0º-knee 90º.
E5: Single-leg Eccentric + isometric Hip-Knee 75º.
Sets x repetitions.
µ: microseconds; s: seconds; Hz: Herzs. T.:Time
+ add load 15% body weight.

opposite leg is kept in the flexed on the plinth in order to alleviate any stress in the lumbar region.

Exercise three (E3) consisted of eccentric, isometric, and concentric bipedal exercises of the quadriceps with the knee-hip joint at 90° (Figure 4.1). This exercise comprised three steps: a) an eccentric phase, from standing to the sitting position, with knee-hip angles from 0° to 90°, lowering slightly for 3 seconds, b) an isometric phase, in which the knee-hip flexion was kept at 90° for a further 3 seconds, and c) a concentric phase, in which the athlete returned to the standing position for one second. A progression from this initial exercise involves the use of weighted jackets or weights placed on the chest. This advanced exercise is referred to as exercise three plus (E3+).

Figure 4.1

Figure 4.3

Figure 4.2

Exercise four (E4), consisted of eccentric, isometric and concentric bipedal exercise of the quadriceps with the knee at 90° and the hip at 0° (Figure 4.2). The progression was similar to the previous exercise (E3). The tension of the tendon was increased by means of changing the angle of the lever arm and by the tension exerted in the stretching of the anterior rectus muscle. Similar to E3, progression involved adding loads. This advanced exercise is referred to as exercise four plus (E4+).

Exercise five (E5) comprised eccentric, isometric and concentric single leg exercises of the quadriceps with the knee at 75° (Figure 4.3). As in the previous two exercises (E3 & E4), progression was accomplished by adding loads, with the progression referred to as exercise five plus (E5+).

Clinical assessment

The initial assessment and the results of the treatment protocol were obtained with use of a visual analogue scale for pain (VAS)[21]. Visual analogue scales have been shown to be efficient and reproducible and are widely used in medical research[7,22-24]. This scale was anchored from zero (absence of pain) to 10 (maximum pain), incapacitating the athlete. Data on pain levels were collected before starting the protocol and three months after completing each protocol (6, 12, 18 and 24 months). This coincided with the end of the competitive phase and took into consideration the pain level after a season of a maximum demand on the patellar tendon (Figure 5).

Statistical analyses

The data was analysed using the PASW statistics data editor program v. 18.0 (SPSS, Inc. Chicago, Il. USA). To analyse the influence of the treatment on the pain level of each participant, Friedman's test for pre-post comparisons was employed. This test is an alternative to one-way ANOVA of fixed effects of repeated measurements (1F FE RM). With the sample consisting of fewer than 30 subjects a post-hoc

Table 3: Subjective pain by visual analogue scale of pain (VAS).

	Mean ±SD
VAS 1. Baseline test	7.67 ±1.96
VAS 2. Month 6	3.67 ±2.34
VAS 3. Month 12	2.50 ±1.52
VAS 4. Month 18	1.00 ±1.67*
VAS 5. Month 24	0.33 ±0.52*
	* p<0.001

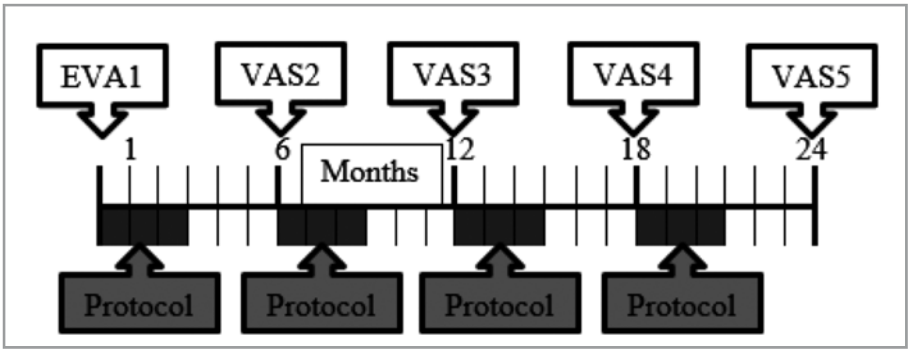

Figure 5: Timeline of interventions. (Data collection by visual analogue scale of pain (VAS) and application protocols.)

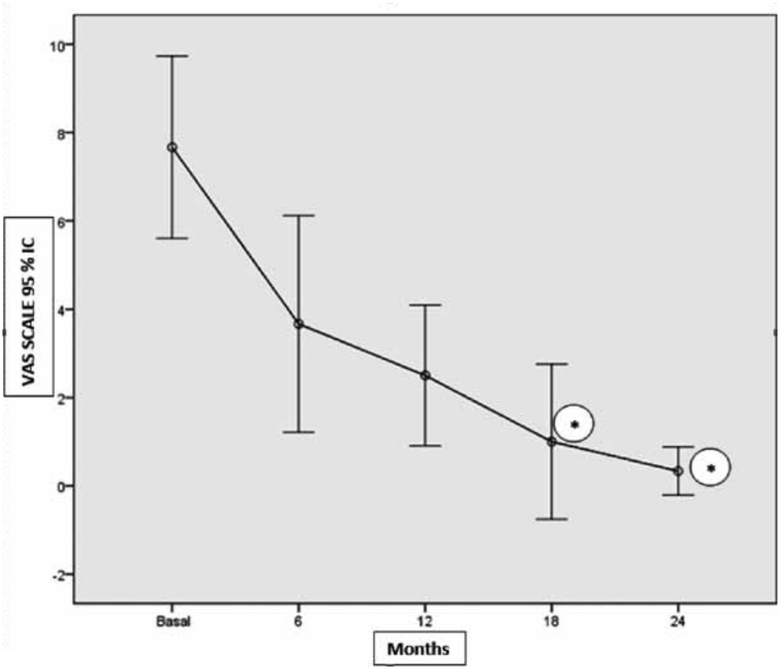

*Figure 6: Subjetive pain by visual analogue sacale of pain (VAS)*Significant differences at 18, 24. (p<0,001)*

Tukey test was performed, comparing the differences in ranks. The level of significance was set at $p<0.05$.

Results

The readaptation protocol had an effect on the athletes' pain levels, and significant differences were observed between the measures of the participants ($\chi 2$ (4) = 23,439; $p<0.001$). On comparing the measurements specifically, the results of the post-hoc Tukey test revealed that pain was significantly decreased when observing the initial mean with measurements at 18 and 24 months ($p<0.001$). There were no significant differences in the comparisons between the other measurements (Table 3; Figure 6).

Following analysis of all the measurements (Table 3), the results showed that after fully completing the first protocol the mean pain level declined notably (VAS 2). However, no statistically significant differences were observed ($p>0.05$) amongst the six participants. This trend was also seen with the second protocol (VAS 3) in which the pain level continued to decrease. However, this too was not statistically significant ($p>0.05$). Referring to both the third (VAS 4 – 18^{th} month) and fourth intervention (VAS 5 – 24^{th} month) significant differences were observed comparing the pain level with the initial pain level ($p<0.05$).

Discussion

In the present study we used electrical stimulation with an excite motor effect as a means to strengthen tendons. This is a novel approach to patellar pathologies and as far as we are aware, the literature contains no references to protocols combined with electrical stimulation such as the one reported here. Therefore, our findings cannot be compared with previous studies of treating Jumpers Knee in this way.

Although electric stimulation has not been included in the design of previous research, the proposal to use it is justified by the beneficial effects of progressive and controlled loading of the tendon, as its tensile strength increases together with the amount of collagen within it[16]. Similarly, this isometric tension is translated into direct mechanical load on the tendon, positively affecting its structure, chemical composition and mechanical properties[18].

The efficacy of our proposal agrees with the scientific literature, which shows satisfactory clinical results in decreasing pain as a response to strengthening exercises with use of eccentric overloading in athletes with chronic patellar tendinopathy[6-10,22-25]. However, it is still not possible to strongly recommend a specific protocol[10, 26-28]. One of the causes of the reduced efficacy is the performance of the exercises limiting the tension applied on the tendon[7,12]. In the present study, exercises that place maximum direct tension on the patellar tendon were selected. The tension created mimicked the tension required for the tendon to adapt to the demands of an aggressive sport.

It should be noted that this protocol indicated benefits prior to the completion of the first intervention. Although they were not statistically significant owing to the small sample size (n=6), this improvement increased progressively with later applications. Based on the present results, it is necessary for three applications to be implemented on a semestral basis for statistically significant differences to be obtained, even though athletes reported a decrease in the sensation of pain after the first two applications.

One important aspect emerging from this study is the duration of the application of the intervention and the follow-up over 24 months. This is important as it takes into consideration the athlete's progress in lieu of the patellar tendinopathy and their exposure to other treatments. This situation was remedied since this intervention can be used in combination with other treatments and training. The interventions made use of and combined eccentric, isometric, concentric exercises and electrical stimulation.

The amalgamation of the present protocol with the athlete's current training programme resulted in the reversal of the use of surgery for three of the athletes, and the ability for all six to continue high-level sports activities. Although the results cannot be compared or contrasted with other studies, the findings of our research suggest promising results for high-level jumpers suffering from jumpers' knee. Nevertheless, our findings should be contrasted with further research.

The diminishing of the athletes' pain during the 24 months of the study suggests that the findings reflect a direct benefit from the proposed interventions. The only controlled variable that changed with respect to the initial situation was the application of the protocol with the various exercises and the electrical stimulation.

The limitations of this study were mainly the lack of a control group and the reduced sample size (n=6). Since the results observed before 18 months cannot be considered significant, a larger sample size is needed as well as a comparison with other exercises used to treat jumpers' knee. Therefore, more studies need to be conducted comparing groups receiving electrical stimulation combined with eccentric, concentric and isometric exercises with other groups using both techniques separately and with a control group.

Conclusions

The results of the present study suggest that use of an intervention combining eccentric, concentric, isometric exercises and electrical stimulation of maximum tension has a positive effect in reducing pain in high-level athletes with patellar tendinopathy. The reduction of pain with use of this protocol suggests that high-level athletes, whose sports involves use of the patellar tendon at the limit levels of tension, need to complete this protocol twice a year to obtain an increase in the benefits. Furthermore, it is suggested that this protocol should be part of their training. However, since there was a low number of subjects in this study, the data and results should be taken with caution. In the future, randomised studies comparing different models of exercise should be carried out.

The present proposal was designed for high-level athletes. The demands and the equipment (inelastic bands and electrical stimulation device) make it difficult for the general population and recreational athletes to be trained in this way. In these cases, the guidelines suggested by COOK & PURDAM[7] should be followed making use of simpler eccentric exercises (i.e., decline squats). However, the present work could be adapted with lesser intensities and demands placed on the general population and recreational athletes.

The recommendations are as follows:

1. The protocol presented in this study should be used as a preventive measure before a lesion in the patellar tendon appears. If the lesion is present, the exercises will be beneficial as a means of strengthening muscles and tendons, preventing future lesions.

2. Adapt to the progress in each individual case. The interventions in this study can benefit athletes who are not jumpers but suffer from patellar tendinopathy due to the demands of their training. In these cases it would be wise to halt their training progress before reaching maximum tendon loads.

3. It is important that work be coordinated with the trainer, preventing any duplication of strength building exercises that could lead to an overload and or overuse effect. This will diminish the progress of the athlete.

4. During the first 3-5 weeks of the protocol, the level of pain rose in the adaptive process, after which it started to gradually diminish. Therefore, athletes should be warned that pain will increase during this first phase.

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