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ORIGINAL REPORT

EFFECT OF BIOMAGNETIC THERAPY VERSUS PHYSIOTHERAPY FOR TREATMENT OF KNEE OSTEOARTHRITIS: A RANDOMIZED CONTROLLED TRIAL*

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Objective: **To assess the effectiveness of pulsed signal therapy in the treatment of knee osteoarthritis (Kellgren II or III).**
Methods: **A randomized, double-blind controlled clinical trial. The first 95 patients sent to the clinic with knee osteoarthritis were selected and randomized into treatment with pulsed signal therapy or conventional physiotherapy. Assessment included recording of usual demographic data, pertinent history, baseline medication and radiographs. Clinical evaluation was made at baseline, 6 weeks and 6 months after the end of treatment by the same blinded doctor. At each follow-up time, the patient was asked to complete a visual analogue pain scale and a Lequesne score. The doctor recorded the degree of pain on motion and the ability to move the affected knee.**
Results: **Both treatments resulted in significant improvements in pain and physical function. A statistical difference was observed only for activities of daily living, where the physiotherapy was more efficient ($p<0.03$). The cost of treatment with pulsed signal therapy was significantly higher, double the treatment cost of conventional physiotherapy.**
Conclusion: **Like physiotherapy, pulsed signal therapy has improved the clinical state of treated patients but with no significant statistical difference. Pulsed signal therapy is, however, more expensive.**

Key words: knee osteoarthritis, treatment outcome, physical therapy, randomized controlled trial, therapeutics.

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INTRODUCTION

Osteoarthritis (OA) is the most prevalent and costly form of arthritis and a major cause of morbidity; many studies have shown the significant cost of this disease (1–3). Symptomatic OA of the knee occurs in approximately 6% of adults aged 30 years and over, with prevalence increasing with age (4, 5). A large community-based survey of non-institutionalized elders revealed that knee OA accounted for the highest percentage of disability in walking, stair-climbing and housekeeping (6). Population ageing will result in exponential growth in the global burden of pain, physical disability and dependency, which will be particularly marked in Europe, North America and Australia (7), although, according to the results of the Mini-Finland Health Survey, the prevalence of knee OA among women had reduced by more than 50% (8).

OA is an idiopathic joint disease characterized by an imbalance between synthesis and degradation of articular cartilage and subchondral bone accompanied by capsular fibrosis, osteophyte formation and variable grades of inflammation of the synovial membrane. Although cartilage degradation is the net result, episodes of inflammation and pain can occur in the disease process; this process is not completely understood, but it is known that there is a close relationship between cartilage and synovial membrane activity. The breakdown of the cartilage matrix is accompanied by bone changes, with osteophyte formation and thickening of the subchondral plate, where an inflammation is often observed (9). A triggering factor causes the division and activation of chondrocytes. This activation may be related to excessive force applied to the joint, or a fundamental defect in the articular cartilage or underlying subchondral bone. The trigger causes chondrocytes to multiply and become metabolically active. Chondrocytes are responsible for the regulation of articular cartilage homeostasis. Many factors are secreted and involved in this regulation, such as interleukin 1 (IL-1), which stimulates the synthesis of degradative enzymes that inhibit the production of proteoglycans. Other cytokines, such as tumour necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6), seem to work synergistically with IL-1. All of these factors are found in inflamed joints. The enzymes identified in proteoglycan and collagen degradation are the matrix metalloproteinases (MMPs). Inhibitors such as tissue inhibitor of metalloproteinase (TIMP) and plasminogen activator inhibitor-7 (PAI-7) balance the activation of the enzymes (10–12). Studies have also shown that IL-1 stimulates the production of prostaglandin E2 (PGE2). PGE2 increases the synthesis of degrading proteins and is also an important pro-inflammatory factor contributing to vasodilatation and pain in patients with OA.

Symptomatic knee OA progresses with a pattern of disease-related impairments, such as joint pain, loss of lower limb

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muscle strength, gait disability and reduced aerobic fitness possibilities (13–15). It is generally accepted that exercise potentially reduces knee pain, improves mobility and limits the decline of physical function in knee OA. But treatment intensity is often limited by the disease-related impairments, together with significant comorbidity in this type of population. An effective treatment "dosage" may therefore require a lengthy, but often economically prohibitive, treatment duration.

Pulsed electromagnetic fields have been used widely to treat non-healing fractures and related problems in bone healing since approval by the Food and Drug Administration (FDA) in 1979, with a success rate averaging 70–80% (16). The original basis for the trial of this form of therapy was the observation that physical stress on bone causes the appearance of tiny electric currents (piezoelectric potentials) that are thought to be the mechanism of transduction of the physical stresses into a signal that promotes bone formation. These piezoelectric potentials are due primarily to movement of fluid-containing electrolytes. When these electrolytes move in the bone channel, which has organic constituents with fixed charges, they generate "streaming potentials" (17). Studies of electrical phenomena in cartilage have shown a mechanical-electrical transduction mechanism similar to that described in bone, appearing when cartilage is mechanically compressed, causing movement of fluid and electrolytes, leaving unneutralized negative charges in the proteoglycans and collagen in the cartilage matrix (18). These streaming potentials apparently serve a purpose in cartilage similar to that in bone, transforming mechanical stress into an electrical phenomenon capable of stimulating chondrocyte synthesis of matrix components (19). These streaming potentials can also lower the threshold of nociceptive afferents innervating the joint capsule (induced by arthritis) and explain the pain reduction observed in many studies.

Increasingly in the last 6 years throughout Europe, more than 150,000 patients have been treated with pulsed signal therapy (PST) for knee OA. As a non-invasive procedure, PST has proven to be completely without side-effects. The long-term results are good and a placebo effect has been excluded (20).

Recently, physical therapists, providing a variety of interventions such as manual therapy techniques, balance coordination and functional retraining technique, have tested the effectiveness of physiotherapy for pain reduction and functional improvement in OA. They found a clinically significant improvement in the 6-minute walk distance test, WOMAC (Western Ontario and McMaster Universities) score and pain level, 4 and 8 weeks after the start of treatment for the physiotherapy group, but not in the placebo group (21).

The treatment with PST lasts only 2 weeks. It takes only a few seconds for a trained therapist to place the knee in the joint coil, whereas the treatment by physiotherapy requires the presence of a physiotherapist during approximately 12 sessions of 30 min each. A successful treatment with PST could save time, staff, and money.

The objective of the present study was to evaluate the effectiveness of PST in the treatment of second- and third-degree knee OA according to the Kellgren and Lawrence radiological classification (22). In order to achieve this, we conducted a double-blind randomized controlled trial comparing one group of patients treated with PST and a second group of patients treated with conventional physical therapy. We used the following criteria to assess the effectiveness of both treatments: outcome in terms of reduction in pain and improvement in the functional index according Lequesne, tolerance in terms of pain during the treatment with PST, appearance of side-effects and analysis of the cost and effectiveness of the two treatments.

MATERIALS AND METHODS

The present investigation is a double-blind randomized controlled trial over an observation period of 6 months. The same rheumatologist obtained historical and subjective data and made all the clinical observations. The study was approved by the ethics committee of the Faculty of Biology and Medicine at the University of Lausanne, Lausanne, Switzerland.

Patients

The first 95 patients sent to the clinic with knee OA at stage II or III according the radiographic criteria published by Kellgren & Lawrence (22) were selected. Informed consent for entry into the clinical trial was obtained and patients were then randomly assigned to PST or conventional physiotherapy. Inclusion criteria required patients to be at least 35 years old, with local symptoms such as pain and stiffness over a period of at least one year, and with persistent symptoms despite non-steroidal anti-inflammatory drugs (NSAIDs). Patients were instructed not to change their basic regimen (drugs) during the observation period. The use of medications was checked by history at each evaluation point. Informed consent for entry into the double-blind trial was mandatory. Exclusion criteria were applied for patients who had an operative treatment (surgery or arthroscopy) in the last 6 months, who had an intra-articular injection in the last 4 months, who had a basic rheumatic disease, who had a homolateral coxarthrosis or who had a malignant disorder. Other exclusion criteria included a body mass index (BMI) greater than 33% of average, pregnancy or inability to understand the visual analogue scale (VAS). Indeed, it was important that the groups were comparable (being overweight can affect the success of the rehabilitation process).

If patients had satisfied the entry criteria and had signed informed consent, they were assigned to the treatment with PST (PST group) or physiotherapy (Physiotherapy group) according to a randomization list and entry number in the study. The PST therapy equipment consisted of a coil system (individual rorid coils arranged in a circle) connected to an electronic unit. It generates impulse-modulated elliptic magnetic fields with direct current at a field strength of approximately 12.5 Gauss in a range between 1 and 30 cycles. On 9 successive days, a 1-h treatment was conducted for each patient. These series were only interrupted by the weekend. The treated knee was positioned in the joint coil according to regulations. The therapist was trained for this purpose prior to the study. The physiotherapy treatment was carried out by the same physiotherapist who had been trained in the treatment scheme according to the manual therapy. The treatment included manual therapy techniques for improving articular mobility, peripatellar massages to improve patella sliding and muscular and proprioceptive strengthening (see Appendix I). Three sessions of physiotherapy per week were given for a total of 4 weeks of treatment.

Data

The data report form used for every patient included a record of usual demographic data, pertinent history and baseline medications. Radiographs were obtained before treatment begun (knee OA, knee lateral and patella skyline views). Clinical evaluations were made at baseline, 6 weeks and 6 months after the end of the treatment by the same blinded doctor. At each follow-up time the patient was asked to mark the degree of pain in the affected site during the past week, using a VAS and to answer a series of questions concerning activities of daily living (ADL) according to the index severity score of Lequesne et al. (23). The physician recorded the degree of pain on motion and the ability to bend the affected knee actively and passively, in degrees. Any soft tissue swelling or synovial effusion was noted.

Index severity score of Lequesne

In the index severity score of Lequesne, the patient reports outcome according to 3 subscales (10 items). The questionnaire focuses on pain and complaints felt by the patient, the maximum walking distance and his ADL. Each answer is graded by points. The addition of these points gives a score, which reflects the patient's disability (see Table III).

A decrease in the score values represents an improvement in knee function.

The algofunctional of Lequesne was validated for knee OA against the WOMAC score (24).

Statistical methods

Sample size calculations revealed that 38 patients would be necessary at least in each group for our purposes. For statistical analysis the patient data were entered on a computer Excel® (Microsoft Office) sheet and subsequently analysed with the Stata™ 9.2 (Stata Corporation, College Station, TX, USA) software. Data were analysed as a whole and for each treatment groups between baseline and follow-up time for each observation. Medians and quartiles were analysed as recommended by Svensson (25). The patients' answers to questions on the Lequesne score index as well as to the VAS questions were recorded as numerical values. They were thus available as parametric data for our population of 95 patients. In addition, the Lequesne score index was weighted according to specifications and divided into scores. Student *t*-tests were carried out at the 0.05 level of significance.

RESULTS

Of the 95 patients initially enrolled in the study, there were 49 in the PST group and 46 in the physiotherapy group. A total of 89 patients, 48 and 41, respectively, completed all treatment and testing at baseline, 6 weeks and 6 months. One patient in the PST group and 5 in the physiotherapy group dropped out of the study; one patient withdrew because of transportation difficulties, 4 for unrelated medical reasons and one patient was excluded for lack of compliance. The data of these patients were excluded from the statistical analysis.

Table I. *Baseline characteristics of study patients. As expected by the randomization process, there was no statistically significant differences between groups as for age, sex, height, weight and body mass index (BMI). Values indicated are means (standard deviations)*

Variable	PST group	Physiotherapy group
Age, years	58 (13)	61 (8)
Sex, men/women	28/20	21/20
Height, cm	171 (7.9)	170 (8.7)
Weight, kg	77.3 (13)	76.3 (12)
BMI	26.34 (3.6)	26.03 (3.05)
Radiographic grade, gr 2/gr 3	28/20	21/20
Kellgren score	2.34	2.45

PST: pulsed signal therapy.

Baseline characteristics of the patients who completed the study are given in Table I. Medications (NSAIDs, paracetamol, etc.), recorded in terms of use or no use and category, at baseline and each follow-up evaluations, showed no statistically significant differences between groups at each follow-up ($p = 0.8669$, $p = 0.5638$, $p = 0.1622$, respectively). Application of the randomization scheme resulted in similar patient groups as expected. Table II shows the changes in passive and active mobility of the treated knee between baseline and the last follow-up time. The start line for mobility was similar in both groups. Improvement in passive and active mobility was statistically significant for all patients and in each treatment group. This improvement was maintained until the last visit ($p < 0.05$). However, there was no significant difference between the groups.

Pair-wise comparison of mean Lequesne score revealed that the 2 groups were similar at initial testing. The 2 different treatments significantly improved the Lequesne score ($p < 0.05$) from the beginning to the end of the observation period without a statistically significant difference between the 2 groups, except for the ADL, where the physiotherapy seemed more efficient ($p < 0.003$) (Table III).

Self-assessment of the pain with the VAS was similar at the beginning of the study in both groups. Both treatments significantly decreased the severity of reported pain, but without a statistically significant difference between groups (Table IV). Self-assessment with VAS for ADL showed a better outcome

Table II. *Mobility changes in study patients. There was no significant statistical difference in the mobility of the treated knee in both groups at the beginning of the study. In both groups, there was a significant improvement in the mobility of the knee after 6 weeks and 6 months. However, the range of improvement was not statistically significant between treatments. Values indicated are medians (25% and 75% percentiles)*

Mobility	Baseline	After 6 weeks	After 6 months
PST group			
Flexion, passive, °	125 (120–130)	130 (125–130)	130 (125–135)
Flexion, active, °	120 (120–130)	125 (120–130)	125 (122.5–130)
Lack of passive extension, °	5 (0–10)	0 (0–5)	0 (0–5)
Lack of active extension, °	5 (0–10)	0 (0–5)	0 (0–5)
Physiotherapy group			
Flexion, passive, °	125 (115–130)	130 (125–130)	130 (125–135)
Flexion, active, °	120 (115–125)	130 (125–130)	130 (125.130)
Lack of passive extension, °	8 (0–10)	0 (0–5)	0 (0–5)
Lack of active extension, °	10 (0–10)	0 (0–8)	0 (0–5)

PST: pulsed signal therapy.

Table III. *Severity index changes according to Lequesne score of study patients. Values indicated are medians (25% and 75% percentiles)*

Severity index	Baseline*	After 6 weeks	After 6 months
PST group			
Pain	4 (3–5)	2 (1–3)	2 (1–3)
Walking distance	1 (1–1)	1 (0–1)	1 (0–1)
ADL	4 (3–5)	3.5 (3–4.5)	3.25 (2–4)†
Total	9.5 (8–11)	7 (5–8)	5.5 (4–7.5)
Physiotherapy group			
Pain	4 (3–5)	2 (1–3)	2 (1–3)
Walking distance	1. (1–1)	1 (0–1)	0 (0–1)
ADL	4 (3–5)	3 (2–4)	3 (2–3)†
Total	9 (7.75–10.5)	5 (3.5–8)	4.5 (3–7)

*There was no statistical difference in the severity index between both groups at the beginning of the study.
†In both groups, there was a significant improvement in the severity index after 6 weeks and 6 months. This improvement was significant for the activity of daily living (ADL) score in favour of the treatment by physiotherapy ($p < 0.03$).
PST: pulsed signal therapy.

in both groups in comparison with the baseline status (the pair-wise comparison at the initial phase was similar). Improvements over the 6 months of observation were maintained. Again, there was no significant group difference (Table V).

Soft tissue swelling or synovial effusion was noted, but these findings were rare and the data were therefore not analysed. No untoward effects, symptoms or clinical findings were observed in any patient treated in our study.

Finally, for the PST group cost analysis, we have added the cost of 3 medical visits to the global price of PST therapy according to the indications of the manufacturer: the device is free of charge, but the dedicated memory card with software costs 600 Euros for 9 treatments. We added 100 Euros for the physiotherapists' work (for patient installation) and the electricity, resulting in a total of 700 Euros.

For the physiotherapy group, the cost of the number of physical treatments (30 min/day) was added to these 3 medical visits.

Table IV. *Self-assessment with the visual analogue scale (VAS) for pain and lack of mobility. There was no statistical difference in the severity index between both groups at the beginning of the study. There was a significant improvement in the self-assessment with VAS for the activities of daily living in both groups between baseline and 6 months. However, there was no difference when both treatments were compared. Values indicated are medians (25% and 75% percentiles)*

VAS	Baseline*	After 6 weeks	After 6 months
PST group			
Pain in the last 2 days	4.4 (3.1–5.1)	2.8 (1.2–4.2)	2.55 (1.2–4.5)
Pain in the last 24 h	4.7 (3.0–6.5)	3.0 (1.7–4.8)	4.25 (1.6–6.2)
Lack of mobility	4.1 (2.0–5.5)	2.0 (0.8–4.5)	1.70 (0.6–3.7)
Pain at night	2.8 (1.0–4.4)	1.3 (0.3–2.8)	0.75 (0.2–2.4)
Physiotherapy group			
Pain in the last 2 days	3.9 (2.1–5.1)	2.5 (1.4–3.6)	2.5 (0.8–4.3)
Pain in the last 24 h	5.2 (3.2–6.1)	2.5 (1.2–5.0)	2.0 (0.7–4.8)
Lack of mobility	4.6 (2.8–5.5)	1.5 (0.8–3.0)	2.3 (0.5–4.2)
Pain at night	2.3 (0.8–3.8)	0.7 (0.2–2.3)	1.0 (0.1–4.1)

*There was no statistical difference in the severity index between both groups at the beginning of the study.
PST: pulsed signal therapy.

Table V. *Self-assessment with the visual analogue scale (VAS) for pain during specific activities of daily living (ADL). There was a significant improvement in the self-assessment with VAS for the ADL in both groups between baseline and 6 months. However, there was no difference when both treatments were compared. Values indicated are medians (25% and 75% percentiles)*

VAS	Baseline*	After 6 weeks	After 6 months
PST group			
Walking more than one block	3.7 (2.1–4.9)	1.9 (0.9–3.1)	1.5 (0.4–2.7)
Going up stairs	4.3 (3.0–6.6)	3.2 (1.6–5.0)	2.6 (1.4–4.7)
Going down stairs	5.7 (3.7–7.0)	4.5 (2.5–6.5)	4.2 (2.6–5.3)
Standing more than 15 min	4.7 (2.6–5.5)	2.3 (1.2–4.3)	2.3 (1.0–4.25)
Getting into/out of a car	4.3 (2.0–6.0)	2.4 (1.1–4.1)	2.5 (1.5–4.4)
Getting into/out of the tub/shower	4.4 (2.0–6.4)	1.9 (0.8–3.4)	1.85 (0.7–3.4)
Physiotherapy group			
Walking more than one block	2.5 (1.5–4.0)	1.1 (0.6–3.0)	0.9 (0.2–2.4)
Going up stairs	3.4 (1.5–5.3)	2.0 (1.0–3.6)	1.5 (0.5–3.6)
Going down stairs	5.9 (3.6–7.5)	4.0 (1.6–6.0)	3.7 (1.5–5.5)
Standing more than 15 min	3. 0 (2.1–4.6)	1.7 (0.7–3.7)	1.6 (0.8–3.4)
Getting into/out of a car	3.9 (2.5–5.3)	1.7 (0.6–3.9)	2.1 (0.5–4.4)
Getting into/out of the tub/shower	3.5 (2.0–6.4)	1.7 (0.8–3.1)	2.2 (0.6–4.0)

*There was no statistical difference in the severity index between both groups at the beginning of the study.
PST: pulsed signal therapy.

Table VI shows a large difference between PST therapy costs (900 Euros) and regular physiotherapy costs (485 Euros).

DISCUSSION

We conducted a double-blind randomized clinical trial (RCT) with patients with second- or third-degree knee OA according to Kellgren & Lawrence (22), comparing a group of patients treated with PST with a group treated with conventional physical therapy. The same clinical benefits were shown for patients in both groups at 6 months follow-up, but there was a significant difference in treatment costs.

In cases of OA of the knee, manual physical therapy and exercises are commonly used to improve self-perceptions of pain, stiffness and functional ability. The beneficial effects of

Table VI. *Comparison total cost/patient. There is a significant difference in the global costs between the treatments (p < 0.001)*

	Euros
PST group	
Medical visits	200
PST treatment	700
Global costs	900
Physiotherapy group	
Medical visits	200
Physiotherapy costs	285
Global costs	485

PST: pulsed signal therapy.

treatment persisted until one year after the end of the therapy. The observed improvement is most likely to be attributable to the physical therapy intervention (20, 26–28). In the last 10 years, starting in Germany and then throughout Europe, thousands of patients have been treated with PST for OA. PST is a new treatment concept, a non-invasive procedure with no known side-effects. The long-term results appear to be good, and randomized controlled studies have excluded placebo effects (20). To our knowledge, there has been no previous study comparing the effectiveness and economic efficiency of PST with conventional physiotherapy.

Using the best study design available, a double-blind RCT, the 2 patient groups were selected. Table I shows that the patient selection process was good, with no statistical difference for age, sex, weight, height, BMI and Kellgren-Lawrence score between both groups. Likewise, the mobility level, the index of severity according to the Lequesne score and the self-assessment of pain and ADL based on the VAS were identical between the 2 groups at baseline. The drop-out rate was higher in the group with physiotherapy treatment (10% vs 2%), but that was unrelated to the treatment itself. Given the design of the study, which included random assignment to study groups, homogeneous groups at the outset and always the same testers (physiotherapist and medical doctor), it is unlikely that causes unrelated to the interventions were responsible for the observed improvements. Although most clinical studies on the efficacy of treatment of OA are clearly based on subjective evaluation using VAS and severity scores such as Lequesne or WOMAC, these parameters provide reasonably satisfactory data for evaluating the effectiveness.

In our study, we observed an average improvement of 7% in mobility in flexion and a decrease of more than 50% in extension deficit (Table II), an average of 46% for the severity index changes according to Lequesne score (Table III), an average of 25% of the pain reduction estimated with the VAS (Table IV) and an average improvement of 35% of the self-assessment for ADL (Table V). These changes are similar to other reports after physiotherapy (2, 21, 26, 27, 29). These changes are significant, since values of 20–25% are generally considered to be clinically important (27).

For the PST patients, our study also showed an improvement in knee mobility (4% on average for flexion and 50% for extension deficit), a reduction of 40% in the severity index changes according to Lequesne score, a decrease of 30% in the pain severity measured with the VAS and an improvement of 35% in self-assessment for ADL. These results are similar to those observed by Trock et al. (20). These authors found a decrease in pain by an average of 37% and an improvement in ADL by 35%. Despite the extensive studies of the effects of PST in numerous laboratories and the demonstration of a variety of *in vitro* effects that could be relevant to cartilage repair, such as increased proteoglycan and collagen repair by chondrocytes cultures, the actual mechanism underlying the clinical effects observed in our study remains unknown and further research is required.

When comparing the 2 groups, we did not see any significant statistical difference in the global improvement in clinical data recorded, with the exception of the ADL measured by the Lequesne score. This is expected since, in the physiotherapy programme, the patients benefited from muscle strengthening and proprioception, whereas PST application was the only treatment in the PST group. However, there was an important difference in terms of costs. The cost of treatment with 9 sessions of PST, according to the manufacturer's proposal, compared with treatment with 12 sessions of manual physical therapy is approximately double (Table VI). Moreover, PST is not refunded by our system of insurance and must be paid by the patient.

Both treatments may also delay the need for total joint replacement. In addition, they were free from side-effects. This is not the case for NSAIDs, which can generate serious side-effects for elderly patients, for example renal insufficiency, arterial hypertension, gastric ulcers, etc. These results confirmed the major role of physiotherapy and PST for second- or third-degree knee osteoarthritis according to Kellgren & Lawrence (22).

OA is a painful and disabling disease that affects millions of patients. Its aetiology is largely unknown, but is most probably multifactorial. OA often begins to attack different joint tissues long before middle age, but cannot be diagnosed before it becomes symptomatic, decades later, at which point structural alterations are already quite advanced. No proven disease-modifying therapy exists for OA, and current treatment options are used to reduce pain and to improve functional ability. Numerous studies have proved the efficacy of manual physical treatment.

In conclusion, like physiotherapy, PST improves the clinical state of the treated patients but there is no statistically significant difference between the two. However, PST is more expensive. Other studies will be necessary to examine *in vivo*, the long-term effects of PST application on cartilage repair, chondrocytes stimulation and proteoglycan synthesis.

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APPENDIX I. Patient exercise programme (3 treatments per week for one month). The number of exercise bouts was increased depending on pain tolerance

1. Stretching	
– Calf, hamstring and quadriceps	3 repetitions with 30 sec hold
2. Range of motion exercise	
– Bike	10 min, increase time and power as tolerated
– Sitting position, knee mid-flexion	2 × 30 sec bouts with 5 sec hold at end to end-range extension range
– Sitting position, knee mid-flexion	2 × 30 sec bouts with 5 sec hold at end to end-range flexion range
3. Strengthening exercises	
– Static quad sets in knee extension	10 repetitions, with 6 sec hold, 10 sec rest between each repetition
– Closed chain exercises	
Standing knee extension	1 × 30 sec bout, increase resistance as tolerated
Leg press	1 × 30 sec bout, increase resistance as tolerated
Proprioception	Balance exercises on mattress or Freeman devices, progress from 2 to 1 leg as tolerated
Step-up	1 × 30 sec bout. Increase step height as tolerated