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SENSORY STIMULATION (ACUPUNCTURE) FOR THE TREATMENT OF IDIOPATHIC ANTERIOR KNEE PAIN

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A randomized controlled study was conducted to evaluate the effect of acupuncture treatment in idiopathic anterior knee pain, a pain syndrome without known aetiology. Fifty-eight patients, clinically and radiologically examined, were randomly assigned to either deep or minimal superficial acupuncture treatment. The patients were treated twice weekly for a total of 15 treatments. The main outcome measurements were one leg vertical jump, functional score, daily VAS recording and skin temperature. Fifty-seven patients completed the study. Pain measurements on VAS decreased significantly within both groups; in the deep acupuncture group from 25 before treatments to 10 afterwards, and in the superficial (placebo) acupuncture group from 30 to 10. There was no significant difference between the groups. The improvement on the VAS recordings remained significant even after 3 and 6 months. Even though the pain decreased after sensory stimulation, neither the ability to jump on one leg, the functional score nor the skin temperature changed. This study shows that patients with idiopathic anterior knee pain benefit from both electro-acupuncture treatment and subcutaneous needling. The pain-relieving effect remains for at least 6 months. Central pain inhibition, caused by either afferent stimulation or by non-specific therapeutic (placebo) effects, is a plausible explanation behind the treatment effects.

Key words: idiopathic anterior knee pain, acupuncture, skin temperature, VAS, functional score, vertical jump.

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INTRODUCTION

Idiopathic anterior knee pain (IAKP), also called patello-femoral pain syndrome, is one of the most common musculo-skeletal disorders (1, 2), which is reported to affect 15–33% of the adult population and 21–45% of adolescents (3, 4). Athletes and non-athletes of both genders are affected (5). Among adolescents the incidence is higher for girls (3, 5).

IAKP is characterized by pain in front of the knee, which is often worsened by climbing and/or descending stairs and by sitting for long periods (2). There has been no consensus on the definition, classification, assessment, diagnosis or management of anterior knee pain nor has there been any explanation for a possible pain mechanism (2). IAKP has been considered to be one of the most typical forms of nociceptive pain. The literature suffers from a lack of standardization in terms of diagnoses, pain scales, small sample size, absence of blinding, absence of stratification for severity, duration of symptoms and patient age.

Acupuncture is a part of Traditional Chinese Medicine, a system with an empirical basis that has been used in the treatment of pain for centuries. Its use for pain relief is supported by clinical trials, but studies taking pain aetiology into account are lacking. Acupuncture effects on pain must devolve from physiological and/or psychological mechanisms with biological foundations. Acupuncture and some other forms of sensory stimulation elicit similar effects in man and other mammals, suggesting that they bring about fundamental physiological changes. Acupuncture excites receptors or nerve fibres in the stimulated tissue which can also be physiologically activated by strong muscle contractions, and the effects are similar to those obtained by protracted exercise (6). Both exercise and electro-acupuncture (EA) produce rhythmic discharges in nerve fibres, cause the release of endogenous neurotransmitters including opioids, monoamines and oxytocin, and have been shown to regulate the sympathetic nervous system (6). Acupuncture also results in the peripheral release of sensory neuropeptides with a vasodilatory role (7). In an uncontrolled study acupuncture was shown to have a clear and durable effect in reducing pain and improving function for patients with patello-femoral pain (8).

The pathogenesis of the anterior knee pain syndrome is not clearly understood (2). Butler-Manuel (9) has proposed an involvement of the sympathetic nervous system and has successfully treated patients with anterior knee pain syndrome using sympathetic blockades. That there is a relationship between pain and sympathetic tone has been demonstrated by Millan (10). Furthermore, sympathetically mediated pain has been shown to be associated with temperature abnormalities (11) and skin temperature has been used as an indirect indicator of autonomic activity after different types of sensory stimulation (acupuncture, transcutaneous nerve stimulation) (12). Also skin temperature measurements have been used in the assessment of patello-femoral arthralgia (13) and patello-femoral pain syndrome (14).

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Table I. *Demographics*

	Total	Men	Women
Subjects (*n*)	58	24	34
Age (years)	33.9	34.4	33.5
Bilateral pain (*n*)	51	22	29
Pain duration (years)	8.4	8.3	8.5
Pain on stair climbing (*n*)	57	23	34
Pain on squatting (*n*)	57	24	33
Pain on sitting for long periods (*n*)	47	20	27

In order to study a possible involvement of the sympathetic nervous system we registered the skin temperature and examined the blood flow in bone tissue using scintigraphy (15).

The aim of our study was to investigate whether acupuncture might decrease pain and improve functional outcome among patients with IAKP and determine if possible effects were related to changes in blood flow as assessed by skin temperature measurements.

Hypothesis: EA but not minimal acupuncture will have a pain relieving effect in patients suffering from idiopathic anterior knee pain ($p < 0.05$).

MATERIALS AND METHODS

Information on our clinical study was sent out to the orthopaedic departments in two local hospitals and to 12 local healthcare centres. Patients were also recruited through advertising in a local newspaper.

Fifty-eight patients, who fulfilled the inclusion criteria, gave informed consent to the study. The research ethics committee, faculty of medicine, University of Lund approved it.

An orthopaedic surgeon and a physiotherapist independently examined all patients.

Patients

Inclusion criteria

Patients aged 20–50 years were included in the study in order to avoid misinterpretations in the scintigraphic assessments emerging from immature bone tissue (15) or from osteoarthritis (16). Patients were included if they had activity-induced pain for more than 6 months, in two out of the following three situations:

1. When stair climbing;
2. On squatting;
3. After prolonged sitting.

Exclusion criteria

Patients were excluded if the clinical examination revealed any symptoms suggesting other pathology of the knee joint such as ligament or meniscus tears, synioval plica, tendinopathia, apophysitis, osteoarthritis, osteochondritis dissecans, neuroma or fat pad impingement. Pathology discovered on radiographic or scintigraphic examinations also led to exclusion. Diffuse uptake on scintigraphy was not regarded as pathologic. Patients were excluded if they had any previous injuries or operations on the leg or had received any treatment for the pain in the last 12 months except for commonly used painkillers, i.e. paracetamol or NSAIDs. Previous experience from acupuncture treatment also excluded the patient.

Demographic details of patients are given in Table I.

Clinical tests

One leg vertical jump: Ergo Power (Ergotest Technology A.S.; Langensund, Norway). The device is based on precise measurement of load displacements of any machine using gravitational loads as external resistance (e.g. leg press, lat. machine, etc). The vertical displacements of the loads were monitored with simple mechanics and a sensor arrangement. The loads were mechanically linked to a shuttle, which glided on a track bar. The sensor consisted of two infrared photo interrupters, locked in the shuttle, facing an optical code strip stuck to the track bar. The two outputs from the sensor were phase shifted by 90°, allowing the detection of the movement direction (up or down). The sensor was interfaced to an electronic device, which included a microprocessor and adequate software. The microprocessor worked internally with a 10 μs time resolution. When the loads were moved by the subjects the signal from the optical transducer interrupted the microprocessor every 3 mm of displacement. Thus, it was possible to calculate velocity, force, power and work corresponding to the load displacements. The device is validated (17) and the day-to-day reproducibility gave a correlation coefficient of $r = 0.88$, 0.97, 0.95 for average push-off force (AF), average push-off velocity (AV) and average push-off power (AP), respectively. In any individual case, the maximal error due to the measurement system was calculated to be less than 0.3%, 0.9% and 1.2% for AF, AV and AP respectively (Fig. 1).

Tegner's activity score. This was used to assess level of *work* and *sport* activity (18).

Visual analogue scale (VAS). Patients were asked to record the highest level of pain experienced during the day. The recordings were done prior to going to bed. The VAS scale was used to assess the pain intensity. Patients were asked to rate their maximum pain on a 100 mm line between the anchor points 0 (no pain at all) and 100 (unbearable pain).

Skin temperature. The patients were acclimatized in a draft-free, temperature-controlled room set at 24–25° C, for at least 15 min before skin temperatures were taken, resting supine and with the lower extremities undressed. A non-contact infrared thermometer (Raytek PM Plus) with an accuracy of 0.1° was used. The distance between the sensor and the skin was fixed at 100 mm to give a spot area diameter of 24 mm.

Experimental design

Patients were randomized into either the electro-acupuncture (group A, 30 subjects) or the minimal superficial acupuncture (group B, 28 subjects) (19) for 15 treatments undertaken twice a week. Skin temperature measurements were made before and after every treatment. All patients recorded their highest experienced pain on VAS daily at bedtime, starting 2 weeks before the first treatment and continuing through the treatment period of 7–8 weeks. Another 2 weeks' VAS recordings were performed as follow-up, at 3 and 6 months. Before the first and the last treatment patients were tested functionally on Ergo Power and had to fill in Tegner's functional score. The patients were told to continue with their normal life activities during the treatment and follow-up period and report any drugs taken.

Test sessions

Temperature was measured at three locations on each leg: the distal end of the rectal femoral muscle, the patella and the midpoint on the anterior tibial muscle. Patients reporting bilateral pain were treated on the more affected side.

The ability to jump vertically on one leg was measured on Ergo Power. The best attempt out of three was recorded. No warming-up exercise was allowed before the test so as to resemble activities of daily living.

Acupuncture treatment

Group A received electro-acupuncture (EA), 2 Hz, constant biphasic square pulses, pulse-width 180 μs (Acus, Cefar Medical AB, Lund Sweden) at six acupuncture points in the knee region (Table II, Fig. 2). The acupuncture points used were chosen from a western approach, i.e. from an anatomic and neurophysiologic background (20), and are all commonly used points in the knee region. Before connecting the cables, the needles were twirled to evoke the sensation of de Qi, which is often described as tension, numbness, tingling and/or tenderness and is

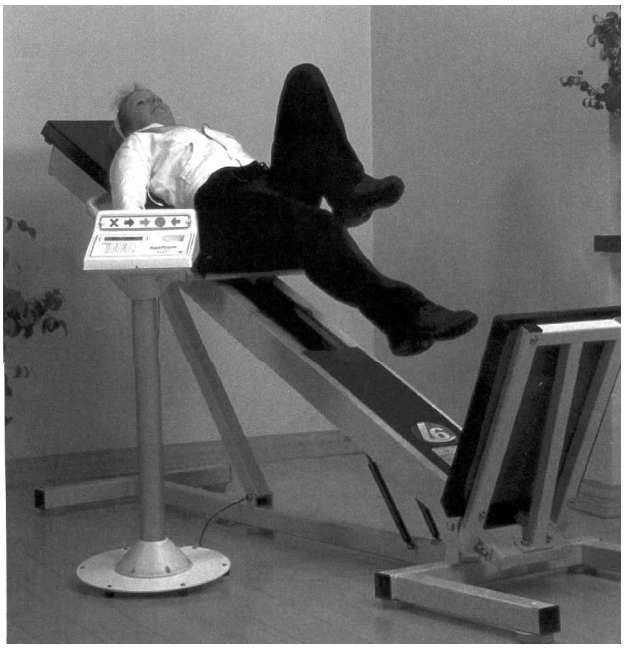

Fig. 1. One leg vertical jump: Ergo Power (Ergotest Technology A.S.: Langensund, Norway). The vertical displacements of the loads were monitored. The sensor consisted of two infrared photo interrupters, locked in the shuttle, facing an optical code strip stuck to the track bar. The sensor was interfaced to a microprocessor working with a 10 μs time resolution. When the loads were moved by the subjects the signal from the optical transducer interrupted the microprocessor every 3 mm of displacement. Thus, it was possible to calculate velocity, force, power and work corresponding to the load displacements.

regarded as essential for the effect of acupuncture. The stimulator delivered pulses at an intensity strong enough to evoke muscle twitching, just below the pain threshold.

Group B was treated with superficial minimal acupuncture, i.e. six needles were inserted subcutaneously in the knee region one inch away from the traditional points but still in the same dermatome. No de Qi sensation was evoked in this group. The cables were connected to the handles of the needles but the electrical stimulator was manipulated in such a way that no stimulation was given. Disposable, sterile stainless acupuncture needles (Hegu Svenska AB), 0.3 mm diameter, 30 mm long (group A) 0.15 mm diameter, 15 mm long (group B) were used. Treatment time in both groups was 30 min. All treatments were performed by two physiotherapists, clinically experienced with almost daily practice in acupuncture treatment for 15 years. Their training with Chinese teachers was western oriented.

Statistical methods

VAS data and the Tegner's score were analysed by non-parametric tests. Data are to be interpreted as ordinal scaled data and should not be analysed by quantitative methods (21). A sign test was used in order to test for systematic differences between two independent groups with respect to change over time. Data were classified as positive or negative change over time. Friedman's ANOVA was used to test for systematic differences between more than two repeated observations and Mann-Whitney in order to test for systematic differences between two independent groups at one time point. The ANOVA for repeated measurement (time) was also used for analysing the continuous data, temperature, since no assumption was made about the underlying distribution. A p-value of < 0.05 was considered statistically significant. The Receiver Operative Characteristics (ROC) curve was used to demonstrate the systematic disagreement in repeated assessments of pain and for the responsiveness of acupuncture treatment (22).

RESULTS

A total of 57 patients (group A 30 subjects, group B 27) completed the study. One patient in the minimal acupuncture group dropped out after the third session and three patients did not complete VAS recordings after 6 months.

One leg vertical jump

Functional testing on Ergo Power showed no increases in any of the parameters (height, velocity, power or force) after acupuncture treatment and there were no differences between the treatment groups (Fig. 3). Initial testing revealed no differences between the right and left leg.

Tegner's functional score

The scores did not change in any of the treatment groups, either for *work* (median 3, range 1–4) or *sports activities* (median 3, range 2–5).

VAS

Pain measurements on VAS decreased significantly within both groups, in Group A from 25 (median, range 0–60) before treatments to 10 (median, range 0–30) after treatments, and in Group B from 30 (median, range 0–60) to 10 (median, range 0–30) (Fig. 4). There were no significant differences between the groups. The improvement on VAS recordings remained sig-

Table II. *The acupuncture points, their innervations and anatomic positions*

Points	Segmental innervation	Localization (45)
ST 34	N. femoralis (L2–4)	In m. vastus lateralis, 2 cun above the laterosuperior border of the patella
ST 36	N. peroneus profundus (L4–5)	In m. tibialis anterior, one finger breadth lateral to the inferior end of the tibial tuberosity
ST 38	N. peroneus profundus (L4–5)	In m. tibialis anterior, 3 cun distal to ST 36
SP 9	N. tibialis (S1–2)	In m. gastrocnemius, on the level of the lower border of the tibial tuberosity in the depression of the medial border of the tibia
SP 10	N. femoralis (L2–4)	In m. vastus medialis, 2 cun above the mediosuperior border of the patella
GB 34	N. peroneus profundus (L5, S1)	In m. extensor digitorum longus, in the depression anterior and inferior to the head of fibulae

ST = stomach; SP = spleen; GB = gall bladder; cun = the Chinese "body inch" (the breadth of the distal phalanx of the thumb at its widest point).

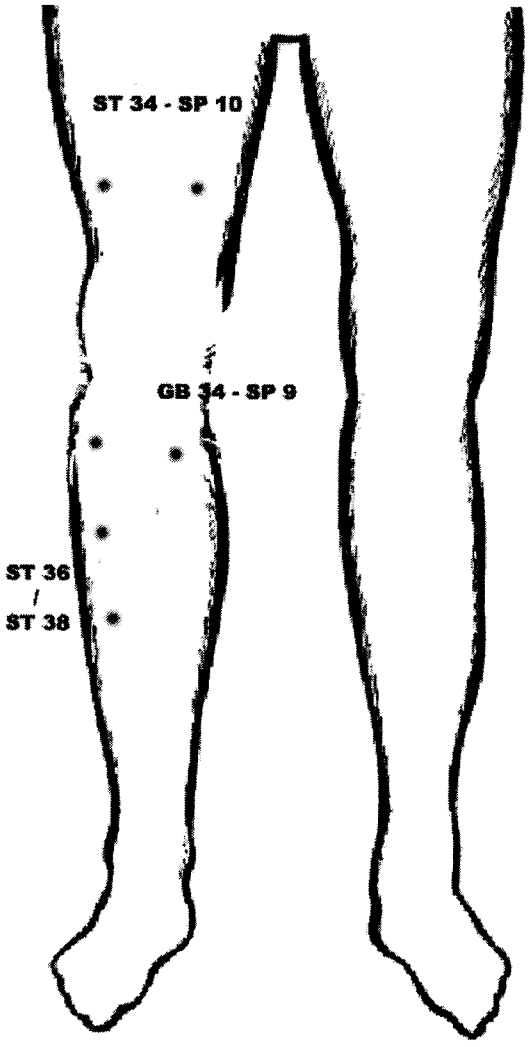

Fig. 2. Anatomical location of the acupuncture points used. Abbreviations in the figure refer to the nomenclature recommended by WHO.

nificant even after 3 and 6 months, 12.5 (median, range 0–50) and 10 (median, range 0–35) in group A and 5 (median, range 0–20) and 5 (median, range 0–30) in group B. No significant changes were distinguished between 3- and 6-month follow-up.

The ROC curve (Fig. 5) illustrates the cumulative frequencies of pain assessments and shows that VAS recordings decreased most in the first part of the treatment series.

Skin temperature

Temperature on three locations in the leg was consistent with recordings in healthy subjects (23). The temperature was overall highest in the lower leg region, lowest in the knee region and did not change from the first to the fifteenth treatment. During each treatment session there was a small but non-significant increase in temperature. The first and the last treatment showed significantly less increase in temperature.

DISCUSSION

The two modes of acupuncture treatment studied had equal effects on idiopathic anterior knee pain and, thus, the hypothesis implying different response to treatment in the two groups could not be verified. The decrease in pain intensity lasts at least 6 months and is not related to mode of stimulation, i.e. deep or superficial. The decrease in pain had no correlation to the functional outcome measurements or the skin temperature.

The use of minimal superficial acupuncture is considered a better placebo control than sham acupuncture because this treatment modality will create less autonomic response (24). The methodological difficulties and challenges in finding suitably acceptable controls for acupuncture trials have probably been the major obstruction to the acceptance of this technique by the conventional medical community. A number of possible choices of control group, both tested and untested, have been proposed. A brief description is given below (25):

A. *No treatment or "waiting list" control.* Differentiating between the specific and non-specific effect of acupuncture cannot be addressed using this type of trial.
B. *Comparison with alternative treatment or standard care.* As no explanation for the pain mechanism involved in anterior knee pain yet has been established, a golden standard for treatment is still lacking.
C. *Invasive sham acupuncture controls.* (1) Deep acupuncture using non-points or inappropriate points. This type of controls will trigger almost all of the afferent stimulation created by "true" acupuncture. Studies using this control have had difficulties with type II statistical errors. There are 747 acupoints in man described by the report of the Shanghai College of Traditional Chinese Medicine. Therefore it would be very difficult to find a site that is not in the immediate vicinity of an acupoint or influencing it. (2) Minimal superficial acupuncture can be assumed to trigger most of the non-specific effects of needling and may minimize the specific. This type of control has previously been chosen in studies on acupuncture for facial pain, migraine, fibromyalgia and xerostomia as well as in our study.
D. *Non-invasive sham acupuncture controls.* A credible non-invasive needling technique has only recently been established and was not described when we planned our study.
E. *Inactivated TENS.* This type of control will not trigger the non-specific effects from needling.
F. *Within-patients crossover study design.* Long-term effects from acupuncture treatment are well described and can be present for 6 to 12 months and thus limit a crossover study design.

We chose invasive minimal superficial acupuncture as the control treatment. Blom et al. (7) and Hansen & Hauser (26) regard minimal acupuncture as the best placebo in acupuncture studies. Superficial acupuncture with minimal stimulation can be assumed to trigger most of the non-specific effects of

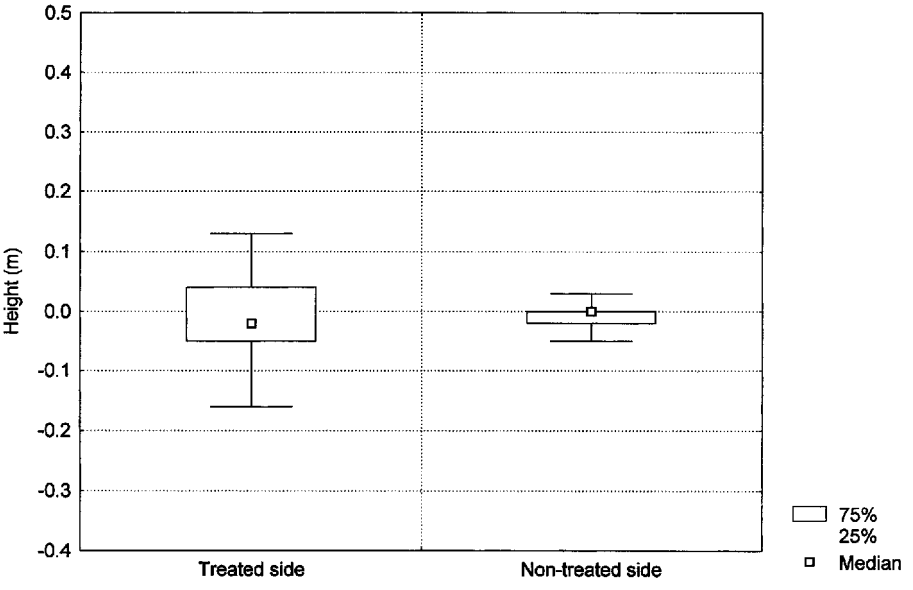

Fig. 3. One leg vertical jump (Ergo Power). Differences in performance before and after treatment.

needling and minimize the specific effects, thus serving as a suitable placebo intervention. This type of control has previously been chosen in studies of acupuncture for facial pain, migraine, fibromyalgia and xerostomia (7).

Acupuncture treatments share the same problems as surgery when it comes to planning randomized double-blind control trials. The unspecified effect (placebo) appears to evoke responses by increasing endogenous opioids (27). The therapeutic response depends on the complicated interaction of patient factors and expectations with therapist factors and his or her expectations, and treatment factors including the specific and non-specific effects of the treatment. Acupuncture treatments, as well as most surgery methods used today, are based on evidence. Only a few operation methods are based on randomized double-blind trials. Recommendations today for trials in surgery are as follows (28): randomization into three groups, one group where the actual therapy is performed, one group receiving a sham operation and the third group as a "waiting-list" control. We randomized our patients into only the first two of these groups because our patients had had their pain for median 8 years and probably would not have experienced any change in their pain status waiting for another 6 months. We also regarded it unethical to exclude any patient from treatment for such a long time.

In a recently presented study on PET scans and acupuncture (29), both true deep and minimal superficial acupuncture were shown to activate Claustrum, Caudatus, Putamen, medial and inferior frontal Gyri bilaterally and to a lesser degree the right anterior Insula. True acupuncture activated the left anterior

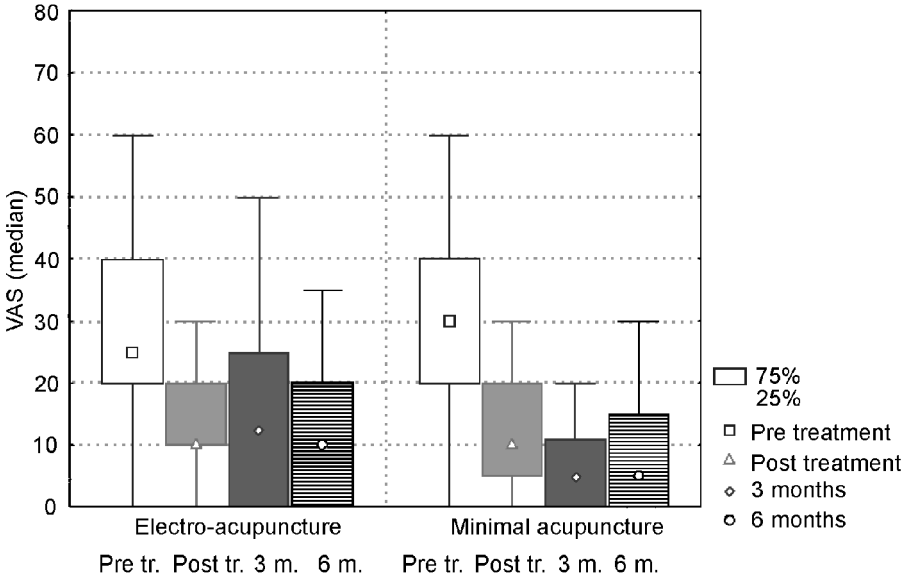

Fig. 4. Daily VAS recordings.

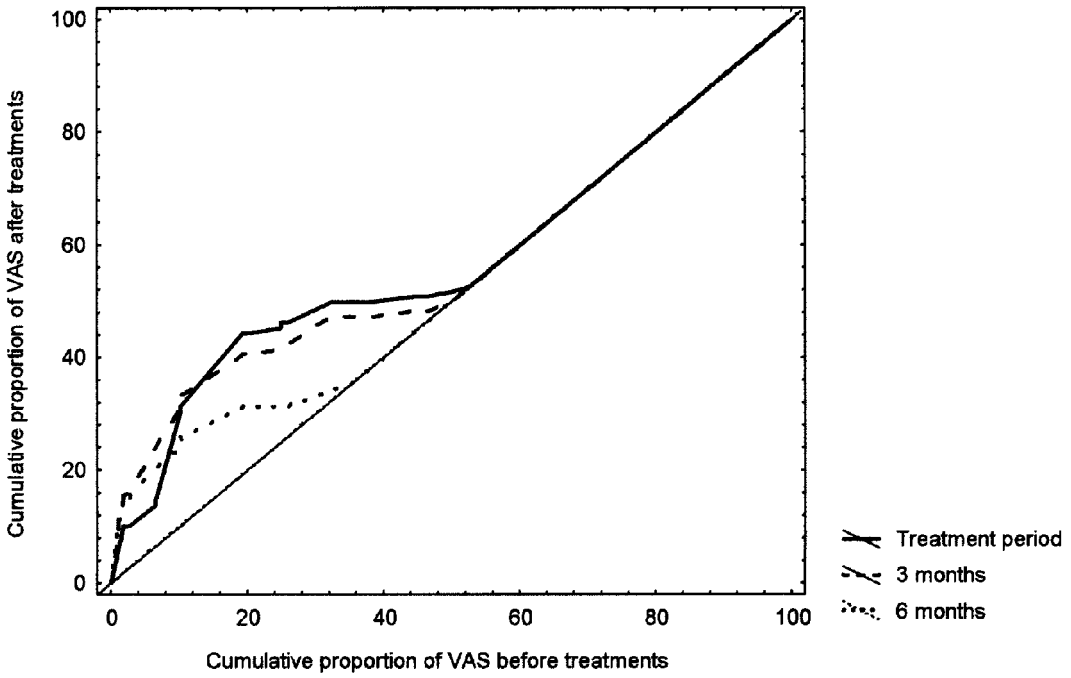

Fig. 5. The Receiver Operative Characteristics (ROC) curve was used to demonstrate the systematic disagreement in repeated assessments of pain and illustrate the responsiveness of acupuncture treatment (22). The ROC curve shows the cumulative frequencies of pain assessments. The convexity of the curve corresponds to a systemic change in the measurements after treatments compared to before, i.e. the perceived pain is rated lower following acupuncture treatments.

Cingulus, the Insulae bilaterally, the Cerebellum bilaterally, the left superior frontal Gyrus and the right medial and inferior frontal Gyri. Minimal acupuncture also activated the Raphè nuclei, the Hypothalamus and the left Temporo-Parietal junction. How these different patterns of activation will impact on a patient with anterior knee pain is impossible to judge as long as we do not know the pain mechanism. Biella et al. (29) concludes that the areas activated only by the minimal acupuncture could be interpreted as placebo effects due to experimental manipulation. In contrast with us, Biella et al., however, used a very short needling time for the minimal acupuncture and that is why definite conclusions cannot be reached.

Our patients did not alter their activity level during the treatment period as they recorded the same activity level on Tegner's score after the treatments, so a discontinuation in physical activities was unlikely to be the reason for the decrease in pain. They were also told to continue with their normal lifestyle. Our group of patients was mostly people with a low level of activity, but there were some who were involved in recreational sports (i.e. jogging, cycling, dancing).

There are two possible explanations for the pain-relieving effect of acupuncture in our study: non-specific (placebo) effects or effects related to the penetration of the skin by the acupuncture needle. As there was no difference in results between true deep and minimal superficial acupuncture the degree of afferent input could not be the major factor in the pain relief obtained.

A striking finding was that there was no correlation between the decrease in pain and functional outcome measurements. This could be due to the lack of specificity of the tests used or because pain assessment with VAS has a low precision, thereby resulting in overestimations of treatment effects (30). If the treatment had resulted in a therapeutic effect one would expect that the patients would have increased their work or sport activities, but this was not the case, suggesting that pain assessed with VAS is not related to functional improvement. Our results are supported by previous studies in IAKP showing the same degree of improvement when using VAS with different modes of sensory stimulation (acupuncture, TENS, stretching, muscle exercise) (8, 31–33) or with the use of different orthotic devices (32, 34). Central pain inhibition caused by non-specific therapeutic (placebo) effects could be a possible explanation for the treatment effects in all of the above-mentioned non-surgical treatments. We have found only five studies (1) regarding this diagnosis, where pain is assessed before and after conservative treatment and where a control group, receiving a "dummy" treatment, meant to trigger most of the non-specific effects and minimize the specific ones, is included. The therapeutic placebo response depends on the complicated interaction of patient factors and expectations with therapist factors plus his or her expectations, and including the specific and non-specific effects of the treatment (35).

The patients were asked to record their highest level of daily pain, which should be the most appropriate way to register the type of pain these patients experience. There are two types of pain, activity induced being sharper than the diffuse pain often

felt when sitting with flexed knees (10). We asked them to record the highest level of pain during the day, i.e. the sensory level of pain and not the emotional, affective level. Most probably this is the pain experienced during a pain-provoking activity.

Previous studies on IAKP and skin temperature have shown contradictory results. Ben-Eliyahu (14), using thermography, reported that the affected knee had a lower skin temperature than the unaffected knee. Siegel et al. (36) found no correlation between increase and decrease in pain and increase or decrease in the skin temperature after a successfully performed rehabilitation programme, suggesting that the skin temperature is not directly related to IAKP. This is in line with our own findings, which showed no correlation between skin temperature and pain. Increased temperature detected after every single treatment session could be the result of an inadequate acclimatization period. The fact that temperature difference in our study was at its lowest on the first and the last treatment sessions could be explained by the fact that the patients were better acclimatized on these occasions than when tested prior to ordinary treatments. In the first and last sessions the patients had to stay indoors for more than 60 min to be able to complete testing on Ergo Power and to fill in the questionnaire for Tegner's score.

CONCLUSION

Our study shows that patients with idiopathic anterior knee pain benefit from both electro-acupuncture treatment and subcutaneous needling. The pain-relieving effect remains for at least half a year. As the pain reduction was not significantly better in patients receiving deep acupuncture compared with the control group, central pain inhibition, caused by either afferent stimulation or by non-specific therapeutic effects, is a plausible explanation underlying the treatment effects.

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