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Peripheral effects of needle stimulation (acupuncture) on skin and muscle blood flow in fibromyalgia

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Abstract

Acupuncture has become a widely used treatment modality in various musculoskeletal pain conditions. Acupuncture is also shown to enhance blood flow and recovery in surgical flaps. The mechanisms behind the effect on blood flow were suggested to rely on vasoactive substances, such as calcitonin gene-related peptide, released from nociceptors by the needle stimulation. In a previous study on healthy subjects, one needle stimulation into the anterior tibial muscle was shown to increase both skin and muscle blood flow. The aim of this study was to examine the effect of needle stimulation on local blood flow in the anterior tibial muscle and overlying skin in patients suffering from a widespread chronic pain condition. Fifteen patients with fibromyalgia (FM) participated in the study. Two modes of needling, deep muscle stimulation and subcutaneous needle insertion were performed at the upper anterior aspect of the tibia, i.e., in an area without focal pathology or ongoing pain in these patients. Blood flow changes were assessed non-invasively by photoplethysmography (PPG). The results of the present study were partly similar to those earlier found at a corresponding site in healthy female subjects, i.e., deep muscle stimulation resulted in larger increase in skin blood flow (mean (SE)): 62.4% (13.0) and muscle blood flow: 93.1% (18.6), compared to baseline, than did subcutaneous insertion (mean (SE) skin blood flow increase: 26.4% (6.2); muscle blood flow increase: 46.1% (10.2)). However, in FM patients subcutaneous needle insertion was followed by a significant increase in both skin and muscle blood flow, in contrast to findings in healthy subjects where no significant blood flow increase was found following the subcutaneous needling. The different results of subcutaneous needling between the groups (skin blood flow: $p = 0.008$; muscle blood flow: $p = 0.027$) may be related to a greater sensitivity to pain and other somatosensory input in FM.

Keywords: Acupuncture; Blood flow; Fibromyalgia; Hyperexcitability; Non-invasive

1. Introduction

According to traditional Chinese medicine, deep needle insertion into the muscle combined with twirling the needle 180° backwards and forwards in order to evoke a distinct sensation is a prerequisite for acupuncture having beneficial effects (Cheng, 1987). However, some acupuncturists prefer subcutaneously inserted needles without further manipulation, mainly because they are more convenient for the patients. The deep mode of needle stimulation, known as DeQi, according to traditional medicine (Cheng, 1987), is characterized by numbness, heaviness, distension or soreness, and sometimes perceived painful. It is suggested that these sensations are related to the activation of Aβ-fibers, thin myelinated Aδ-fibers and thin unmyelinated C-fibers in skin and muscle (Wang et al., 1985; Andersson and Lundeberg, 1995).

Acupuncture and transcutaneous electrical nerve stimulation (TENS) is commonly used to alleviate pain in various pain conditions (Ezzo et al., 2001; Proctor et al., 2002). Moreover, experimental studies of TENS and electro-acupuncture (EA) are shown to enhance subcutaneous blood flow and recovery in surgical flaps (Kjartansson et al., 1988; Jansen et al., 1989a,b). EA as

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well as manual deep acupuncture is shown to increase blood flux in skin overlying the parotid gland in patients suffering from xerostomia (Blom et al., 1993). Muscle blood flow, measured using percutaneous laser Doppler flowmetry, in rat biceps femoris muscle is also shown to increase following electrical stimulation of the ischiadicus nerve (Sato et al., 2000) and EA-like stimulation to the hindpaw in rats (Noguchi et al., 1999).

Fibromyalgia (FM), a chronic pain syndrome, affects mostly women and is characterized by widespread continuous pain and tenderness on palpation of 11 out of 18 defined tender points, according to the criteria of the American College of Rheumatology (ACR) 1990 (Wolfe et al., 1990). A generalized, non-modality-specific increase in deep and cutaneous pain sensitivity, also at spontaneously non-painful sites, is shown in these patients (Kosek et al., 1996; Sörensen et al., 1998). The cause of the pain and tenderness is unknown, but dysfunction in central processing of somatosensory input has been put forward as a pathogenic basis (Kosek et al., 1996; Mense, 2000). However, the cause of the pain may not be the same in all patients or even at all pain sites (Sörensen et al., 1998). In a subgroup of FM patients, gentle deep acupuncture resulted in a long-lasting decrease in pain in the neck–shoulder region, however, the alleviating effect on the generalized pain was weaker and of short duration (Sandberg et al., 1999). The mechanism behind the alleviating effect of acupuncture on the neck–shoulder pain is not known, but increased muscle blood flow was considered.

Recently, local blood flow changes in the tibialis anterior muscle and overlying skin following needle stimulation were evaluated in healthy subjects (Sandberg et al., 2003) by using a novel non-invasive technique utilizing photopletysmography (PPG) (Zhang et al., 2001). Needling into the muscle was found to induce greater increase in both skin and muscle blood flow to merely inserting the needle subcutaneously. No increase was found in skin blood flow by the subcutaneous stimulation, whereas a transient non-significant increase was found in muscle blood flow. In FM, the anterior aspect of the tibia, absent from focal pathology, is mostly free from spontaneous pain although embraced by allodynia inherent in these patients (Sörensen et al., 1998). Whether this clinical feature of central hyperexcitability to somatosensory input will interfere with the effects of sensory stimulation (acupuncture) on blood flow is not known. The aim of this study was to evaluate effects of deep and subcutaneous needle stimulation on local blood flow in the tibialis anterior muscle and overlying skin in FM patients by using a modified non-invasive technique (PPG), and to compare the results with previously published data on healthy subjects. The psychological impact of the needling situation was also evaluated. The clinical relevance of studying blood flow changes by needle stimulation in tibial anterior muscle in FM patients was to prepare for future similar studies in painful shoulder muscles, which might be subject to a disturbed microcirulation (in patients with fibromyalgia and localized trapezius myalgia). In addition, by needling into a spontaneously non-painful area, this study might add some understanding to the consequences of hyperexcitability on local blood flow in these patients.

2. Patients and methods

2.1. Patients

Fifteen FM patients with an average age of 39.9 years (range 24–54 years) participated in the study. Seven women comprised a younger age group, 20–35 years, and 8 women an older group, 40–55 years. Average height was 165 cm (range 154–175 cm) and average body mass 68 kg (range 56–84 kg). The average duration of generalized pain was 7.7 years (range 3–13 years). General pain ‘as usual’ varied between 40 and 80 mm on a 0–100 mm visual analogue scale (VAS; 0 = no pain, 100 = worst pain imaginable) (Huskisson, 1974), with an average of 59 mm. Only two patients had minor spontaneous pain at the anterior aspect of the tibia, VAS 5 and 20 mm, respectively. Inclusion criteria were female gender, diagnosis according to the ACR criteria of 1990 (Wolfe et al., 1990), Swedish speaking, and age between 20 and 55 years. Exclusion criteria were smoking, abuse of drugs or alcohol, neurological, psychiatric or cardiovascular disorders, any other severe disease, pregnancy or breast-feeding. The patients were recruited through the Pain and Rehabilitation Centre at the University Hospital in Linköping, Sweden. Fourteen healthy female subjects, with equal number in the two age groups as in the FM group, were used for comparison, data from which is published in detail elsewhere (Sandberg et al., 2003). The patients were informed both verbally and in writing about the experiments, and gave their informed consent. The ethical principles in the Declaration of Helsinki were followed, and the local Ethics Committee approved the study.

2.2. Assessment

2.2.1. Blood flow recordings

A custom-designed optical probe with accompanying PPG instrumentation, described earlier, was used (Sandberg et al., 2003). The probe utilizes two wavelengths: green (560 nm), reflecting subcutaneous blood flow, and near infrared (880 nm), reflecting deep flow emerging from the muscle. Fig. 1 shows the application site and the circular shape of the probe allowing the acupuncture needle to be inserted in the middle. The signals from each wavelength are simultaneously processed in an amplifier and stored on a laptop PC. A

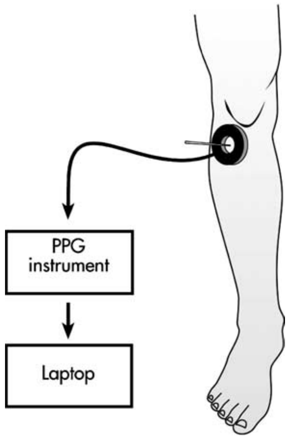

Fig. 1. The experimental set up, including the probe application site and instrumentation.

pulsatile signal, reflecting the blood flow, is measured from a large area on the skin surface, which gives an integrated PPG signal from a large vascular volume. This integration partly compensates for spatial blood flow variations. A rectangular probe (Zhang et al., 2001) was used for simultaneous blood flow recordings from a corresponding site on the contralateral leg. The optical geometry of this probe was somewhat different compared to the circular probe, with the light sources and photodetectors placed on a straight line above the muscle.

2.2.2. Subjective ratings

After randomization but before needle stimulation, a 0–100 mm VAS with the left endpoint depicting "not at all" and the right endpoint "worst imaginable" was used to rate anxiousness. Immediately after the end of the trial, the patients rated both pain intensity and discomfort experienced from the trial, using the VAS with the same endpoints as above.

2.2.3. Needle stimulation

The needle insertion site was the anterior upper aspect of the tibia, corresponding to acupuncture point ST 36 in traditional Chinese medicine (Jenkins, 1990). Two different modes of needle stimulation were performed in each patient: subcutaneous needle insertion (i.e., ~2–3 mm into subcutaneous tissue) (SC), and deep, ~20 mm insertion into the anterior tibial muscle, immediately followed by gently twirling the needle in order to elicit a distinct deep sensation (Deep). The needle was inserted perpendicular to the skin using sterile stainless-steel acupuncture needles with the same dimension in all sessions (Hwato 0.30-mm diameter, 30 mm long).

2.2.4. Procedure

Those patients who had no previous experience of acupuncture had an initial individual visit to the clinic to experience the needling. All patients were instructed not to eat, to drink coffee, chocolate or tea, or to exercise within 2 h before the sessions. Each patient participated in three randomly distributed sessions, separated by 2–5 days, each at the same time of the day. All sessions were performed in a quiet room with moderate light and a constant temperature (23 ± 1 °C). All interventions were performed by one of the authors (MS) with clinical experience of acupuncture. The sessions included either of the two needle stimuli or a control situation with no stimulation (Control). The patients were lying in a supine position, and a pre-stimulation period of 30 min was allowed for blood flow stabilization. The circular probe was attached to the skin with double-adhesive tape on the right leg 15 min prior to stimulation (Fig. 1). The rectangular probe was applied at the corresponding site on the contralateral leg. After needle stimulation, the needle was left in situ for 20 min. Blood flow recordings were performed for 30 s every 5th min, starting 10 min prior to needle stimulation and thereafter throughout the trial, with the PPG instrument turned on during 30 min. From 1 min prior to the intervention to 5 min after, blood flow recordings were performed continuously, i.e., during 360 s. During the control situation, an identical recording protocol was followed (Fig. 2).

2.3. Statistical analysis

The statistical package Statview 5.1 (Abacus SAS Institute, NC, USA) was used for statistical analyses. In the figures, mean value ± one standard error of the mean (SEM) is presented. The Friedman's two-way analysis of variance was used and, if significant, followed by the non-parametric Student–Newman–Keul's test to correct for multiple comparisons. The Wilcoxon signed rank test was used to test differences between −5 min and baseline (denoted 0, Fig. 2), differences between muscle and skin blood flow changes and differences between stimulated and non-stimulated leg. The Mann–Whitney

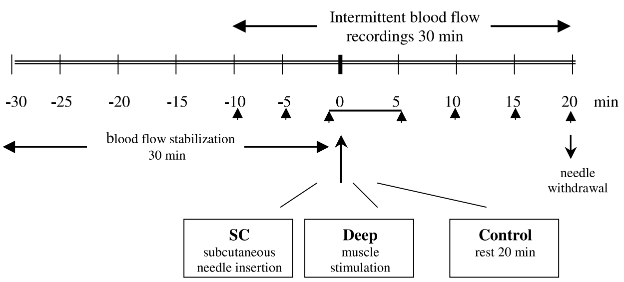

Fig. 2. Schematic protocol depicting the experimental design and procedure. ▲ shows 30 s of blood flow recordings intermittently performed every 5 min. ▲—▲ shows 360 s of continuous blood flow recordings, starting 60 s prior to intervention to 300 s after stimulation (= 360 s).

U test was used for testing differences between FM patients and available data from healthy subjects (present in detail in Sandberg et al., 2003). Spearman's test was used for correlation analyses. The level of statistical significance was set at $p < 0.05$.

All analyses were carried out on the area under curve (AUC) (blood flow vs. time) (Altman, 1999), calculated for 3 periods: 5-min pre-stimulation period (pre-5) and initial 5-min post-stimulation period (T:1). The remaining 15-min post-stimulation period was divided by 3 in order to obtain a mean AUC (T:2). Blood flow changes are expressed as mean percentages of the mean value obtained from the 60-s recording prior to the intervention (= baseline, denoted 0). In facilitating comparisons with healthy subjects, data of which are reported in detail elsewhere (Sandberg et al., 2003), corresponding data from these subjects are presented in figures and tables, as well.

3. Results

All patients fulfilled the three sessions of subcutaneous needle insertion (SC), deep needle stimulation (Deep) and the control session without any needling. No complications or side effects were observed or reported.

3.1. Blood flow changes at the different stimuli, including control

3.1.1. Five-min pre-stimulation period

Skin blood flow did not differ between the two stimuli and control during pre-5 period (Table 1(a)). At the control situation, no significant change in skin or muscle blood flow existed between −5 min and baseline (denoted 0) (Fig. 3(a)). However, prior to both subcutaneous and deep modes of needle stimulation, muscle blood flow change was significantly different from control (Table 1(b)); the changes were rather similar for the two modes of active stimulation (Figs. 3(b) and (c)).

3.1.2. Post-stimulation periods

At control, skin blood flow was increased both during T:1 and T:2, compared to pre-5 (Fig. 3(a)). For muscle blood flow at control, a significant difference existed between pre-5 and T:2 (Fig. 3(a)). Both deep stimulation and subcutaneous needle insertion resulted in increased skin as well as muscle blood flow during both post-stimulation periods (T:1 and T:2), compared to the pre-5 period. Following deep stimulation, mean (SE) skin blood flow increase for initial 5 min, relative to baseline, was 62.4% (13.0) and in muscle 93.1% (18.6). Corresponding figures at subcutaneous insertion were 26.4% (6.2) and 46.1% (10.2) for skin and muscle blood flow increase, respectively (Figs. 3(b) and (c)).

3.1.3. Blood flow changes following the needle stimuli compared to control

Compared to the control situation, the deep needling resulted in a larger increase in both skin and muscle blood flow at T:1 and T:2 (Table 1(a) and (b)). Compared to control, subcutaneous insertion resulted in a larger increase in skin blood flow during T:1 and in larger muscle blood flow during both T:1 and T:2 (Table 1(a) and (b)). Moreover, the deep stimulation was superior to subcutaneous insertion in increasing both skin and muscle blood flow (Table 1(a) and (b)).

3.1.4. Comparisons between skin and muscle blood flow changes

At control, no differences existed between skin and muscle blood flow changes during pre-5 or T:1, whereas during T:2 muscle blood flow increased more than skin blood flow ($p = 0.009$) (Fig. 3(a)). In contrast, following both deep and subcutaneous needle stimuli, larger increases were found in muscle than in skin blood flow during both post-stimulation periods (SC: $p = 0.006$ and 0.001, respectively; Deep: $p = 0.003$ and 0.001, respectively) (Figs. 3(b) and (c)). Moreover, at pre-5, prior to both modes of needle stimuli muscle and skin blood flow changes were significantly different.

3.1.5. Comparisons between the stimulated and un-stimulated leg

Neither during all the control period, nor at any of the pre-5 periods did any differences exist in skin or muscle blood flow change between the two legs. Significantly larger increases in both skin and muscle blood flow were found in the stimulated leg, compared to the un-stimulated leg, following each mode of needle stimulation.

3.1.6. Psychological variables

VAS ratings of pain and discomfort after the test were higher for the deep needle stimulation (pain: mean 24, range 0–55; discomfort: mean 7, range 0–30) compared to subcutaneous needle insertion (pain: mean 6, range 0–35; discomfort: mean 0.5, range 0–5) ($p = 0.028$ and 0.028, respectively). In contrast, no difference existed between the stimuli on ratings of anxiety prior to the stimuli (Deep: mean 6, range 0–40; SC: mean 5, range 0–55). No significant correlations were found between psychological variables and blood flow changes.

3.2. Differences between FM patients and previous data on healthy subjects

3.2.1. Five-min pre-stimulation period

During pre-5 of the control situation, no differences existed in skin or muscle blood flow changes between FM patients and healthy subjects (presented in detail in Sandberg et al., 2003) (Table 1(a) and (b)). However,

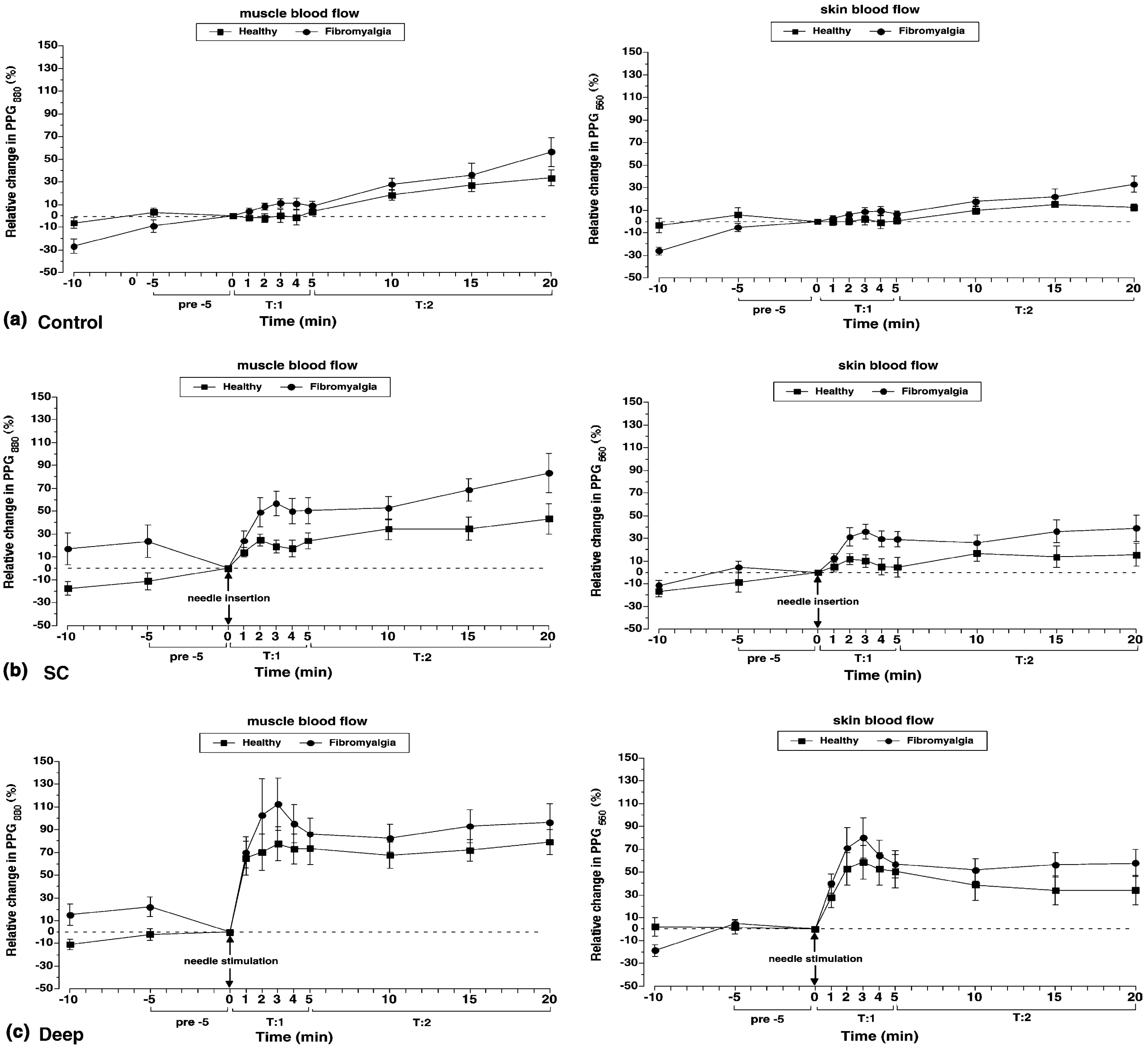

Fig. 3. Relative changes (%) in skin and muscle blood flow at (a) rest (Control), (b) subcutaneous needle insertion (SC) and (c) deep muscle stimulation (Deep). The blood flow values are expressed as the mean (± 1 SEM) 60 s prior to intervention, and corresponding time point for control.

prior to each of the needle stimuli, muscle blood flow changes were significantly larger in FM patients compared to healthy subjects (Deep: $p < 0.015$; SC: $p = 0.032$), with values above baseline in the patients. In healthy subjects, muscle blood flow was stable or slightly below baseline. Skin blood flow changes did not differ between the groups during pre-5 (Table 1(a)).

3.2.2. Post-stimulation period

At the control situation, no significant differences in blood flow changes existed between the two groups (Table 1(a) and (b)). However, during T:1 subcutaneous needle insertion induced significantly larger skin ($p = 0.008$) and muscle ($p = 0.027$) blood flow increases in FM patients compared with healthy subjects. A tendency toward larger increases at T:2 existed, as well ($p = 0.059$). At deep needle stimulation, no significant differences in blood flow change existed between the two groups.

3.2.3. Psychological variables

No differences were found between the two groups on pain intensity at the deep needle stimulation (FM: mean 24, range 0–55; healthy: mean 26, range 0–75) or subcutaneous needle insertion (FM: mean 6, range 0–35; healthy: mean 4, range 0–36). However, compared to FM patients, healthy subjects rated higher discomfort following the deep stimulation (FM: mean 7, range 0–30; healthy: mean 21, range 0–73; $p = 0.043$). Moreover, a

Table 1
Statistical results of relative (a) skin and (b) muscle blood flow changes between subcutaneous needle insertion (SC), deep muscle stimulation (Deep) and control at different time points in 15 fibromyalgia patients and 14 healthy subjects

Time	Fibromyalgia ($n = 15$)		Healthy subjects ($n = 14$)		Between-group comparisons[c]		
	p-Value[a]	Post hoc-test[b]	p-Value[a]	Post hoc-test[b]	Control	SC	Deep
(a) *Skin blood flow*							
Pre-5	0.248	NA	0.170	NA	0.369	0.147	0.383
T:1	0.001	Deep, SC > control; Deep > SC	0.002	Deep > SC, control	0.076	0.008	0.601
T:2	0.002	Deep > SC, control	0.205	NA	0.065	0.056	0.190
(b) *Muscle blood flow*							
Pre-5	0.031	Deep, SC > control	0.205	NA	0.189	0.032	0.015
T:1	<0.001	Deep, SC > control; Deep > SC	<0.001	Deep > SC, control	0.069	0.027	0.316
T:2	<0.001	Deep, SC > control; Deep > SC	0.039	Deep > SC, control	0.438	0.056	0.359

Pre-5 denotes 5-min period before intervention and T:1 initial 5-min period after intervention. T:2 denotes last 15-min period after intervention divided by 3.

NA, not applicable; >, significantly different from...

Detailed results from healthy subjects are presented elsewhere (Sandberg et al., 2003).

[a] Friedman's test was used to test differences between control, SC and Deep.

[b] Student–Newman–Keul's test was used for post hoc tests.

[c] Mann–Whitney U test was used to test differences between fibromyalgia patients and healthy subjects.

tendency existed toward higher ratings of anxiety prior to the deep stimulation in the healthy subjects ($p = 0.074$), as well as higher ratings of discomfort following subcutaneous insertion ($p = 0.078$). Nine of 15 FM patients rated 0 on VAS pain at subcutaneous needle insertion and 3 patients rated between 15 and 35. In the healthy group 8 of 14 subjects rated 0 on VAS pain at subcutaneous needle insertion, while 1 subject rated 35.

4. Discussion

The main finding of the present study was that one needle stimulation into the anterior tibial muscle, as well as one subcutaneously inserted needle, induced both skin and muscle blood flow increase in FM patients. However, the deep needle stimulation was superior to subcutaneous insertion in increasing both skin and muscle blood flow. There was no significant difference between FM patients and healthy subjects on blood flow increase following deep needle stimulation. However, subcutaneous needle insertion induced a significantly larger increase in both skin and muscle blood flow in the patients, compared to the healthy subjects where no such increase was found.

4.1. Methodological considerations

The non-invasive method (PPG) for monitoring deep blood flow, preferably from the muscle, has been described earlier (Zhang et al., 2001). To evaluate the depth of light penetration by the modified PPG instrument, an optic fiber was inserted into the anterior tibial muscle in three subjects and connected to an Optical Power Meter for recording the radiant power of radiation in the muscle. Exact location of the fiber tip was determined by ultrasound Doppler. The PPG sensor was placed over the tibial muscle above the fiber tip. The radiant power measured in the muscle tissue indicated that the near-infrared light penetrates at least down to a vascular depth of 13.0 mm from the skin surface. The distance between the skin surface and the muscle fascia was also measured in 40 subjects. The mean value was 6.5 mm (range 2.1–13.8 mm) with a standard deviation of 2.9 mm (Zhang, 2003). However, it must be pointed out that the signal emerging from the muscle is to some extent influenced by changes in subcutaneous blood flow. As the latter flow is also monitored the influence should be taken into consideration when the results are interpreted.

In all sessions, a 30-min resting period was allowed for blood flow stabilization. Yet, an increase in blood flow was apparent at control (Fig. 3(a)). This is due to a local temperature increase as a result of the application of the probe on the skin surface, and subsequently to local blood flow regulation. However, from previous results in healthy subjects, no increase in either skin or muscle blood flow existed during the first 5-min period at control, indicating no temperature-induced influences on blood flow in this group (Sandberg et al., 2003). However, for this reason post-stimuli results are presented separately for the first 5-min and for the remaining 15-min periods, respectively. Blood flow changes following the needle stimuli are compared with corresponding control values, hence, the warming effect will not affect the results of the two modes of stimulation to a substantial degree. However, some precautions must be taken in interpreting the between-group comparisons since the warming of the probe may affect blood flow differently in FM patients and healthy subjects.

Due measures were taken to maximize the standardization of the procedure, not only for physical, but also for psychological factors. To reduce anxiety, the subjects were offered initial visits to experience the needling, to gain further information if needed, and also by having the 30-min rest before the intervention.

4.2. Blood flow changes following needle stimulation

In FM, a generalized, non-modality specific increase in pain sensitivity and additional abnormalities in the perception of somatosensory information exist (Kosek et al., 1996; Mense, 2000). A state of central hyperexcitability involves phenomena like hyperalgesia and allodynia, i.e., lower pain thresholds and pain in response to non-noxious stimulus, respectively. Furthermore, compared to healthy subjects, extended areas of referred pain following noxious stimuli to the spontaneous non-painful tibialis anterior muscle, i.e., the same site for stimulation as in the present study, have been reported (Sörensen et al., 1998).

Deep needle stimulation, combined with rotation of the needle in order to elicit specific sensations of numbness, heaviness, distension or soreness, are suggested to activate myelinated Aβ- and Aδ-fibers and unmyelinated C-nociceptive fibers (Wang et al., 1985; Andersson and Lundeberg, 1995). When activated by noxious somatic sensory stimulation, vasoactive neuropeptides, such as calcitonin gene-related peptide (CGRP) and substance P (SP), are released from their peripheral terminals and local vasodilatation will be evoked (Kashiba and Ueda, 1991; Jänig and Lisney, 1989). In the present study, primary nociceptive afferents were activated by the deep needle stimulation and followed by skin blood flow increase. This finding is in accord with other studies reporting on acupuncture-induced vasodilatation and skin blood flow increase (Jansen et al., 1989b; Blom et al., 1993; Sandberg et al., 2003). Muscle blood flow increase, found in both groups, following deep needle stimulation is consistent with findings of skeletal muscle vasodilatation and increased muscle blood flow measured using laser Doppler flowmetry in anesthetized rats following stimulation of group III and IV afferents (Sato et al., 2000; Noguchi et al., 1999). However, no reports are found on muscle blood flow changes following needle stimulation in humans. Mechanisms underlying blood flow changes in the studies mentioned above, and by others, are suggested to primarily rely on the release of CGRP from peripheral terminals of nociceptors, or by antidromic axon reflex-like mechanisms and/or dorsal root reflexes (Jänig and Lisney, 1989; Willis, 1999). This phenomenon is part of neurogenic inflammation.

The finding of significantly increased skin blood flow following the mostly non-painful subcutaneous needle insertion contrasts to findings in studies mentioned above on pain-free subjects, where no significant skin blood flow increase existed. Moreover, subcutaneous needle insertion was found to induce a long-term muscle blood flow increase in FM patients, which also contrasts to previous findings in healthy subjects (Sandberg et al., 2003). Although not known, it may be speculated whether the phenomenon of hyperexcitability to somatosensory input in FM might be involved in the more pronounced blood flow increase following subcutaneous needle stimulation in this group, compared to healthy subjects. This view may be supported by experiments on neurogenic flare responses to noxious mechanical stimulation, showing exaggerated flares in FM patients compared to healthy subjects (Gibson et al., 1994). Normally, antidromic stimulation of Aβ-fibers does not evoke vasodilatation (Jänig and Lisney, 1989). However, in areas of allodynia, Aβ-fiber-evoked skin vasodilatation has been reported, resulting from antidromic activation of nociceptive cutaneous afferent fibers (Cervero and Laird, 1996; Gottrup et al., 2000; Garcia-Nicas et al., 2001). The authors suggested that centrally mediated mechanisms, involving dorsal root reflexes, lay behind these finding. Thus, the needling techniques used in the present study might, apart from inducing enhanced activity in high-threshold receptors, also activate low-threshold mechanoreceptors, resulting in antidromic vasodilatation. In the clinic, it should be of importance to take these findings into consideration when dosing the intensity of needle stimulation in FM patients.

Moreover, a potential warming effect from the probe may explain blood flow increase found at control, appearing during the first 5-min post-stimulation period in the patients, but not until the last 15-min in the healthy subjects, indicating an increased sensitivity to warmth in the patients. Thus, findings of greater blood flow increases following subcutaneous needle stimulation in FM patients, compared to healthy subjects, might reflect consequences of a state of hyperexcitability to pain and other modalities of somatosensory input existing in FM (Kosek et al., 1996; Mense, 2000). Interactions with autonomic nervous system on blood flow change must also be considered (Andersson and Lundeberg, 1995; Budgell and Sato, 1996). However, in the present study a potential sympathetic vasoconstriction in the skin from the needling may be hidden by vasodilatation due to release of vasoactive substances (Ochoa et al., 1993; Häbler et al., 1997).

No stimuli-induced blood flow changes were observed at the corresponding site on the contralateral leg. Muscle blood flow consistently changed more than skin blood flow following both modes of needle stimulation, and warming from the probe. Moreover, the more pronounced change in muscle blood flow was apparent in the patients also prior to both modes of needle stimulation, in contrast to changes during the corresponding time point at control.

4.3. Psychological aspects

A significant difference between FM patients and healthy subjects was found on muscle blood flow changes at pre-5 prior to the needle stimuli. Anticipation of the needling, in contrast to the control situation, might possibly have induced a decrease in muscle blood flow in the patients, interpreted as a physiological manifestation of mental stress. This response contrasts to findings in a study on healthy subjects, where increased muscle sympathetic activity in the lower extremities during experimental mental stress resulted in increased muscle blood flow (Andersson et al., 1987). However, an altered sympathetic nervous system response is reported in FM patients (Qiao et al., 1991; Arroyo and Cohen, 1993), rendering some support to the finding in the present study. In the healthy subjects, a tendency toward a positive relation existed between anxiety and skin blood flow change post-stimulatory (Sandberg et al., 2003), whereas no such relation was found in the patients. Generally, emotional expressions appeared to be more pronounced and differentiated in the healthy group, compared to FM patients. Healthy subjects, in contrast to the patients, rated a significantly higher degree of anxiousness prior to the deep stimulation compared with the subcutaneous needle insertion. Moreover, according to the strong bodily reactions observed at the deep mode of stimulation, FM patients would be expected to rate higher on VAS pain than the healthy subjects. Yet, the healthy subjects rated a significantly higher degree of discomfort, as well as a tendency toward more anxiousness. Thus, emotional expressions might have been underreported in the patients, and no reliable conclusions can be drawn on emotional influences on blood flow changes in FM from this study.

5. Conclusions

It is concluded that one needle stimulation (acupuncture) into the anterior tibial muscle and overlying skin increases local skin and muscle blood flow in FM patients. Deep needle stimulation produces a greater increase to merely inserting the needle subcutaneously. However, the deep mode of needle stimulation also induces more pain and discomfort to the patients, which should be considered in the clinic. In contrast to FM patients, healthy subjects do not respond to subcutaneous needle insertion with increased skin or muscle blood flow. As yet, it is not known whether these results are valid for painful muscles in fibromyalgia patients.

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