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Effects of intensity of electroacupuncture upon experimental pain in healthy human volunteers: A randomized, double-blind, placebo-controlled study

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Abstract

Electroacupuncture is commonly used for pain relief. Despite an extensive evidence-base guiding the selection of stimulation parameters, little methodologically robust research exists regarding the level of intensity required to provide effective doses. This study investigated the hypoalgesic effects of two stimulation intensities compared to placebo on pressure pain thresholds (PPTs) in pain-free humans. Forty-eight acupuncture-naïve volunteers (mean age 23), stratified by gender, were screened for relevant contraindications and randomly allocated to four groups: control, placebo, high-intensity ("to tolerance but sub-noxious") or low-intensity ("strong but comfortable"). True or placebo electroacupuncture, using the Streitberger placebo needle, was administered to acupoints on dominant forearm (1I10, TH5) and ipsilateral leg (GB34, ST38). True needles {30 mm long, 0.3 mm diameter) were inserted 20-25 mm and *"de-qi"* was elicited from active groups, prior to administering 30 min of 4 Hz, 200 s electroacupuncture. No electrical stimulation was performed on control and placebo groups, and placebo needles were used. After the intervention period, all needles were removed. Volunteers were monitored for 30 further minutes, Two PPT measurements were taken bilaterally from muscle bellies of first dorsal interosseous by an independent rater, at baseline and at six subsequent 10-min intervals. Square-root transformed data were analysed using repeated-measures ANOVA, with baseline data as covariate, The high-intensity group was significantly different from the placebo group for both measurement sites (p = .020. p = .033). The control group displayed stable PPT readings over time. No significant differences were observed between the placebo and control groups. These findings suggest that high-intensity levels may be important in optimal dose selection.

Keywords: Electroacupuncture: Humans, Intensity; Mechanical pain; Pain threshold: Nocebo

1. Introduction

Acupuncture is commonly applied in two ways: electroacupuncture and manual acupuncture. E

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pain than manual acupuncture {Ulett et al., 1998; Wan et aL, 2001). However, central to its effective use is the issue of dose selection. Electroacupuncture treatment dose comprises a range of parameters (e.g. . frequency, intensity, pulse duration, stimuIation location , stimulation duration, size of needles and depth of insertion) from which a spectrum of individual values are availabIe. With respect to these key components of electrostimulation-induced analgesia, previous electro-

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acupuncture research has largely focused on the effects of manipulating stimulation frequency (Han et al., 1991; Chen and Han, 1992a,b: Hsieh et al., 2000; Han, 2003), with few studies systematically investigating the effects of different levels of intensity, which have been shown to be an important component in other electrostimulation modalities (Chesterton et al., 2002, 2003a; Bjordal et aL , 2003),

Tentative evidence from the few (predominantly animal model) electroacupuncture studies systematically investigating intensity (Mao et al., 1980; Han et al., 1983; Romita et al., 1997: Huang et al., 2002) does, however, suggest it may be an important parameter in achieving optimal analgesic effects, such that high intensity is more efficacious than low intensity, irrespective of other parameters. Notwithstanding the lack of detail in the reporting of these studies, the findings were limited by several methodological issues, which included low statistical power, lack of blinding and an absence of control or placebo groups. Specifically with regard to the animal studies, issues surrounding the potentially ambiguous translations of intensities used (e.g., 20 times muscle contraction threshold), the generalizability of the hypoalgesic effects and the possibility of the confounding effect of stress-induced analgesia restrict the interpretation and extrapolation of findings to human populations (Carlsson, 2002). Hence, whilst preliminary electroacupuncture experimental studies and evidence for electrostimulation in the wider sense suggest a difference in hypoalgesic effect between varying levels of intensity, findings for electroacupuncture stimulation in human populations remain equivocal. Moreover, conflicting findings from systematic reviews on the clinical effectiveness of electroacupuncture in a range of conditions suggest the urgent need for greater guidance in parameter selection to direct treatment dosages (Melchart et al., 2001; Casimiro et al., 2002; Proctor et al., 2002; Green et al., 2002, 2005). Without this fundamental knowledge of the effects of varying levels of intensity of electroacupuncture on a normal human population, parameter dose in a clinical setting or in future clinical trials will continue to be subject to empirical selection. Therefore, this study evaluated the efficacy of high-intensity and low-intensity electroacupuncture compared to that of placebo electroacupuncture (Streitberger and Kleinhenz, 1998), using an experimental model of pain within a protocol previously applied in this laboratory. The inclusion of a placebo group in addition to a control group attempts to partition the non-specific effects of electroacupuncture analgesia. The use of the placebo needle protocol aims to address some of the methodological difficulties inherent in double-blind, placebo-controlled acupuncture trials, which are areas commonly critiqued in experimental designs.

2. Method

A randomized, double-blind, placebo-controlled, parallel-group, repeated-measures design was used. Ethical approval was obtained from the University Research Ethics Committee.

2.1, Subjects

Forty-eight healthy volunteers (24 male; mean age 23, range 18-41 years) were recruited from the university staff and Student population. This sample size was dictated by resource constraints. Participants reported to a consultation room, adjacent to the laboratory, and were screened for previous experience of acupuncture or electroacupuncture, chronic pain, current pain, injuries and medication, cardiac. respiratory, neurological, haematological and psychological conditions, diabetes mellitus and allergies. Participants menstruating at the time of the study and pregnant volunteers were also excluded.

Participants were provided with written information sheets and verbal explanations. Written consent was obtained and participants were allocated using a computer-generated random numbers table to one of four experimental groups: control, placebo, high-intensity or low-intensity. Randomization was blocked by gender, ensuring that groups were balanced for this factor.

2.2. Groups and stimulation

To maintain blinding, all participants had needles (true er placebo) placed on their dominant forearms and their ipsilateral legs at four acupuncture points (LI1O and TH5 in the forearm, GB34 and ST38 in the lower leg). These sites represent, respectively , segmental and extrasegmental locations, in relation to the pain measurement sites. The use of local and distal points in this way represents common clinical practice and has been shown to be the most commonly used technique in high quality trials for musculoskeletal conditions (Trink, 2002). The active electrostimulation groups received simultaneous stimulation at all four points using 4 Hz and 200 us electrical stimulation, at either high er low intensity. In addition, although the control and placebo groups were connected to the electroacupuncture stimulator to maintain blind conditions, no currents were delivered as the machine remained switched off. Table 1 summarizes the stimulation parameters of the experiment.

2,3. Measurement procedure.

The outcome measure for the experiment was pressure pain threshold (PPT), Using a Type II Somedic algometer (Somedic, Sweden) with a 1 cm² probe, PPT measurements were taken at the first dorsal interosseous muscle of the dominant and non-dominant hands; this is within the superficial radial nerve dermatome of the stimulated sites L110 and TH5. These points have previously been used successfully (Walsh et aL, 1995, 1998; Chesterton et al.. 2002).

Prior to experimentation, the independent ratet (SLHT) was trained in the use of the algometer. Accurate location of the muscle bellies, application of the probe perpendicular to the skin surface at a constant rate of approximately

Table I
Group stimulation parameters

Group	Intensity	Needles	Explanation to partcipants
High inzensity 141) 4 Hz, 200 µs	"To tolerance bot sub-noxious"	True needles	hey feel some "pricking or tapping sensations" and may experience muscle contraction beneath some er ad 0,t- the needles Asked to indicate the level of intensity at which stimulation was "strong and uncomfortable, as much as tolerable. but not panful"
Low intensity (Ll) 4 Hz. 200 µs	-Strong bot	True needles	Told they may feel some "tingling sensations" beneath and may experience muscle contraction at some or all of the needles Asked to indicate the level of intensity at which stimulation was "strong and comfortable, and in no way uncomfortable"
Control	No stimulation	Placebo needles of independent rater	Explanation and demonstration of the placebo needles. Explicitly told that no treatment would be administered and the electrostimulator would remain switched off throughout the study
Placebo (P)	No stimulation	Placebo needles blinding of independent rater and participants	Told that stimulation at high frequency, low-intensity currents would be administered. which some individuals "may or may not feel"

50 kPa/s, and the withdrawal response were practised over I weck. The reliability of algometry techniques after training has been previously documented (Delaney and McKee, 1993). The independent rater was acupuncture-naïve and blind to the aims of the study and the number of experimental groups.

During the measurement procedure, participants were instructed to fix their gaze directly ahead on a mark placed on the wall. Hence, they were unable to see the digital display of the algometer or the skin displacement at the point of its application. Participants were then instructed to directly say "stop" when the sensation of pressure changed to one of pain. The independent rater immediately withdrew the algometer. The highest pressure reading stored on the digital display units of kilopascals (kPa) was taken to represent the PPT. The participants ware instructed to remember what the sensation feit like when they indicated their PPT and attempt to say "stop" consistently at the same perceived Sensation level for subsequent measurements. Two PPT readings were taken from each measurement site, with 10-20s intervals in between each reading.

Participant

Sites for PPT measurement were highlighted on the skin using a semi-permanent marker. These points ware marked using the procedure described by Chesterton et al. (2002). Points ware marked distal to a 3.5 cm card which was placed from the proximal edge of the "anatomical snuff-box", in line with and in the direction of the first dorsal interosseous muscle bellies. Two PPT practice trials *ware* given to the participants on both hands. The ambient room temperature was maintained between 20 and 22 °C. Participants were positioned on a standard examination plinth, in "Iong-sitting" supported by two pillows under the knees, with both arms resting comfortably er two side tables (Fig. I). They were instructed to assume a omfortable position and not to move during Ilse 30-min stimulation period. Prior to leaving the laboratory.

the independent rater measured baseline PPT bilaterally. These values ware recorded on the data collection sheet by Experimenter 1 (PB).

All needling procedures were conducted by a licensed acupuncturist with more than ten years experience (PB). The acupuncture points were sterilized using an alcowipe (Alkotip, Servofarma GmbH) and a simple "sharp-blunt" discrimination test was performed at each site to ascertain sensation integrity, using a neurotip ((Wen Mumford , UK).

Needling procedure

Effective blinding within acupuncture trink is a well-recognized challenge and there is little consensus regarding the most appropriate type of sham or placebo procedures (Trinh, 2002). The placebo needle is one contemporary options and is described as having "a blunt tip which is not attached to the

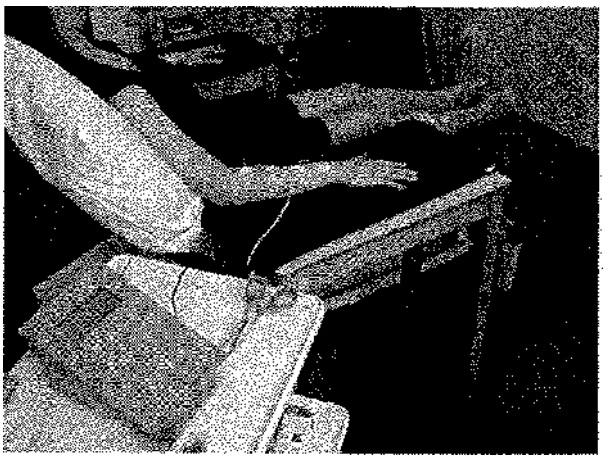

Fig. I. EperimentaI setup.

handle and may move freely inside the handle' (Streitberger and Kleinhenz, 1998. p. 364). When the needle is applied to the patient's skin, the shaft of the needle glides into the handle, giving the illusion of insertion into the skin as the needle length shortens (Streitberger and Kleinhenz, 1998). The credibility of the placebo needle has been observed in several studies using both clinical (Kleinhenz et ah. 1999; Fink et al. . 2001) and non-clinical populations (Streitberger and Kleinhenz, (1998). in these studies, participants were unable to distinguish between truc and placebo needling with respect to needle penetration, Although there has been sonne controversy over this placebo acupuncture technique (White et ah, 2,003) in relation to participants reporting a different overall sensation from true versus placebo needling, this physioiogically inert placebo protocol has subsequently been used successfully in several studies (Streitberger et ah, 2003, 2004; Fink et al., 2004: Schneider et ah, 2005). Additionally, in a pilot study of placebo needling in this laboratory, using a crossover design, we administered baff) true acupuncture needles and the Streitberger placebo needles to acupuncture-naive healthy human participants. We found that a similar number of participants (9 vs 10 for true and placebo needling. respectively) receiving each type of needle, prior to the crossover, reported they had thought "acupuncture would feel like this" (unpublished data). Hence, this method of blinding was considered the most

In accordance with the application procedure described by Streitberger and Kleinhenz (1998), for participants in all groups, the acupuncture points were covered with a plastic 0-ring and secured using 4 cm' squared seif-adhesive tape (Leukotape Classic, Beirsdorf SA, Spain). In the groups receiving true acupuncture, sterile, disposable, 30 mm, 0.3 mm diameter needles (Nr 16, Special, Asia-Med, Germany) were used. Needles were inserted at a depth of 20-25 mm and the acupuncture Sensation of fullness, heaviness, dun aching or warmth, referred to as *"de-qi"* (Andersson, 1993; Park et ah, 2002), was confirmed through verbal report of the participant at each point. The *de-qi* sensation was elicited to ensure the accurate location of acupuncture points. In the groups receiving placebo acupuncture, sterile, sham disposable needles, seemingly identical to the true needles, were used (Streitberger and Kleinhenz, 1998; Nr 16, Special, Asia-Med. Germany). The collapsible shaft created an illusion of insertion to the participant.

Expianations and instructions given to participants were as indicated in Table 1. During the insertion of the needles, all participants were instructed to close their eyes, in order to minimize anxiety and mask the placebo procedure. The electroacupuncture stimulator (Acus II, CEFAR, Sweden), situated behind the field of vision of the participants, was then

leads were seeured to the forearm and leg using self-adhesive tape, to prevent accidental dislodging of the needles. The experimental setup of all participants, irrespective of group allocation, appeared identical to the independent rater.

2.6. Stimulation procedure and instructions

The 30-min stimulation period was divided into three 10-min intervals. At the end of euch 10-min interval, electrical stimulation was interrupted. the electroacupuncture stimulator switched off and the independent rarer returned to measure PPTs. Following completion of the measurements and another 10-min interval of stimulation began, During the stimulation periods, Experimenter 1 recorded intensity levels in milliamperes (mA). In keeping with clinical practice, these levels were regularly adjusted every 2-3 min, depending on the verbal report of the participants, maintain the required intensity according to group allocation.

At the end *of* the 30-min stimulation, all needles, electrodes and tape were removed and a further 30 min of monitoring and three sets of PPT measurements were undertaken at 10 min intervals. Moreover, throughout the experimental

discouraged and participants were requested to reserve questions regarding the nature of the experiment until the end of the session.

2.7. Data analysis

The mean of the two PPT measurements taken at each site and at euch time point was calculated. As the raw data exhibited a positive skew, a square-root transformation was applied prior to further analysis. The transformed scores were analysed using repeated-measures ANOVA with 'time' as the within-subjects factor (baseline, 10, 20, 30, 40, 50 and 60 min) and with 'group' au a between-subjects factor. 'Gender' was included in the model au the blocking factor and baseline PPT scores were entered as a covariate. Where the 'group' factor was significant, a posteriori tests with Sidák adjustment were used identify pairwise group differences (Sidák, 1967). Statistical significance was set at p .05, two-tailed. and all results (including those with Sidák adjustment) are reported with reference to this cutoff. All analysis was undertaken blind to the identity of treatment groups, using SPSS 13 for Windows.

2.8. Sick effects

Four male participants fett unwell shortly after the insertion of the needles, but prior to the initiation of electrostimulation. Oise participant (female) fainted shortly after initiation of electrostimulation (low-intensity graut)), Stimulation was immediately switched off and the needles removed. Participants were monitored and allowed to recover fully before leaving the laboratory. Additional participants were recruited to replace these excluded volunteers.

3. Results

The altes of the participants in each group are given in Table 2: as these were similar across groups, age

Fable 2
Mean (SD) age of participants in each group

Group	n	Age Mean
High intensity (HI)	12	23 (2.9)
Low intensity	12	22 (4.6)
Control (C)		22 (4.4)
Placebo (P)	12	25 (6.9)
Total	48	23

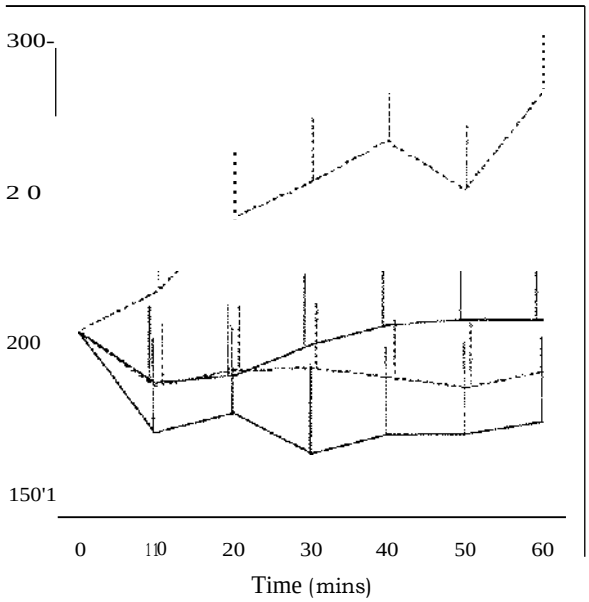

Fig. 2. Mean (+1 standard error) pressure pain threshold (PPT) in kPa for the dominant hand at each time point. Data are adjusted for baseline PPT, so that all aroups appear with the same baseline value. Upper broken line, high-intensity groupe lower broken line, iow-intensity group; upper solid line, control zroup: lower solid line, placebo group.

was not entered in the analysis as a covariate. Figs, 2 and 3 display the baseline-adjusted mean PPT values for the two outcorne measures. The pattern of response

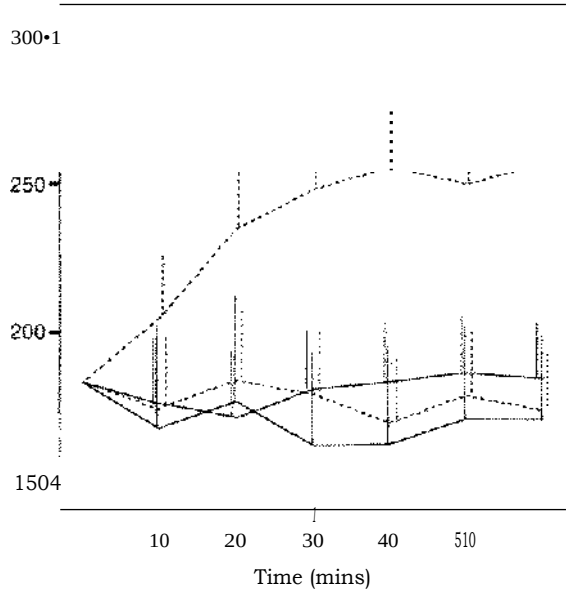

Fig. 3. Mean (+1 standard error1pressure pain threshold (PPT) in kPa for the non-dominant hand irr each time point. Data am adjusted for baseline PPT, so that all 2.rdcps appear wirb t)..e value. Upper broken line, high-Int-risity group; leer broker) line, low-intensity nroup; upper solid line, control aroup; lower solid line, placeho aroup.

Table 3
Mean pressure pain thresholds (kPa) for mich aroup, averaged across time points post-hasenne, prior to transfortnation but adjusted for haseline scores

Group	Dominant hand	Non-dominant hand
High intensity (HH	250.61 (67,60)	241.41 (72.94)
Low intensity (.1.11	(91.03 (67.62)	183.81 (73.02)
Control (C)	199.28 167.61)	187.05 (73.00)
PIacebo (9)	165.35 (67.63)	154.88 (73.21)
p abÃe'	.027	047

p values "raset(an sinalysis of varia across groups

for the four groups is scen to be sirnilar for hoth dominant and non-dominant hands, and in both cases, the largest difference in response was between the placebo and high-intensity groups. Table 3 summarizes the baseline-adjusted PPT scores, averaged across all time points post-baseline, for each experimental group.

There were significant differences between the four groups in PPT variables for both dominant 3.361; df = 3,42; p .027) and non-dominant (F = 2.847; df = 3,42; p .047) hands (Table 3), On a posteriori testing with Sidk adjustment, there were significant pairwise differences between the placebo and high-intensity groups for the dominant hand (p = .020) and non-dominant hand (p---,- .033). No other pairwise cornparisous showed signiticant differenees. The average intensities (mA) recordecl across the 30-min stimulation period for the high-intensity and Iow-intensity groups are given in Table 4. This shows that the high-intensity .9..roup received approximateiy twice the milhampere stimulation received by the low-intensity group.

4. Discussion

These results dernonstrate that low-frequency clectroacupuncture applied at a high, but sub-noxious, level of (subjective} intensity, had a significantly iarger hypoalgesic effect than placebo stimulation. The response displayed a steadily increasirtg analgesic profile, with a trend that was maintained post-stimulation and was observed at both ipsilateral (with respect to stimulation

Table 4
Average stimufiltion inteashics in rni mperes (mAl recorded across the 30-min stimulation period

Location	Stimulation period im(n)	High rntensity (mAi	Low intensity (mA)
Dominant arm	10	4.3	
(segmental)	20	5.7	3.7
	$0	7.0	4.0
Mean		5.7	3.5
Ipsila (eral. leg	10	7.8	4.1
(extra-seemental)	20	10.0	4.7
	30	11.9	5.7
Mirean		9.9	4.7

sites) and contralateral measurement sites. In contrast, the low-intensity stimulation group showed hypoalgesic responses and a flat measurement profile over time. with no significant difference from the placebo group.

These intensity-specific effects corroborate findings from previous electroacupuncture investigations using animal models. For example, Huang et al. (2002) used a pain mode] of flick latency' in mice, and showed that incremental increases of stimulation intensity (0.5, 1 and 2 mA) applied at both low (2 Hz) and high (100 Hz) frequencies for a 20-min period produced statistically significant and positive linear analgesic differences compared to a no-stimulation control group. Intensities below 0.5 mA showed na difference and increasing the intensity from 2 to 3 mA did not increase the analgesic effect, suggesting a plateau effect. Using the same pain mode] in anaesthetized rats, Romita et al. (1997) showed that 20 min of low-frequency (4 Hz) electroacupuncture stimulation at a high intensitv (20 times the threshold to evoke muscle twitch) produced rapid onset analgesia, which persisted for more than 1 h post-stimulation. However, when intensity was decreased to 10 times the muscle twitch threshold, analgesia during the stimulation period decreased by 30% and no persistent response was observed. lt is of interest that no analgesia was observed when stimulation was set at threshold level (muscle twitch); this is of note since in our study the low-intensity group , using a verbal report of 'strong but comfortable', was often characterized by the absence of muscle twitch. This is relevant since a criticism of studies which make use of animal models is that they often employ stimulation intensities deerned intolerable in humans (e.g., 20 times muscle contraction threshold; Romita et ab., 1997). In our stucly, the high-intensity group sustained an average current of 5.7 mA (range 4.3-7.0) in the arm (segmentally) and 9.9 mA (range 7.7- 11.9) in the leg (extrasegmentally; Table 4), which suggests comparable levels with those of some animal studies queted.

The importance of sufficiently high intensities in electroacupuncture stimulation, demonstrated in the present study, is confirmed by experimental investigations of other electrostimulation rnodalities thought to elicit similar physi.obogical responses. Several stuclies investigating transcutaneous electrical nerve stimulation (TENS) have shown that adequate intensity levels (i.e., sub-noxious, to tolerancc) arc more likely to result in persistent analgesia (Melzack, 1975; Fox and Melzaek, 1976) and, in some cases, may eonvert. non-respc.mders' (no hypoalgesic respense to Iow-intensity stimulation) to 'responders' (Sjolund and Eriksson, 1979; Chak-our, 1998).

With respeet to the pain-modulating nieeharnstils activated by electroacupuncture, applied at low frequeney (<5 Hz), such stimulation has been shown to generale both endonertous opioid responses (Lee and Beitz, 1992; Han, 2003, 2004), and anti-inflarnmatory cffects that are non-opioid (Zhang et al., 2004). However, the physiological mechanisrns underpinning intensity-specific effects within the low-frequency range remain unclear. Several authors suggest analgesia produced by low-intensity electroacupuneture te.g., 2 mA in ratsy may be opiotclergic, whilst the hypoalgesic effect observed at higher intensities (e.g,. >2 mA in rats) is non-opioid (Ernst and Lee, 1987; Romita et al., 1997). Rornita et al. (1997) observed that lower doses of naloxone were required to block analgesia produced by low-intensity electroacupuncture stimulation (2 mA) whilst higher doses were required to block analgesia produced usin2 3 mA. Other studies investigating physiological responses of specific afferent mechanisrns to various intensities of eiecuestimulation show that in vitro recruitment of Ad, and C tibres using higher-intensity stimulation produced bong-terrn depression of nociception in the spinal corcl (Sandkühler et al., 1997). Likewise, in a study of primate spinothalamic tract cell responses to peripheral TENS stimulation, it has been argued that the rnost effective way to produce analgesia via peripheral electrostirnulation is with an intensity at least strong enough to activate A8 fibres (Chung et al., 1984). Furthermere, a recent TENS study taking recorclings of dorsurn coal potentials reveals that sensory-1evel stimulation activates only large diameter afferent fibres, whereas increasing intensity to twice the motor Ihreshold recruits Aö fibres (Radhakrishnan and Sluka, 2005). Hence, this body of literature suggests a physiological rationale for the theory that recruitment of high-threshold primary afferents via high-intensity stimulation may be responsible for persistent post-stimulation analgesic effects, and may therefore also explain the specific hypoalgesic responses seen in the high-intensity stimulation group in the current study.

Given this range of physiological evidence, of note in this study is the lack of hypoalgesie etfeet in the low-intensity group, even though an initial Sensation of *de-qi* was elicited in all participants in this group. Since *de-q(* is definecl as a sensation of fullness, heaviness, dull aching or warmth (Andersson, 1993; Park et al., 2002), this also suggests that stimulation of A8 and possibly C afferent fibres has occurred. Stimulation of these fibres has been shown to elicit pain-modulating actions at the level of the dorsal hont, and to be associated with the release of endogenous opiates within centres in the centraf nervous system (Andersson and Holmgren. 1975: Kawakita and Gotoh, 1996; lisieh et al., 2001). Initial *de-qi* Sensation in the current study is, however. separate from ongoing Sensation of stimulation intensity, which was described as "strong bot conifortable" or "to toterance but sub-noxious". In recent reports, using low-frequency (4 Hz) TENS, also applieci at high or low intensity and with the same model of PPT (Chesterton et ale 2002, 2003h), we showed that low-intensity stbin-

ulation was insufficient to activate an analgesic response regardless of where the stimulation was a_pplied. Therefore, although initial *de-qi* as applied in this study rnay be necessary to evoke a therapeutic effect, as suggested by Okada et al. €996), it may not be the sole determinant of ongoing and sustained hypoalgesia, as previou

The behaviour of the placebo group is noteworthy. A recent report (White et al. 2003) questioned the validity of the placebo needle protocol, suggesting that 40',/Q of patients studied could detect a difference in treatment type between the true and placebo needies. Moreover, their study showed no difference in therapeutic outcome between both types of needles. In contrast, in a study by Streitberger and Kleinhertz (19981, none of the 60 volunteers believed that the placebo needle did not penetrate their skin. In the current study, which uses Streitberger needles, na statistical difference from the control group is seen. These results therefore provide SOITIC further tentative evidence of the credibility of the placebo needle protocol, at least within acupuncture-naive individuals.

The stable response of the control group over time in this study further conflrmed the repeatability of the pressure threshold model of pain and the stable physiological response to the experirnental protocol, previously reported (Chesterton et al.. 2003b). The different profiles of the placebo and control groups (albeit non-significant) show the importance of including placebo interventions in acupuneture research, since the placebo group indicates the combined effect of both the Intervention and the outcome measure. Reports of non-specific factors from acupuncture treatment influencing clinical outcomes (Kalauokalani et al., 2001) may also be disputed when considering mar results. In. particular, the findings observed in the active groups may depict a true. physiological effect of electroacupuncture, since these hypoalgesic changes are observed in healthy volunteers with no treatment expectation.

The present investigation is not without limitations. It is noted that the observed maximal hypoalgesic levels produced within the high-intensity group, for both ipsilateral (85.26 kPa = 8.5 N cm $^{-2}$ = 0.85 kg cm $^{-2}$) and contralateraI (86.53 kPa = 8.7 N cm $^{-2}$ 0.87 kg cm $^{-2}$) rneasurement sites, mav not represent putative clinically important levels of change, which have been suggested to be 100 kPa 10 N cm $^{-2}$ 1 kg cm $^{-2}$ (Chesterton et al., 2003a). Resource limitations determined the santple size, and thereby restricted how mang participants could be recruited, reducing the power of the analysis. Although significant differences were found with respect to the placebo group, more precise estimates of hypoalgesic effects would have been obtained with a larger sarnple, partieularly in light of the relatively large standard deviations that characterize PPT measurements. Thus, effect sizes for the differences between the high-intensity and low-intensity groups and between the high-intensity and control groups, for *the* dominant and non-dominant hand, ranged from 0.745 to 0.881. To detect such effects with 80% power would require between 22 and 30 subjects per group at a two-tailed significance level (or between 33 and 46 subjects with the Sidtik correction used in this study), Further research investigating the exact mechanisrns underlying intensity-induced analgesia is clearly required. Moreover, replication of these results using patient populations is essential in establishing clinical efficacy.

In conclusion, this study reports that low-frequency electroacupuncture appears to have an intensity-dependern hypoalgesic response when compared to a placebo in an experirnental model of mechanical pain, where high intensity is required to elicit a significant effect. Furthermore, the differential response persisted beyond the stimulation/needling period. Therefore, findings from this study have further demonstrated the potential importance of careful parameter selection for optimal hypoalgesic effects and the value of the placebo needle protocol.

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