



Original Article

Effect of low frequency transcutaneous electrical nerve stimulation of TE5 (waiguan) and PC6 (neiguan) acupoints on cold-induced pain

EDUARDO JOSÉ NEPOMUCENO MONTENEGRO¹⁾, GEISA GUIMARÃES DE ALENCAR²⁾,
GISELA ROCHA DE SIQUEIRA¹⁾, MARCELO RENATO GUERINO^{1)*}, JULIANA NETTO MAIA¹⁾,
DANIELLA ARAÚJO DE OLIVEIRA¹⁾

¹⁾ Department of Physical Therapy, UFPE-Federal University of Pernambuco: Recife, PE, Brazil

²⁾ Graduate of Physical Therapy, UFPE-Federal University of Pernambuco, Brazil

Abstract. [Purpose] This study assesses the effect of low frequency transcutaneous electrical nerve stimulation (TENS) of the TE5 (waiguan) and PC6 (neiguan) acupoints on cold-induced pain. [Subjects and Methods] Forty-eight subjects were divided by convenience into three groups: TENS with electrodes of 1 cm² area, TENS with electrodes of area 15 cm² and a placebo group. The study consisted of three phases: cold-induced pain without electroanalgesia, cold-induced pain with electroanalgesia or placebo, and cold-induced pain post-electroanalgesia or placebo. [Results] Acupuncture like TENS increased the pain threshold latency during treatment ($45.7 \pm 11.7s$) compared to pre-treatment ($30.9 \pm 8.9s$) in the TENS group with 1 cm² electrodes. In the TENS group with 15 cm² electrodes, the pain threshold latency increased at post-treatment ($36.2 \pm 12.9s$) compared to pre-treatment ($25.5 \pm 7.4s$). The placebo group showed no significant changes. The group with 1 cm² electrodes showed a significantly higher pain threshold latency ($45.7 \pm 11.7s$) than the other two groups. At post-treatment, the pain threshold latencies of both the 1 cm² ($39.4 \pm 11.5s$) and 15 cm² ($36.2 \pm 12.9s$) TENS group were higher than that of the placebo group ($22.4 \pm 7.4s$). [Conclusion] Acupuncture like TENS applied to PC6 and TE5 acupoints increased the pain threshold latency. The pain intensity was reduced by TENS with an electrode area of 1 cm².

Key words: TENS, Acupoints, Pain

(This article was submitted Aug. 25, 2015, and was accepted Oct. 9, 2015)

INTRODUCTION

Transcutaneous electrical nerve stimulation (TENS) is the application of an electric current through the skin to stimulate the nervous system. This type of electrical stimulation activates spinal afferent pathways that connect to spinal gray matter of the dorsal horn modulating sensory afferent traffic. The electric current stimulates the underlying fibers producing painless paresthesias without causing damage to the skin^{1, 2)}. Its application technique varies depending on several parameters and can be divided into high frequency (≥ 50 Hz) low intensity and low frequency (≤ 10 Hz) high intensity TENS, both of which are used to relieve both acute and chronic pain³⁻⁵⁾.

Acupuncture is also widely used in clinical settings for the relief of pain caused by lower back injury, fibromyalgia, and headache disorders, among others. Uniting the technique of acupuncture analgesia with electrotherapy, with certain modifications, has created electroacupuncture which is used as a substitute for conventional acupuncture, and in cases where clinical acupuncture alone has no effect^{5, 6)}.

Low frequency TENS is also called acupuncture like TENS, because it is interacting with the peripheral nervous system eliciting a pricking sensation, that is modulated by the frequency of electrical stimulation, the current intensity and the pulse

*Corresponding author. Marcelo Renato Guerino (E-mail: marceloguerino@hotmail.com)

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duration. To present this kind of sensation, this type of TENS has started being used to stimulate acupoints. The procedure differs from classical electroacupuncture, as it does not use needles, only electrodes with a high intensity of the electrical current⁷⁻⁹). Currently, several terms are used to describe the transcutaneous electrical stimulation of acupoint. For example: Acu-TENS (TENS applied to an acupoint) and TEAS (transcutaneous electric acupoint stimulation) that involves any electric current applied to acupoints¹⁰).

In this study, two different areas of electrodes, 1 cm² and 15 cm², TE5 (Waiguan) and PC6 (Neiguan) acupoints. According to Chinese traditional medicine stimulation of the TE5 acupoint is indicated for arthritis in the wrist and finger joints, and that of the acupoint PC6 is indicated for pain in the forearm, carpal tunnel, and wrist, median nerve palsy, and pain and contracture in the elbow and arm. This study analyzed whether the areas of electrodes elicit different effects. When TENS is applied to acupoints frequency of 10 Hz with sufficient intensity to promote muscle jerks. The latency of the pain threshold and its intensity in healthy subjects subjected to cold-induced pain was measured.

SUBJECTS AND METHODS

This was a single-blind, quasi-experimental study with a control and placebo. Forty-eight subjects (convenience sample) were recruited from the Departmental Centres of the University Federal of Pernambuco (UFPE). They were divided into three groups of 16 subjects, composed of both sexes aged between 18 and 30 years. The groups were formed by the allocation of the subjects who were verbally invited to participate and sent to the laboratory. All of the participants provided their written informed consent. After reading and accepting the terms of the study, subjects were allocated to three groups: the 1 cm² electrode group, the 15 cm² electrode group, and the placebo group. The subjects were allocated by raffle in blocks of four to each group in succession. During the period of experimentation subjects showed no pathological state in the region subjected to cold-induced pain, did not use allopathic and/or homeopathic drugs, showed no intolerance or phobia at low temperatures, and the female subjects, were not in a state of pre-menstrual tension or menstrual flow. None of the subjects had prior knowledge of TENS.

All experiments were performed in the Laboratory of Electrothermy at the Department of Physical Therapy of the Federal University of Pernambuco. The first experimental group (8 males and 8 females) was stimulated by acupuncture like TENS on the TE5 and PC6 acupoints with 1 cm² electrodes; the second experimental group (9 males and 7 females) was also stimulated by acupuncture like TENS on the same acupoints with 15 cm² electrodes; and the placebo group (10 females and 6 males) were told they were receiving microcurrent stimulation of the deltoid muscle with a 15 cm² electrode. The study received approval from the University Federal of Pernambuco's Research Ethical Committee, under the registration of SISNEP FR-294607, CAAE-0315.0.172.000-9 based on resolution 466/12 National Health Council.

The experimental intervention consisted of three stages (six cycles) which were termed pretreatment time (cycles 1 and 2), treatment time (cycles 3 and 4) and post treatment time (cycles 5 and 6). Each cycle lasted ten minutes, making a total of one hour trial.

In the first cycle, subjects put their non-dominant hand in a container of warm water (37 °C) for five minutes. The temperature was maintained by an electrical water heater and constant measurement by mercury thermometer INCOTERM-L 212/04. This procedure aimed to equalize the temperature of the hand of all subjects before the procedure of cold-induced pain.

After this, the hands were removed from the container and placed into another with icy water 0–2°C (control performed by the mercury thermometer INCOTERM-L 212/04). The time to pain threshold from when the individuals put their hands into the icy water to the moment when they expressed “pain” was measured in seconds by digital stopwatch (CRONOBIO SW2018). The subjects were asked to keep their hands in cold water for thirty more seconds, during this time (depending on the tolerance) they were asked to describe the painful sensation using a visual analog scale (values from 0 to 10, where 0 corresponds to no pain and 10 refers to the maximum tolerable pain) to assess pain intensity. After this they were allowed to take their hands out of the icy.

After a rest interval, that varied among the individuals, but was short enough to complete half the period of the last five minutes of the first cycle, the subjects again put their hands for 5 minutes in warm water, beginning the second cycle, followed immersion in cold water. Procedure was repeated, completing two cycles of cold-induced pain, with pretreatment time, lasting twenty minutes.

In the third cycle after wiring for TENS, subjects again put their hands into the warm water for five minutes, and then into the container with cold water. The time to the pain threshold and pain intensity were measured, and the procedure was repeated for a fourth cycle, twenty minutes of TENS application in total. Acupuncture-like TENS (10 Hz) was delivered with a balanced, asymmetrical, biphasic pulsed current (TENSYS ET9771 KLD) of 1 ms (millisecond) pulse duration, with sufficient intensity of electric current to cause muscle jerks when placed over the TE5 and PC6 acupoints, located two from the wrist crease, on the posterior and anterior forearm, respectively. To standardize electrical stimulation the cathode was placed on the TE5 and the anode on the PC6 acupoints. The electrical stimulation of acupuncture-like TENS was performed with 1 cm² and 15 cm² electrodes.

At the end of the treatment period, the subjects were subjected to two more cycles, the fifth and sixth following the same method described above, to evaluate the effect of TENS post-treatment (TENS off).

In the placebo group, subjects were subjected to the same procedure of the cold-induced pain test (pre-treatment, treatment

and post-treatment), but the electrodes were placed on the shoulder (without connection to any acupoint) on the belly of the anterior deltoid muscle and the individuals were told that they were receiving a microcurrent treatment, in which they would not feel any sensation. They were told that the microcurrent works with very low intensities, was imperceptible, and had a painkilling effect. They were connected to the first channel of the equipment, and the second channel was connected so that the lights on the device certified that the current was supposedly operating. However, no form of electrical stimulation was delivered to the site.

The data of the latency of the pain threshold are presented as the mean \pm standard deviation (SD). The results of pain intensity are presented as the average scores on the visual analog scale (VAS). The latency of the pain threshold between cycles within each group was examined using repeated measures one-way ANOVA and the post hoc Newman-Keuls test. For the pain intensity, the analysis between cycles within each group was performed using the Friedman test. The groups pain threshold latencies were compared one-way ANOVA followed by, post hoc Newman-Keuls test, when necessary. The effect size was calculated using Cohen's d formula to investigate the clinical significance. Significance was accepted for values of $p < 0.05$.

RESULTS

A acupuncture-like TENS with electrodes with an area of 1 cm² showed effects on the pain threshold latency during application, while acupuncture-like TENS with 15 cm² electrodes showed effects after TENS application. The placebo group showed no significant changes in any experimental phase (Table 1).

The intensity of pain was reduced during TENS treatment with 1 cm² electrodes both in relation to the time before treatment and after treatment (Table 2). With the 15 cm² electrode the sensation of pain increased in relation to the time before treatment. In the placebo group there were no significant changes.

Table 3 shows the results of the pain threshold latency times of the groups. During the treatment, the 1 cm² electrode group showed a longer pain threshold latency than the other two groups. After treatment the TENS groups (1 cm² and 15 cm²) electrodes showed pain threshold latencies longer than the placebo group.

Table 1. The latency threshold (seconds) of pain in the different periods of acupuncture TENS with electrodes of 1 cm², 15 cm², and placebo

Electrodes	Pretreatment	Treatment	Posttreatment
1 cm ²	30.9 \pm 8.9	45.78 \pm 11.8*	39.5 \pm 11.6
15 cm ²	25.5 \pm 7.7	32.0 \pm 12.9	36.3 \pm 13.0*
Placebo	25.2 \pm 10.7	25.2 \pm 7.6	22.4 \pm 7.4

ANOVA and post hoc Newman-Keuls. Results expressed in Mean \pm SD (seconds)

*Significant difference from pre-treatment

Table 2. Pain intensity in the different periods of acupuncture-like TENS with electrodes 1 cm², 15 cm², and placebo

Electrodes	Pretreatment (mean ranks)	Treatment (mean ranks)	Posttreatment (mean ranks)
1 cm ²	2.9	1.1**	2.0*
15 cm ²	1.3	2.6*	2.1
Placebo	2.1	2.1	1.7

Friedman test. *Significant difference from pre-treatment. **Significant difference from pre-treatment and post-treatment

Table 3. Pain threshold latency (seconds) of the groups

	Placebo	1 cm ²	15 cm ²
Pre-treatment	22.4 \pm 7.4	25.2 \pm 10.7	25.2 \pm 7.6
Treatment	39.5 \pm 11.6*	30.9 \pm 8.9	45.8 \pm 11.8**
Post-treatment	36.3 \pm 13.0*	25.5 \pm 7.7	32.0 \pm 12.9

ANOVA and post hoc Newman-Keuls. *Significant difference from the placebo group at pre-treatment.

**Significant difference between the 15 cm² group and placebo group

The effect size (Cohen's *d*) with 1 cm² electrodes was *d* = 0.98 pain and of 15 cm² was *d* = 0.88 for the pain threshold latency time and respectively *d* = 0.96 and *d* = 0.91 post-treatment pain threshold latency time.

DISCUSSION

To induce experimental pain without causing tissue injury we used a model called the cold pressure test, also known as the cold-induced pain test. In this model pain is induced through local hypothermia, since low temperatures (0–4°C) cause to painful sensations through both vasoconstriction^{11, 12)} and the activation of thermal nociceptors (A-δ and C fibers) that signal potential tissue damage. This information is sent via the peripheral and central pathways to the somatosensory cortex¹¹⁾. This information of pain has different representations in the cerebral cortex, a sensory version and a psychological one, that might be interpreted in this experiment as the pain threshold latency and pain intensity, respectively¹³⁾.

Acupuncture like TENS is usually used for chronic nociceptive processes. This is due to the characteristics of electric current, that has low frequency and high intensity, activating the supra-segmental pathways of β-endorphin and met-enkephalin¹⁴⁾. We found that the low frequency, high intensity TENS was bearable, and prolonged the pain threshold latency in the acute phase, and that prolongation of the pain threshold latency was dependent on the size of the electrode.

A previous study¹⁵⁾ demonstrated that analgesia of 80 Hz TENS for pain induced by mechanical which was measured subjectively by subjects pressure was by increasing the intensity of electrical current. In that study there was no description the size of the electrodes used. The frequency and pulse duration are also parameters that influence analgesia¹⁶⁾. In our study, it was found that the size of the electrode and its location affected analgesia. Initially, a high threshold of stimulation was required for both electrodes at the respective coupled acupoints, that are distal from the muscular motor points of the forearm, and required high intensities to promote muscle twitch and sting sensation.

A functional magnetic resonance imaging study of healthy subjects subjected to cold-induced pain, and demonstrated that the periaqueductal gray, the superior frontal gyrus, anterior cingulate cortex, thalamus, left insula, right inferior frontal gyrus and left inferior temporal gyrus were activated¹⁷⁾. These structures are related to the perception of the pain threshold, but not pain intensity. These structures are also activated when stimuli acupoints, by needles or by transcutaneous electrical current¹⁸⁾.

As the action of acupuncture-like TENS with 10 Hz was relatively rapid at prolonging the pain threshold latency, during or after application, it suggests that it acts directly on A-δ and C fiber, promoting action potentials in them. This would have served as a mechanism of segment concurrence, which is usually seen as fibers A-β mediating the stimulation of high frequency TENS. When the painful stimulus of low temperature triggered the A-δ and C fibers they were already receiving electrical stimulus, leaving them less responsive to the cold stimulus. Its influence on the pain threshold latency during and after TENS application, may be due the concentration of the stimulus in the receptive field of the nerve endings being stimulated by electrical current, the smaller electrode focused on the acupoints, while the larger electrodes encompassed this area and most of the surrounding regions. These acupoints are stimulated by needles, classically, and they have a large concentration of mechanical stimuli in their areas. Studies have shown that acupoints located in the areas of dermatomes, myotomes and sclerotomes which are pain afferents, are more effective than acupoints which are distant from them^{18, 19)}. In the placebo group, which received no electrical stimulation, no statistical differences were observed among the pre-, and during-, and post-treatment periods.

Table 3 compares the pain threshold latencies of the groups. During TENS treatment, the 1 cm² electrode group showed significant differences from the other two groups. This result corroborates the hypothesis that the concentration of electrical stimulus in a small area is more effective than that over larger areas.

Acupuncture points have intrinsic neuronal properties, as well as increased conductance, low impedance, and high electric potential compared to other locations. It has been suggested that the meridians are more a functional concept than anatomical, a multiple system incorporating the physiological, neurological, endocrine and immune systems⁹⁾. Therefore stimuli with densities of well-concentrated energy may be more effective.

Table 2 shows the mean pain intensities of the groups. The values show that the 1 cm² electrode group showed a reduction in pain intensity during the TENS treatment compared to pretreatment, while the 15 cm² electrode group showed an increase in pain compared to pretreatment. As mentioned above, the pain threshold latency and pain intensity are mediated differently by the central nervous system¹¹⁾.

Another study¹⁴⁾ applied TENS to the LI4 (He-Gu) and PC6 (Neiguan) acupoints of subjects submitted to cold-induced pain with a current intensity of 3 mA, pulse duration of 300 μs and frequency of 4 Hz, and noted a reduction in pain intensity relative to a placebo group over periods of 30 to 170 seconds of cold-induced pain.

Some other studies^{1, 20)} have also reported significant changes in pain intensity with electroanalgesia, while, others^{11, 21, 22)} have reported that the intensity of pain showed no significant change with the use of TENS. Items that differed in these works were the experimental pain models, parameters of electrical stimulation, location of the electrodes and the number of subjects involved in each experiment, as well as the recruitment and randomization methods. Another controversial point is the measurement of pain using the visual analog scale since, even though it is widely used and accepted, its results tend to be contradictory.

The 15 cm² electrode group showed an increase in the sensation of pain intensity, rather than a reduction, during the

TENS treatment, but there was no significant difference in the time of the pain threshold latency. We have no explanation for this. In the case of the 1 cm² electrode, the result was consistent. The intensity of pain is subjective measure which depends on the interpretation and previous experience of each individual. This may cause some confusion at the time of assessment, making it impossible to compare the results of pain intensity between groups. We suggest that as well as the measurement of pain intensity using the VAS scale, some objective form of measurement is also used, such as the pain threshold latency, measurement of the conduction velocity of nociceptive fibers.

The effect size, as calculated by Cohen's *d*, of the 1 cm² electrode group showed a percentage ranging from 88% to 98% when compared to the other groups, indicating that the 1-cm² group, during the TENS treatment, had this percentage of individuals with higher values than their respective control. At post-treatment the percentage was 91–96% compared to the placebo group. This demonstrates there was a clinically significant difference between the 1 cm² group and the placebo group. In the literature, we could find no other references reporting statistically significant results for this type of treatment.

Our findings support the view that acupuncture-like TENS at 10 Hz frequency, applied to PC6 and TE5 acupoints with the parameters described above, increases the pain threshold latency during TENS treatment with 1 cm² electrodes and post-treatment with 15 cm² electrodes. The pain intensity was reduced during TENS treatment when applied to the acupoints with an electrode area of 1 cm². The effect size calculations show that TENS applied to these acupoints were clinically significant. The combination of acupuncture-like TENS and acupoints is a treatment choice for acute pain in the hand region.

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