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Effects of different frequencies of conventional transcutaneous electrical nerve stimulation on pressure pain threshold and tolerance

İlkim Çıtak Karakaya[a,*], Mehmet Gürhan Karakaya[a], Esra Erğun[b], Sedanur Elmalı[c] and Tüzün Fırat[d]
[a]*Department of Physiotherapy and Rehabilitation, Muğla School of Health, Muğla Sıtkı Koçman University, Muğla, Turkey*
[b]*Avicenna Hospital, Istanbul, Turkey*
[c]*Department of Physiotherapy and Rehabilitation, Tokat State Hospital, Tokat, Turkey*
[d]*Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Hacettepe University, Ankara, Turkey*

Abstract.
BACKGROUND: Pulse frequency is one of the key determinants of analgesic outcomes by transcutaneous electrical nerve stimulation (TENS). However, optimal settings remain unclear.
OBJECTIVE: To compare the effects of different frequencies of TENS, on pressure pain threshold and tolerance.
METHODS: Currents with pulse duration of 110 μs, and pulse frequencies of 60 pps or 150 pps were applied on the volar aspects of the dominant forearms of 20 healthy volunteers, on two consecutive days, in a randomized order. Threshold and tolerance were measured at the beginning, after the 15^{th} and 30^{th} minutes of the applications, and 30 minutes after the applications.
RESULTS: Pressure pain threshold and tolerance values were higher at the 150 pps frequency, at all measurement times ($p < 0.05$). However, no frequencyXtime interaction and time-dependent changes were found for the outcome measures ($p > 0.05$).
CONCLUSIONS: These findings established that, at 150 pps conventional TENS, threshold and tolerance values were consistently higher. These results are presented to inform future research regarding optimal conventional TENS parameters and to provide support for clinical applications.

Keywords: Transcutaneous electrical nerve stimulation, frequency, pressure pain threshold, pressure pain tolerance, algometer

1. Introduction

Transcutaneous electrical nerve stimulation (TENS) is a simple, non-invasive analgesic technique that is used for the symptomatic management of nociceptive, neuropathic, visceral and musculoskeletal pain [1]. TENS is considered to facilitate the interruption of the neural transmission of pain by generating action potentials in underlying peripheral nerves [2]. There are different TENS application methods which can be used to stimulate nerve fibers selectively in order to activate pain reduction mechanisms. Conventional TENS is the most frequently used TENS method in clinic applications [3,4].

Conventional TENS is defined as sensory level stimulation, which selectively activates large-diameter non-noxious afferents (Aβ nerve fibers) [5]. In the litera-

*Corresponding author: İlkim Çıtak Karakaya, Department of Physiotherapy and Rehabilitation, Muıgla School of Health, Muğla Sıtkı Koçman University, 48000, Muğla, Turkey. Tel.: +90 252 2113205; E-mail: ilkim74@yahoo.com, ikarakaya@mu.edu.tr.

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ture, various ranges of pulse duration and frequencies are mentioned for use in conventional TENS. With a wide range, these are biphasic pulses with durations of 20–600 μs and frequencies below 200 Hz [5,6]. Watson (2008) has stated that currents with approximately 10–200 pps frequency, 50–500 μs pulse duration and non-painful intensity are effective in selectively activating Aβ fibers [1]. They are considered to cause interruption of pain transmission at the dorsal horn level due to the gate-control mechanism [2].

Treatment dose in TENS applications are determined by many parameters such as frequency, intensity, pulse duration, pulse pattern, site and duration of stimulation, and electrode size [7]. In the literature, there are various studies, which investigated the effects of these parameters on hypoalgesic/analgesic responses and/or compared superiority of different modulations to each other [5,7–14]. Although many authors state that intensity and frequency are the key determinants of analgesic outcomes [7–10], optimal TENS settings remain unclear due to a variety of research characteristics such as methodology, design of the study and outcome measures. Therefore, this study was conducted to compare the effects of different frequencies (60 pps and 150 pps) of conventional TENS on pressure pain threshold and tolerance.

2. Materials and methods

This prospectively designed, double-blind and randomized controlled study was conducted as a graduation study for Physiotherapy and Rehabilitation students.

Permission for the study was obtained from the University Rectorate. The study was completed on 20 voluntary first-year students from the Physiotherapy and Rehabilitation Department, who fulfilled the inclusion criteria and signed the informed consent form.

The sample size of the study was determined by considering the sample sizes of previous studies with the same experimental design, which were specified to have adequate statistical power [5,15,16].

The inclusion criteria for the study were as follows:

- Having no known disease (neurological, systemic, psychological, etc.);
- Using no medication;
- Having no sensory deficit (sharp-blunt test);
- Having no pain;
- Having no contraindication for TENS,
- Being unfamiliar to TENS:
- Having no knowledge about TENS;
- Having no fear of electrical stimulation;
- For females, not being pregnant and not being in the menstrual bleeding phase.

Gender (female/male), age (year), height (m), weight (kg), body mass index (kg/m^2) and dominant sides (right/left) of the subjects were recorded.

2.1. Measurement of pressure pain threshold and tolerance

The pressure pain threshold and tolerance of the subjects were measured by an algometer (JTech Commander Algometer) having 1 cm^2 flat and circular probe. The algometer was placed over the first dorsal interosseous muscles of both hands, which is the sensory area of the superficial branch of the radial nerve [7]. Subjects were seated in an arm-chair with their backs supported and forearms in 90° flexion and supination. The evaluator applied pressure with the algometer, perpendicular to the tissue and with an approximate rate of 4 N/s. Subjects were previously informed about the application of the algometer and were asked to say "yes" when their feelings of pressure turned to pain. The probe was retracted at that moment. In order to measure pain tolerance, pressure was applied up to the point of maximal toleration. Subjects were not permitted to see the algometer readings during measuring. Pressure pain threshold and tolerance were measured at the beginning (0 min), at the end of 15$^{\text{th}}$ and 30$^{\text{th}}$ minutes of TENS application, and 30 minutes after TENS application. These evaluations were performed twice, bilaterally and by the same researcher. The researcher was previously trained in algometer measurements and was kept both absent and uninformed during the application of TENS. Average values for the dominant sides of subjects were included in the statistical analysis.

2.2. TENS application

After cleaning the volar aspect of the dominant forearm with alcohol, two self-adhesive electrodes (5 × 5 cm) were attached starting at the proximal wrist line and placed 5 cm apart from each other.

An asymmetrical biphasic current with a 110 μs pulse duration and a 60 pps (low) and 150 pps (high) frequency were applied for 30 minutes to the same subjects, on two consecutive days, and in a randomized order (drawing lot) (Chattanoga Group, Intelect TENS). Subjects were blinded to the frequency level that was

Table 1
Physical characteristics of the subjects

	X ± SD
Age (year)	19.80 ± 0.83
Height (m)	1.70 ± 0.11
Body weight (kg)	63.55 ± 11.09
Body mass index (kg/m^2)	21.75 ± 2.02

being used at the time of application. 60 pps or 150 pps frequencies were selected for comparison, since being among the preset frequencies on the commonly used portable TENS machines. These were the frequencies which also conformed to conventional TENS frequency ranges.

In order to prevent outcome measure variations due to inter-subject differences, traditional independent group design was not preferred for the comparison of the effects of different frequencies on pressure pain threshold and tolerance. To provide a balanced distribution of gender, gender-specific envelopes were used to randomize the order of the frequencies. During applications, current intensity was adjusted to and maintained at the "strong but non-painful" electrical stimulation level, by increasing the intensity when required.

Upon completion of applications and measurements, subjects were asked to indicate their preference of frequency in the event of required treatment by TENS, by indicating; "1st application", "2nd application" or "doesn't matter".

2.3. Statistical analysis

The data were analyzed by using the SPSS 15 program. Frequency (150 Hz/60 Hz) X time (0/15/30/60 min) interaction and time-dependent changes for the pain threshold and tolerance values of the same subjects were evaluated by using the two-way repeated measurements ANOVA technique. The level of statistical significance was $p < 0.05$.

3. Results

Twenty subjects (10 females, 10 males) were included in the study. The dominant side of all the subjects except one was the right. Mean age (year), height (m), body weight (kg) and body mass index values (kg/cm^2) of the subjects are presented in Table 1.

Pain threshold and tolerance were higher at 150 pps TENS application at all measurement times ($p = 0.048$ and $p = 0.042$ for pain threshold and tolerance, respectively) (Figs 1, 2).

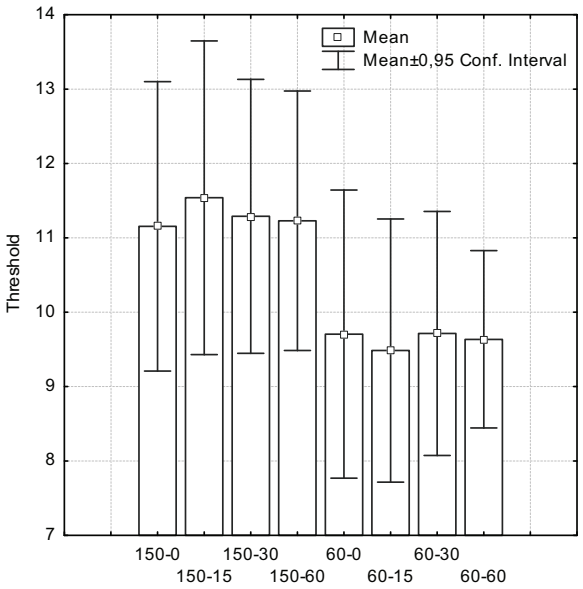

Fig. 1. FrequencyXtime interaction, time-dependent change and inter-frequency difference of pressure pain threshold values (lbs).

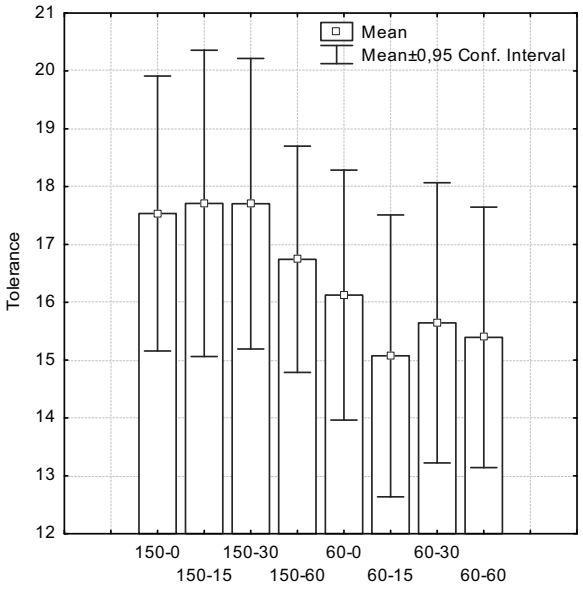

Fig. 2. FrequencyXtime interaction, time-dependent change and inter-frequency difference of pressure pain tolerance values (lbs).

FrequencyXtime interactions ($p = 0.879$ for pain threshold and $p = 0.692$ for tolerance) and time-dependent changes ($p = 0.995$ for pain threshold and $p = 0.456$ for tolerance) in the investigated parameters were not significant for either application (Figs 1–2).

The subjects' frequency level preference was assessed and showed that nine (%45) subjects preferred

150 pps, six subjects (%30) preferred 60 pps, and five (%25) subjects indicated "doesn't matter".

4. Discussion

The results of this study revealed that TENS application at a frequency of 150 pps caused higher pressure pain threshold and tolerance values than the 60 pps frequency. When applied at the 150 pps frequency level, pain threshold and tolerance values were still higher 30 minutes after cessation of TENS. Also, the ratio of 'preference by the subjects' was higher for the 150 pps frequency.

Subject related literature includes research samples, which present parallel findings to the present study. It also includes other studies that compare the effects of different frequency and/or intensity combinations and reach conflicting findings.

Chesterton et al. (2002) investigated the relative hypoalgesic effects of different TENS parameters (frequency, intensity and stimulation site) upon experimentally induced mechanical pain. They pointed out that high frequency (110 Hz), 'strong but comfortable' segmental stimulation at a fixed pulse duration (200 μs) produced a large and rapid hypoalgesic effect; however, this effect was not sustained post-stimulation [12].

In another study by Chesterton et al. (2003), it was stated that the high frequency (110 Hz), high intensity (highest tolerable) and segmental stimulation groups showed rapid onset and significant hypoalgesic effects. This effect was sustained for 20 minutes post-stimulation in the high frequency segmental group. All other TENS intervention groups showed hypoalgesic responses similar to the placebo TENS group; and none of these groups reached a clinically significant hypoalgesic level [13].

Chen and Johnson (2010) studied the effects of strong non-painful TENS administered at 3 pps and 80 pps on cold-pressor pain in healthy human participants [10]. They concluded that strong non-painful TENS at 3 pps was superior to 80 pps at experimentally induced cold-pressor pain. In another study by the same authors (2010), it was found that strong, non-painful TENS at 80 pps produced larger increases in experimentally induced blunt pressure pain threshold when compared to TENS at 3 pps [17].

These conflicting research findings with relation to the effects of different frequencies of TENS on pain threshold are thought to originate from the varying methodology and outcome measures used in the studies [10,12,13,17]. It has been previously reported that high frequency TENS provides affective analgesia by activating delta opioid receptors and increasing gamma aminobutyric acid (GABA) release at the spinal cord level [18]. Theoretically, high frequency TENS creates more afferent impulses than low frequency TENS, and causes stronger segmental inhibition in conductive neuron cells [19]. Also, Watson (2008) stated that large diameter nerve fibers, such as Aβ fibers, have short refractory periods and they produce high frequency nerve impulses. This situation may lead large diameter nerve fibers to produce stronger blockage of afferent nociceptive signals during transmission to the central nervous system [1]. Our findings are in accordance with these theoretical bases.

Most of the available studies reported only the effects of TENS on pain thresholds, but seldom on tolerance to pain [20]. Cheing and Chan (2009) stated in their study that despite the application of TENS, a trend of hyperalgesia developed over time [20]. They commented that the observed hyperalgesia could be due to the sensitization of nerve endings by the repeated testing of pain tolerance. Also, they found no influence of TENS on mechanical pain tolerance. This is likely due to the great individual variations in perceived mechanical pain tolerance among the participants. Our results also support these findings. It should be noted that repeated testing of pain threshold and tolerance could have sensitized nerve endings, masking the effects of TENS on pressure pain threshold and tolerance.

Use of a single sensory modality testing procedure (pressure pain threshold and tolerance by an algometer) in this study, and not assessing other modalities of nociception (i.e. thermal and electrical) may be considered a limitation of this study. Also, the ability to generalize the results of this study may be limited as our recruitment strategy focused on university students rather than a general population-based sample. Nevertheless, the findings of this study can be used to inform the design of a broader study on patients with pain. They may also be useful in determining the optimal conventional TENS settings in physiotherapy programs, in case of being supported by future research from basic and clinical sciences.

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