

# Comparison of skin sensory thresholds using pre-programmed or single-frequency transcutaneous electrical nerve stimulation

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**Abstract.** [Purpose] The purpose of the present study was to compare the sensory thresholds of healthy subjects using pre-programmed or single-frequency transcutaneous electrical nerve stimulation. [Subjects] Ninety healthy adult subjects were randomly assigned to pre-programmed or single-frequency stimulation groups, each consisting of 45 participants. [Methods] Sensory thresholds were measured in the participants' forearms using von Frey filaments before and after pre-programmed or single-frequency transcutaneous electrical nerve stimulation, and the result in values were analyzed. [Results] Significant increases in sensory threshold after stimulation were observed in both groups. However, there were no significant differences between the two groups in sensory thresholds after stimulation or in the magnitude of threshold increases following stimulation. [Conclusion] Our results show that there are no differences between sensory threshold increases induced by pre-programmed and single-frequency transcutaneous electrical nerve stimulation.

**Key words:** Pre-programmed TENS, Sensory threshold, Single-frequency TENS

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## INTRODUCTION

Physical therapists routinely use transcutaneous electrical nerve stimulation (TENS) for pain relief in patients<sup>1, 2)</sup>. TENS promotes the transmission of afferent sensory impulses from cutaneous receptors to the spinal cord, which closes the spinal pain gate and thereby blocks transmission of pain signals<sup>3)</sup>. Pain relief using TENS relies on continuous excitation of sensory fibers to hold the pain gate in a closed state. Therefore, sensory fiber accommodation must be prevented<sup>4)</sup>. As continuous single-frequency stimulation often causes accommodation<sup>5)</sup>, TENS commonly incorporates frequency modulations<sup>6)</sup>. Most commercially available TENS units are now equipped with a frequency-modulated preset program; even those TENS units that do not allow the choice of single frequencies are produced today. Many physical therapists prefer to use pre-programmed TENS (PPT) and strongly believe that this modality is more effective than single-frequency TENS (SFT). Previous studies examining the relationships between TENS and pain relief have addressed the effects of SFT<sup>1, 2)</sup> or PPT<sup>7)</sup>, however, studies comparing PPT and SFT are rare. Therefore, the aim of the present study was to examine differences in sensory

thresholds among subjects using PPT or SFT using the von Frey filament test and thereby provide a scientific basis for the selection of TENS parameters.

## SUBJECTS AND METHODS

Ninety healthy adults with no sensory problems were included in the study. In accordance with the Declaration of Helsinki, the study was respectively explained in detail to all subjects and only those subjects who gave written informed consent were included. The study was approved by the institutional review board of the Catholic University of Pusan (CUPIRB-2015-030).

The 90 subjects were randomly assigned to a PPT or an SFT group, each consisting of 45 participants. Sensory thresholds were measured in all subjects, with eyes closed, before and after TENS using von Frey filaments (Leica Biosystems, Wood Dale, USA) in the center of the forearm, 1 cm proximal to the radial styloid process. TENS was applied using a CWM602 stimulator (Chungwoo, Seoul, Korea). Biphasic symmetrical waveforms with a 150- $\mu$ s pulse width were used as pulse parameters. Two 3 cm  $\times$  3 cm square adhesive electrodes (3M, Seoul, Korea) were attached to the edges of the radial and ulnar styloid processes on the dorsal side of the forearm. The PPT group was subjected to stimulation with a 10-min 1–140 Hz frequency modulation program consisting of repeated increases and decreases between 1 and 140 Hz for 7 min and then between 1 and 50 Hz for 3 min. The SFT group was subjected to 10 min of 100-Hz single-frequency stimulation. Stimulation was applied at the maximum intensity that could be endured by the subject,

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but within intensity levels at which no motor response was observed. Dependent t-tests were used to compare sensory thresholds within each group before and after TENS. Independent t-tests were used to compare post-TENS threshold of the PPT group to those of the SFT group and to compare the magnitudes of TENS-induced sensory threshold changes between the PPT and the SFT groups.

## RESULTS

The mean sensory thresholds of the PPT group before and after TENS were  $2.45 \pm 0.63$  g and  $3.32 \pm 0.63$  g, respectively, those of the SFT group before and after TENS were  $2.25 \pm 0.67$  g and  $3.24 \pm 0.73$  g, respectively. Thus, significant sensory threshold increases were induced by TENS in both groups ( $p < 0.05$ ). However, no significant difference in sensory thresholds after the application of TENS was observed between the groups ( $p > 0.05$ ). The magnitude of the sensory threshold increases induced by TENS were  $0.98 \pm 0.44$  g in the SFT group and  $0.86 \pm 0.38$  g in the PPT group. This difference was not significant ( $p > 0.05$ ).

## DISCUSSION

Frequency-modulated TENS is hypothesized to be more effective than single-frequency TENS<sup>8)</sup>, because it can activate both low- and high-frequency hypoalgesia mechanisms<sup>5)</sup>. Several previous studies support this hypothesis. For instance, in a study of animal models of arthritis, TENS with frequencies modulated between 4 and 100 Hz showed sufficient analgesic effects<sup>7)</sup>. However, the effectiveness of frequency-modulated TENS compared to that of conventional single-frequency TENS has not been sufficiently studied.

Koo found no differences in cold pain thresholds between subjects using PPT and 80-Hz SFT. However, this was a small-scale study and the frequency modulation program used was not specified. A more recent study reported that TENS with frequencies fluctuating between 20 and 100 Hz for 8 s periods had a similar hypoalgesic affect to that of 80-Hz SFT<sup>9)</sup>. This result is consistent with the results of the present study. Both parameters used in our study resulted in significant increases in sensory thresholds. There were no significant differences between the two groups. Hence, it is unclear which TENS method is more effective. Consistent with our results, pain or sensory thresholds are thought to show similar increases in response to different frequency modulation program.

TENS is generally thought to block the transmission of pain signals to the central nervous system by stimulating sensory nerves<sup>1,2)</sup>. This mechanism is based on the pain gate theory. And pain gate theory is important to accommoda-

tion<sup>4)</sup>. However, the pain gate theory is not the only basis for electromedical pain management. TENS at specific frequencies can induce absolute refractory periods and maintain nerve cells in a depolarized state<sup>10)</sup>. Using this mechanism, nerves that transmit sensory and nociceptive signals can block additional sensory impulses depending on the intensity of stimulation. In the present study, the significant increases in sensory thresholds following PPT and SFT are likely attributable to the blocking of nerve fiber conduction.

Most commercially available TENS units are equipped with unique frequency modulation programs. Units with these diverse stimulation patterns may be widely used based on the unfounded theory that PPT is more effective. Further studies will be necessary to address this question. Independent variables, such as the frequency of stimulation and the intensity of stimulation, as well as dependent variables, such as the type, intensity, and duration of pain being treated, should be included in future studies.

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