Effect of Different Forms of Transcutaneous Electrical Nerve Stimulation on Experimental Pain

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The purpose of this study was to compare the effects of five different types of transcutaneous electrical nerve stimulation on experimentally induced pain threshold and tolerance in healthy subjects. Fourteen subjects received the following treatments on different days: low frequency TENS, burst frequency TENS, hyperstimulation TENS, high frequency TENS with a low voltage galvanic stimulator, and high frequency TENS with a high voltage galvanic stimulator to the left upper extremity. Pain threshold and tolerance were tested with electric current on a fingertip of the left upper extremity before each treatment, immediately after each treatment, and 20 minutes after the end of each treatment. Data were analyzed using separate two-by-five analyses of variance with repeated measures for pain threshold and tolerance. No significant effects of treatment or time for pain threshold or tolerance were found. A significant interaction between treatment and time for pain threshold was found. Further study is needed to compare the effects of these treatments in patients with clinical pain.

Key Words: *Electric stimulation, Pain, Physical therapy.*

Several types of transcutaneous electrical nerve stimulation, differing in intensity and electrical characteristics, are used widely in physical therapy practice: high frequency (40–150 Hz, 50–100 μsec pulse width, moderate intensity), low frequency (1–4 Hz, 100–400 μsec pulse width, high intensity), burst frequency (1–4 Hz with high internal frequency, 100–250 μsec pulse width, high intensity), and hyperstimulation (1–4 Hz, 10–500 msec pulse width, high intensity). Unfortunately, the choice of which form of TENS to use often is approached in a trial and error manner because the relative effectiveness of each is not clear.

A considerable amount of evidence supports the view that the various forms of TENS are effective methods of reducing pain.[1–9] The effect of TENS on pain, however, varies according to the nature of the pain,[4,8] individual pain threshold,[9] electrode placement,[3] intensity of the stimulation,[2,3,8] and electrical characteristics of the applied stimulus.[2,4,7,10] Some investigators have shown that pain threshold may not change at all or that it may decrease with some applications of TENS.[8,9] The fact that different forms of TENS produce different effects indicates that each form involves a different physiological pain-relieving mechanism.[10] Unfortunately, these studies comparing the effectiveness of various forms of TENS have provided contradictory information.

Fox and Melzack compared the pain-relieving effects of acupuncture, manually rotating the needles at three acupuncture points, with TENS applied at the same points.[5] Acupuncture stimulation can be compared to hyperstimulation, and the TENS used by these investigators (60 Hz sine wave train, 3 per second) can be compared to burst frequency TENS. Both forms were applied with a painful, but tolerable, intensity. Statistical analysis of the subjects' responses on the McGill Pain Questionnaire showed no significant differences in degree or duration of pain relief between treatments with acupuncture and TENS. O'Brien et al also concluded that groups receiving high frequency and low frequency TENS showed no significant differences in their perceptions of experimentally induced pain.[11] Andersson et al compared needle electroacupuncture with surface electrode stimulation.[1] The only difference between the two types of stimulation was a pulse width of 0.9 msec for the electroacupuncture and a pulse width of 0.2 msec for the TENS; both had a frequency of 2 Hz and a high intensity. The authors observed an increase in pain threshold values that was similar for both types of treatment. No statistical comparison of treatments was undertaken; however, a graphic comparison showed higher pain thresholds with TENS than with electroacupuncture. Hansson and Ekblom concluded that their subjects' pain intensity ratings were similar when either high frequency or burst frequency TENS was applied.[6] (Note: The authors used a burst frequency but called it low frequency.) Again, no statistical comparison verified their findings.

In contrast to those studies cited above, some investigators have shown that the degree of pain relief differs depending on which form of TENS is used. Andersson et al compared the effects of high frequency and low frequency TENS on the reduction of chronic pain.[2] They found "weak or non-existent" pain relief in 11 of the 12 patients treated with low frequency TENS. Seven of the 12 patients treated with high frequency TENS demonstrated "marked" pain relief. No cumulative effects were noted with either treatment. They concluded that the difference in the relieving effects between the two forms of TENS was due to the patients' inability to tolerate an intensity of stimulation with low frequency TENS that was sufficient to reduce pain. Similarly, Mannheimer and Carlsson found that low frequency TENS was less effective than either high frequency or burst frequency TENS in reducing pain in patients with rheumatoid arthritis.[7] Neither

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TABLE 1
Characteristics of Transcutaneous Electrical Nerve Stimulation Treatments

Treatment Type	Pulse Width	Rate
High (LVGS)[a]	80 μsec	80 Hz
Low	250 μsec	2 Hz
Burst	200 μsec	85 Hz (2 burst/sec)
Hyperstimulation	250 msec	2 Hz
High (HVGS)[b]	65 μsec	80 Hz

[a] LVGS = low voltage galvanic stimulator.
[b] HVGS = high voltage galvanic stimulator.

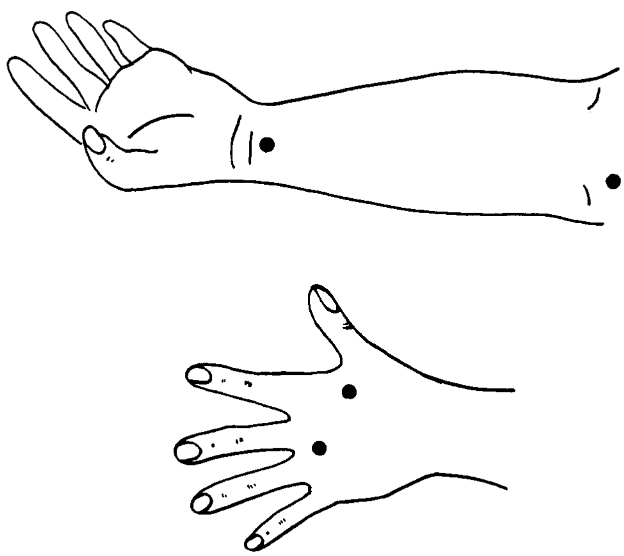

Fig. 1. Points used for electrode placement.

of these studies included statistical comparisons. Eriksson et al stated that, although they could not make a true comparison of the effects of high frequency and burst frequency TENS, only 35% of the patients in their study had good pain relief with high frequency TENS.[4] When burst frequency TENS was given to those patients who had not benefited from high frequency TENS, an additional 20% of the patients had good pain relief. (Note: The authors used a burst frequency but called it acupuncturelike.) Willer et al compared the effects of electroacupuncture and high frequency TENS on the blink reflex.[10] They demonstrated that both electroacupuncture and high frequency TENS depressed the blink reflex. They found differences, however, in the manner in which the two forms of treatment depressed the reflex. Although all of these studies have shown some differences in the effects of various stimulus characteristics, the findings are inconsistent.

None of the authors compared more than three commonly used forms of TENS, and some used types of TENS not used frequently by physical therapists. The researchers used statistical methods to compare the effects of treatments and to verify the conclusions in only two studies.[5,11] The purpose of my study, therefore, was to compare the effects of five different, commonly used types of TENS treatments on experimentally induced pain threshold and tolerance in healthy subjects. I expected that the effects of the various forms of TENS on pain threshold and tolerance would differ between treatments and over time.

METHOD

Subjects

Fourteen healthy women between the ages of 20 and 25 years (mean age, 23 years) participated in the study. At the time of testing, none of the subjects had used pain-relieving medication or alcoholic beverages within the previous 24 hours. The institutional research review committee approved the project, and each subject signed an informed consent form before participating.

Instrumentation

I tested pain threshold and tolerance with a TECA* model CH3 variable pulse generator. The cathode was the active electrode, 4 mm in diameter, and the anode was the dispersive electrode, 13.3 cm in diameter. The unit delivered a rectangular monophasic direct current wave form of 1 msec duration at a rate of 166 Hz. The electrical characteristics fall within the range for frequency and duration recommended by Nottermans for producing a reliable "pain-prick" sensation.[12] I applied high frequency, low frequency, and burst frequency TENS with a NeuroMod® Selectra™† stimulator attached to standard TENS electrodes (3.9 × 4.7 cm). Because the wave form characteristics of high voltage galvanic stimulation may recruit large sensory afferent fibers selectively better than low voltage TENS devices,[13] I also applied high frequency TENS with an Amrex Electronics‡ Model HVG 700 stimulator connected to 4- × 4-cm sponge-covered metal active electrodes. I used an MRL Neuroprobe§ System II stimulator with a remote control to apply hyperstimulation TENS. The pulse characteristics of these five types of TENS are delineated in Table 1.

Procedures

Each subject received one treatment with each of the five types of TENS. Treatments were given at least four days apart according to a Latin square design.

One investigator determined both pain threshold and tolerance before each treatment. Harris and Rollman concluded that experimental pain measurements should include both threshold and tolerance testing because they are indicators of different aspects of pain.[14] Measurements were obtained by applying a slowly increasing electrical current to the tip of the subject's left third digit. Pain threshold was defined as the point (measured in milliamperes) at which the subject stated that the sensation first became painful. Pain tolerance was the point (measured in milliamperes) at which the subject indicated that the pain had become too intense for the stimulation to be continued.

An assistant then administered the TENS treatments. Treatments involving low frequency TENS, burst frequency TENS, hyperstimulation TENS, and high frequency TENS, using both low and high voltage galvanic stimulators, were performed in a similar manner, with electrodes applied to four points on the left upper extremity. Two electrodes, placed at

* TECA Instruments Corp, 3 Campus Dr, Pleasantville, NY 10570.
† Medtronic, Inc, Neuro Division, 6951 Central Ave NE, PO Box 1250, Minneapolis, MN 55440.
‡ Amrex-Zeton, Inc, 12583 Crenshaw Blvd, Hawthorne, CA 90250.
§Physio Technology Inc., 1925 W. 6th, Topeka, KS, 66606

the wrist and medial aspect of the arm along the pathway of the median nerve, constituted one channel; placements corresponding to acupuncture points for pain of the fingers[15] constituted a second channel (Fig. 1). Intensity was increased slowly during the first 5 minutes of the treatment to a high, but nonpainful, level. Each treatment lasted 20 minutes. Treatments with hyperstimulation consisted of individually stimulating the same four points, each for 90 seconds, at a painful intensity just tolerated by the subject. This shorter application time, as compared with the other forms of TENS, was necessary to avoid the adverse thermal effects produced by a long pulse duration and high intensity. Immediately after each treatment and 20 minutes after the end of each treatment, I again measured the pain threshold and tolerance.

Data Analysis

For each treatment, I determined the subject's change in pain threshold separately by subtracting from the pretreatment pain threshold (baseline) 1) the pain threshold measurement obtained immediately after the treatment and 2) the measurement obtained 20 minutes after the treatment ended. I calculated changes in pain tolerance in the same way.

I submitted these values for data analysis using a two-by-five analysis of variance (ANOVA) with repeated measures. Scores for pain threshold and tolerance were analyzed separately.

RESULTS

The mean changes from the baseline in pain threshold and tolerance for each treatment are summarized in Table 2 and in Figures 2 and 3. Tables 3 and 4 contain the ANOVA summaries.

The main effects of treatment and time for pain threshold were not significant. The interaction between treatment and time, however, was significant ($p < .01$).

Because of this significant interaction, I performed a Tukey's Honestly Significant Difference test. This test demonstrated a significant difference between the effects of hyperstimulation and low frequency TENS on pain threshold at the immediate posttreatment time ($p < .05$). In addition, the pain threshold difference obtained immediately after treatment was significantly less than that obtained 20 minutes after the high frequency TENS treatment ($p < .05$). None of the other comparisons was significant. The ANOVA for pain tolerance showed no significant main effects or interaction between time and treatment.

DISCUSSION

The results of this study indicate that, under the conditions of my testing protocol, the type of TENS used does not, by itself, have a significant effect on pain threshold or tolerance for experimentally induced pain. These findings are in agreement with those of two other studies using experimentally induced pain.[1,11] Two studies using patients with clinical pain also found no differences in the effects of different forms of TENS on pain ratings.[5,6] The types of TENS compared in these studies had different rates and pulse widths, but the intensity of stimulation was similar, either painful or nonpainful. Some authors have speculated that intensity of stimulation is the variable that makes the critical difference in pain relief.[1,5,8] If this hypothesis is correct, the significant difference between hyperstimulation and low frequency TENS found immediately after treatment in this study could be due to the difference in the intensity of stimulation. Hy-

TABLE 2
Mean Pain Threshold and Tolerance Differences (mA) (N = 14)

Treatment	Immediately Posttreatment		20 min Posttreatment	
	$\bar{X}$	s	$\bar{X}$	s
Threshold				
High (LVGS)[a]	−0.17	0.60	0.10	0.45
Low	−0.35	0.27	−0.15	0.29
Burst	−0.02	0.77	−0.07	0.84
Hyperstimulation	0.38	0.55	0.21	0.50
High (HVGS)[b]	−0.05	0.47	0.04	0.33
Tolerance				
High (LVGS)	−0.05	0.54	0.10	0.40
Low	−0.14	0.30	0.00	0.23
Burst	−0.14	0.55	−0.04	0.48
Hyperstimulation	0.16	0.55	0.28	0.64
High (HVGS)	0.09	0.42	0.08	0.29

[a] LVGS = low voltage galvanic stimulator.
[b] HVGS = high voltage galvanic stimulator.

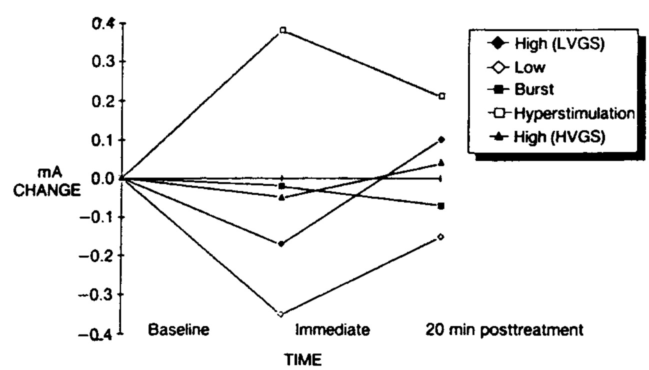

Fig. 2. Average differences from baseline in pain threshold over time.

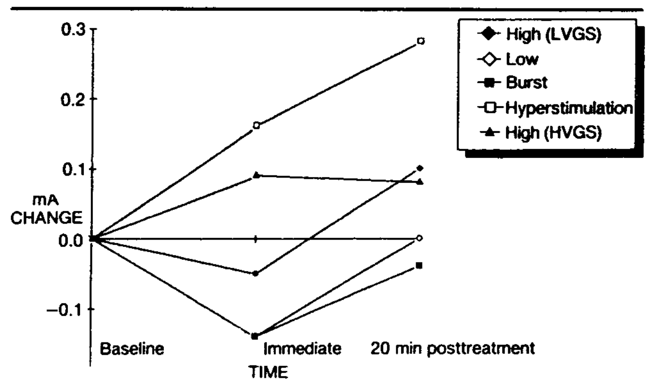

Fig. 3. Average differences from baseline in pain tolerance over time.

TABLE 3
Analysis of Variance, Pain Threshold

Source	SS	*df*	MS	*F*	*p*
Subjects	10.14	13			
Treatment	4.24	4	1.06	2.36	NS
Error	23.65	52	0.45		
Time	0.16	1	0.16	1.78	NS
Error	1.12	13	0.09		
Treatment × time	0.89	4	0.22	4.40	<.01
Error	2.82	52	0.05		
Total	43.02	139			

TABLE 4
Analysis of Variance, Pain Tolerance

Source	SS	*df*	MS	*F*	*p*
Subjects	6.32	13			
Treatment	1.75	4	0.44	1.33	NS
Error	16.90	52	0.33		
Time	0.33	1	0.33	3.67	NS
Error	1.22	13	0.69		
Treatment × time	0.12	4	0.03	0.60	NS
Error	2.77	52	0.05		
Total	29.41	139			

perstimulation was applied at a painful intensity and low frequency TENS was applied at a high, but nonpainful, intensity. The same difference in intensity existed between hyperstimulation and the other TENS treatments, although the differences in their effects were not significant. The results of my study suggest that hyperstimulation may be more effective than low frequency TENS in the immediate reduction of pain. A future study could include comparisons of treatments that varied in intensity only.

This study does not support the belief that the types of TENS differ in their effects over time. I cannot explain adequately the difference between the pain threshold difference obtained immediately after treatment with high frequency TENS and that obtained 20 minutes after treatment. The first measurement actually was below the baseline. In comparison, Willer et al demonstrated a rapid depression of the blink reflex associated with high frequency TENS that did not outlast the treatment.[10] They also showed that electroacupuncture differs from high frequency TENS in its effects over time, and they concluded that different types of stimuli depress pain through different neural mechanisms.

Comparing my results with those of other studies, unfortunately, is difficult because of the wide variety of stimulation characteristics used and the way they are applied. The electrical characteristics and treatment applications that I used in this study are similar to those used in physical therapy practice. The results of this study, however, give no clear basis for selecting various forms of TENS in the clinical setting.

One important aspect of this study that also limits the clinical application of the results is the use of measurements of experimentally induced pain in healthy subjects. Pain induced by electrical current at the fingertip is a well-localized and sharp sensation. Chronic pain, in contrast, is often a diffuse and dull or aching sensation. Physiological stress and psychological coping mechanisms interact to affect pain perception in patients with clinical pain. These variables are not factors in healthy subjects. Although the measurement of pain tolerance and pain threshold may reflect some consideration of the motivational aspect of pain,[14] important differences still exist between experimental pain and clinical pain. Future studies comparing the forms of TENS used in this study on the pain perception of patients with clinical pain are needed.

CONCLUSION

The results of this study fail to support the belief that various types of TENS affect pain threshold and tolerance differently. The findings also do not support the theory that the effects of TENS on pain threshold and tolerance vary over time. The significant difference between the effects of hyperstimulation and low frequency TENS on pain threshold immediately after treatment suggests that hyperstimulation may be the more effective of the two treatments for immediate relief of pain. Because the pain was experimentally induced in healthy subjects, further study is required to determine whether the results are similar for patients with clinical pain.

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