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Effect of Electrical Microcurrent on Median Nerve Conduction Velocity and Mechanical Pain Threshold in the Median Nerve in a Randomized Single Blind Controlled Trial

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Keywords

- Median Nerve;
- Microcurrent electrical stimulation
- Nerve conduction velocity
- Pressure Pain threshold
- Randomized Single Blind Controlled Trial

Abstract

Background: Microcurrent electrical stimulation (MES) is a promising line for treating a variety of conditions. Its outcome on the peripheral nerves remains vague. *Objective:* The purpose of this work was to assess the impact of MES on nerve conduction velocity (NCV) of the median nerve and pressure pain threshold in healthy people. *Subjects and Methods:* It was a randomized single blind controlled trial that was conducted on sixty healthy students of the Faculty of Physical Therapy, Cairo University. Participants were assigned randomly into two groups: control and study groups; who were exposed to MES for 30 minutes using a frequency of 10 Hz, an intensity of 100 µA at the volar aspect of the non-dominant forearm. Median NCVs (motor and sensory) and pain pressure threshold were assessed before, immediately after and 30 minutes after the MES application. *Results:* Concerning the pain pressure threshold, there was a significant difference between both control and study groups favouring the study group (p value < 0.05), and between pre and post measures of the sensory distal latency and sensory nerve conduction velocity (SNCV) in the study group (p- value < 0.05). While, no significant results on median nerve motor parameters were recorded (p- value > 0.05). *Conclusion:* Within the limitation of this study, a single application of MES over the course of median nerve in healthy subjects was effective in increasing pressure pain threshold, and sensory distal latency; and decreasing SNCV, So, upon these results MES could be promising in treating painful conditions.

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INTRODUCTION

Microcurrent Electrical Stimulation (MES) is a relatively novel treatment in physical therapy field introduced in the United States in 1970, delivering electrical current in the microamperage range (μA) [1,2], thus it is analogous to in vivo currents [3]. Unlike other forms of electrical stimulation, MES is a type of subsensory stimulation modality [4,5].

The Food and Drug Administration categorized MES as a class II medical regimen; because its stimulation parameters lie within the established safety standards [6]. A great number of clinical data confirmed the benefits of MES for the treatment of tissue damage and healing process [4,7-9].

It has been reported that MES produces its effect mainly at the cellular level as it regains the membrane potential of the cell; via improving the electric energy transport across the cell membrane [10]. Also, MES produces a potential difference along sensitive channels of the cell and it opens the cell membrane [11].

The suggested mechanisms of MES to display its effect is through increasing ATP generation by about 500% via stimulation of the electron transport system in the mitochondria and enhancement of both amino acid transport and protein synthesis, leading to both cellular and extracellular matrix production and neogenesis of tissues [2,3].

Microcurrent Electrical Stimulation has been used as an alternative regimen for painful diabetic neuropathy, yet the available research on its effectiveness in the diminution of pain in comparison with placebo is sparse and of low quality. Two of three studies in this area demonstrated that both MES and placebo significantly reduced pain but no one was more effective than the other [12,13].

Although MES is widely used in physiotherapy, still its mechanisms of action remain unclear [2], and given the scarcity of research regarding the neurophysiological effects of MES. So, the goal of the current work was to speculate the effectiveness of MES on the peripheral nerves and mechanical pain threshold, thereby might add to the overall understanding of the neurophysiological impacts of MES.

Subjects and methods

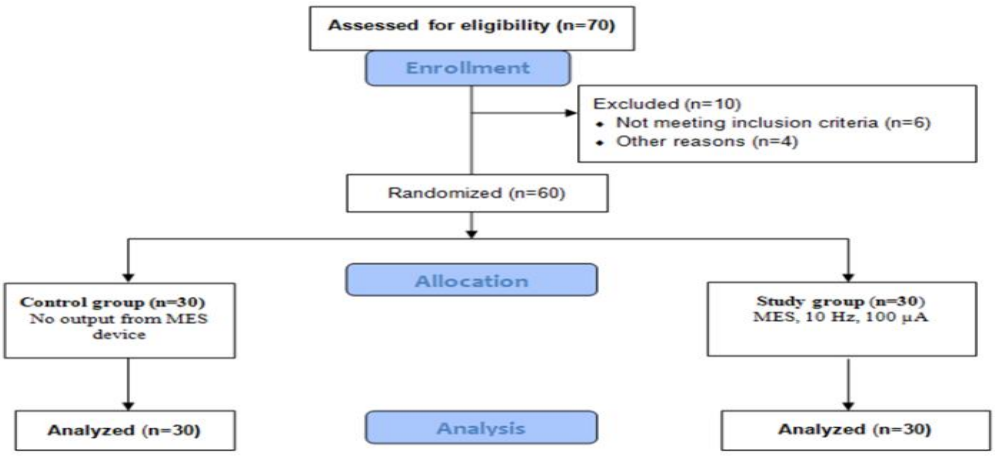
Study design: It was a randomized single blind controlled trial. Subjects were selected randomly via computer-generated random number sequence with a block size of four. Randomization was distributed into both control and study groups as demonstrated in figure (1).

Subjects: Sixty healthy male subjects (aged from 18 to 25 years, and their BMI was ranging from 22-25), participated in this trial.

Subjects were excluded if they were smokers or diabetics, receiving any pain killers, had altered skin sensations or had a history of diseases such as: neuromuscular diseases, vascular diseases, peripheral neuropathy, pervious peripheral nerve injury, carpal tunnel syndrome, trauma or surgery to the tested upper limb, and also subjects who played sports that affect the upper limb such as tennis and hand balls, were excluded from the study [14].

Sample-size determination: sample size estimation was done using G*Power 3.1 software (Institutfür ExperimentellePsychologie: Heinrich-Heine-Universität niversitätsstraße, Düsseldorf, Germany) based on a pilot study, the primary

clinical outcomes of the current study were sensory distal latency, motor distal latency and pain pressure threshold (PPT) that with a power of 0.8 with alpha level of 0.05 with an effect size of 0.71; total sample-size would be 25 participants per group and to account for dropout rate, total sample was 60 in both groups [15].



n: number, MES: microcurrent electrical stimulation

Figure (1): flow chart of the study design

Procedures and setting of the study:

Application of MES: in 2018, in the electromyography Lab, at Faculty of Physical Therapy, Cairo University, the subjects were allowed to rest and adjust to room temperature for about 10 minutes before initiating our study.

Before initiating the MES, the sites of electrodes placement were disinfected by alcohol to minimize the skin resistance and an electrode gel was applied for good conduction then two circular self-adhesive electrodes (Skintact electrodes, Austria) were fixed firmly with an adhesive tape [16,17] to the volar aspect of the forearm; one electrode just above the wrist level and the other just below the elbow joint alongside the course of median nerve. After the electrodes were taped into place, the device was turned on and adjusted as following: frequency of 10 Hz and intensity of 100 µA using Trio-300 (ITO Co., Ltd., Tokyo, Japan) [18]. MES was applied for 30 minutes. Immediately before, immediately after and 30 min after initiating the MES, the electrophysiological parameters: motor nerve conduction velocity (MNCV) and sensory nerve conduction velocity (SNCV), and PPT were measured. For the control group MES application procedure was the same as the study group except that the intensity was kept at zero µA. All measurements were done under standard room temperature of 25°C. Neurophysiological assessments were performed using the same equipment and the same operator for all participants and the participants were informed about the sensations they were going to experience during the whole study.

Assessment

I. Assessment of electrophysiological parameters:

Conventional NCVs were administered with standard methodology protocol using the Toennis Neuroscreen Plus device.

1-Assessment of MNCV

For the motor nerve conduction studies; a pair of surface recording electrodes; an active electrode was placed on the abductor pollicis brevis muscle and a reference electrode was placed at the tip of the thumb finger. For the distal segment stimulation; the bipolar stimulating electrode was placed above the wrist joint between the tendons of the palmaris longus and flexor carpi radialis muscles on the course of the median nerve, with the negative pole distal towards the active recording electrode, and the positive pole proximal, and at the elbow medial to the biceps tendon for the proximal segment stimulation. Ground electrode was placed between stimulating and recording electrodes at the wrist level.

The distal motor latency was measured from the onset of the stimulating artifact to the onset of the compound muscle action potential. Median MNCV for the forearm was calculated in m/sec using proximal and distal onset latencies as follow: MNCV= [distance between wrist and elbow stimulation sites (mm)]/ [latency at elbow-latency at wrist (ms)] [19].

2-Assessment of SNCV

A Pair of ring electrodes was placed around the proximal and distal interphalangeal joints of the index finger for recording, and the sensory nerve was stimulated antidromically at the same site used for distal motor nerve stimulation. Sensory distal latency was measured from the stimulating artifact to the peak of sensory nerve action potential according to Aminoff [20]. At least 20 sensory nerve action potentials were averaged and antidromic sensory nerve latencies were calculated as appropriate. Sensory nerve action potential and compound muscle action potential amplitudes were measured from the baseline to the negative peak. Sensory and motor latencies were measured to the onset of the initial negative deflection.

II- Assessment of the PPT:

A pressure algometer (Pain Diagnostics and Treatment Inc, Italy) was used to quantify the PPT which was the amount of pressure in pounds (lb) that each participant immediately perceived as painful, the measurement point was standardized midway between two stimulating electrodes. Once the initial contact was made, manual force was applied perpendicularly onto the skin through the circular probe head (1 cm^2 surface area) of the algometer. The force was increased at a steady rate until the PPT was registered. PPT was determined by the subject's verbal report when a pain sensation was elicited as participants were instructed to say "Stop" when the pressure became painful [21].

Statistical analysis:

Numerical data was explored for normality by checking the distribution of data, calculating the mean, median and mode values, drawing histogram and box plot as well as using the tests of normality (Shapiro-Wilk tests). All neurophysiological parameters that were measured (latency, and conduction velocity for both sensory and motor aspects of median nerve), and PPT showed a parametric distribution. So, two-way mixed model MANOVA was used to compare the

neurophysiological parameters and mechanical pain threshold -between and within groups- across different time periods [22].

For demographic data of the participants; independent t- test was used for comparison. All numerical data was represented as mean ± standard deviation. The significance level was set at P ≤ 0.05. Statistical analysis was performed with IBM® SPSS® Statistics Version 20 [23].

Results

1. ***Demographic data of the participants:***

There was no significant difference between both groups concerning age, weight, and height (p- values >0.05) as shown in table (1).

Table (1): Demographic data of the participants

Variables	**Control Group (n=30)**	**Study group (n=30)**	**P- value**
	Mean ± SD	**Mean ± SD**	
Age (years)	21.2± 2.4	21.13±2.1	0.937
Weight (Kg)	68.46±13.5	62.8±14	0.270
Height (cm)	166.46±10.1	167.13±9.68	0.855

P value: probability (significance level), SD: standard deviation, n: number

2. ***Electrophysiological parameters:***

There was no significant difference between both control and study groups either before or after application of MES (p- value> 0.05) as shown in table (2). In addition there were no significant changes in the neurophysiological parameters within the control group (p- value >0.05) as shown in table (3). However within the study group there was a significant increase in sensory distal latency immediately after (p- value <0.005) and 30 min after application of MES (p- value= 0.002), in addition there was a significant decrease in sensory nerve conduction velocity immediately after (p- value= 0.028) and 30 min after application of MES (p- value= 0.041) as shown in table (3), while there were no significant changes in the motor distal latency or MNCVs after application of MES (p- value >0.05) as shown in table (3).

3. *Pain pressure threshold:*

Regarding the PPT, the study group showed a significant increase immediately after and 30 min after application of MES (p- value <0.05) compared to the control group as shown in table (2). Also, within the study group, PPT significantly increased immediately after, and 30 min after application of MES (p- value <0.05) relative to the pre application of MES. However, there were no significant changes in the pain pressure threshold within the control group (p- value >0.05) as shown in table (3).

Table (2) Mean ± Standard deviation values and results of comparison of neurophysiological parameters and pain pressure threshold between the two groups.

Values	Time	Control group M±SD (n=30)	Study group M±SD (n=30)	P value
Sensory distal latency (sec)	Pre application	2.54±0.38	2.5±0.36	0.715
	Post 1	2.77±0.3	2.68±0.35	0.289
	Post 2	2.73±0.41	2.69±0.36	0.117
Sensory velocity (m/sec)	Pre application	64.34±10.29	66.82±9.86	0.329
	Post 1	61.8±8.5	64.19±9.9	0.964
	Post 2	63.66±8.76	65.5±8.9	0.633
Motor distal latency (sec)	Pre application	3.32±0.38	3.37±0.34	0.575
	Post 1	3.27±0.27	3.39±0.28	0.096
	Post 2	3.3±0.29	3.42±0.29	0.102
Motor velocity (m/sec)	Pre application	61.14±3.8	61.3±3.6	0.864
	Post 1	60.77±7.67	61.57±6.7	0.658
	Post 2	60.52±5.57	61.29±4.96	0.562
Pain pressure threshold(lb)	Pre application	15.18±3.4	15.23±4.04	0.956
	Post 1	15.34±3.48	17.69±4.04	0.016*
	Post 2	15.18±3.33	17.44±4.25	0.022*

P- value: probability (significance level), *Significance at p≤ 0.05, SD: standard deviation. Post 1: immediately after Microcurrent Electrical Stimulation, Post 2: 30 minutes after Microcurrent Electrical Stimulation

Table (3): Mean ± standard deviation values and results of comparing the neurophysiological parameters and pain pressure threshold at different follow up periods within each group.

Values	Control group				Study group			
	Pre-application	***Post 1***	***Post 2***	**P value**	**Pre-application**	***Post 1***	***Post 2***	**P value**
Sensory distal latency (sec)	2.54±0.38	2.58±0.37	2.55±0.34	>0.05	2.5±0.36	2.68±0.35[a]	2.69±0.36[a]	<0.01*
Sensory velocity (m/sec)	64.34±10.29	64.3±9.8	64.36±10.27	>0.05	66.82±9.86	64.18±10[a]	65.5±8.9[ab]	<0.01*
Motor distal latency (sec)	3.32±0.38	3.27±0.27	3.3±0.29	>0.05	3.37±0.34	3.39±0.28	3.42±0.29	>0.05
Motor velocity (m/sec)	61.14±3.8	60.77±7.67	60.52±5.57	>0.05	61.3±3.6	61.57±6.7	61.28±4.96	>0.05
Pain pressure threshold (lb)	15.18±3.4	15.34±3.48	15.18±3.33	>0.05	15.23±4.04	17.69±4.04[a]	17.44±4.25[a]	<0.001*

P value: significance level *Significance at p≤0.05. Different superscripts in the same row are statistically significant, SD: standard deviation. Post1: immediately after Microcurrent Electrical Stimulation. Post 2: 30 minutes after Microcurrent Electrical Stimulation application. a: means statistically significant compared to study group pre application. b: means statistically significant compared to study group post-1

Discussion

The current study revealed a possible neurophysiologic and pain relief effect of MES application as demonstrated by the significant increase in sensory distal latency and a consequent decrease in SNCV of the median nerve in addition to the increase in pain pressure threshold after single MES application. MES could exert these

protective effects on nerve conduction and pain in different ways; it facilitates the production of beta endorphin [24], it relieves delayed onset of muscle soreness (DOMS) and facilitates tissue healing [10,25]. In addition MES reduces pain level with accompanying substantial reduction in serum levels of the inflammatory cytokines interleukin-1, 6 and neuropeptide substance P, and an increase in serum cortisol [26]. Although the exact mechanism of MES in pain relief in the human study is not clearly understood, it is known that MES is closely related to calcium homeostasis among cells [27]. The application of MES facilitates pain relief by stimulation of the cells with low intensity electrical energy [28]. Moreover MES has been reported to increase the synthesis of ATP; as a consequence of stimulation of mitochondria electron transport system. It is proposed that ATP molecules act as either transmitters or modulators of activities of peripheral and central nervous system [29].

Furthermore, the effects of MES might be attributed to reduction of peripheral nerve excitability [18]. Similarly, *Yoon et al.,* [18] found that MES produced significant increase of H-reflex latency, and F-wave latency and decrease of H-reflex amplitude, denoting reduction of nerve excitability and they suggested that MES might alter the excitability of the anterior horn and nervous system conduction and it has a local inhibitory effect upon peripheral nerves.

Additionally, MES is thought to increase the oxygenation levels and membrane permeability of cells [3]. *Wikstrom et al.* [30], reported that microcurrent stimulation was shown to increase microcirculatory blood flow in intact skin and wounds.

The results of the present work were consistent with previous studies of *Lee et al.* [31] in which repeated application of either transcutaneous electrical nerve stimulation (TENS) or MES on experimental neuropathy in rats was found to be more effective than single application for treatment of mechanical allodynia. Moreover, *Naeser et al.* [32], and *Branco and Naeser* [33] recorded that combining MES and Low Intensity Laser Therapy (LILT) for carpal tunnel syndrome (CTS) showed a significant reduction of pain using McGill pain Questionnaire (MPQ) after 12 to 15 treatment sessions. Also, *Naeser et al.* [32], reported no significant change in the motor latency after 3-4 weeks of application. But they found a significant decrease in median nerve sensory latency.

On the contrary to the findings of the present study, a single-blind, placebo-controlled study examined the analgesic effects of MES to cold-induced pain, the authors found no significant differences between MES (600 μA, 103 Hz) and placebo MES on experimentally induced pain threshold and pain intensity rating in 36 healthy university student volunteers. This discrepancy might be due to differences in the parameters used; in the present study, we used 100 μA, unlike their study using higher intensity of 600 μA, as increasing intensity more than 500 μA is a possible cause of getting less biological effects [18,34,35].

Within the limitations of this study, MES of the studied parameters could be used in the treatment of painful conditions. Further studies are needed to study the effects of application of different MES frequencies and intensities on many peripheral nerves in different diseases.

Conclusion:

The application of a single therapy of MES over the course of median nerve in healthy subjects was effective in reducing pressure pain threshold, increasing sensory distal latency and decreasing SNCV.

Declarations:

Ethical approval and consent to participate: Prior to starting the study the participants signed an institutionally approved informed consent form, which was approved by the ethical committee of the Faculty of Physical Therapy, Cairo University with number (P.T.REC/012/001248). .

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Authors contribution: all Salah, Olfat and Fatma shared in: formulating the paper idea, designing the study, practical application and writing the manuscript.

Consent for publication: We declare that all the authors had contributed significantly and agreed with the content of the manuscript.

Availability of data and material: We declare that all data and materials are available upon request.

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Abbreviation list

BMI: Body mass index

CTS: Carpal tunnel syndrome

DOMS: Delayed onset of muscle soreness

LILT: Low Intensity Laser Therapy

M: Mean

MANOVA: Multivariate analysis of variance

MES: Microcurrent electrical stimulation

MNCV: Motor nerve conduction velocity

MPQ: McGill pain Questionnaire

N: Number

NCVs: Nerve conduction velocities

P: Probability

PPT: Pain pressure threshold

SD: Standard deviation

SNCV: Sensory nerve conduction velocity

TENS: Transcutaneous electrical nerve stimulation

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