The Effects of 250μs Transcutaneous Electrical Nerve Stimulation on the Hip Joint Range of Motion

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Abstract: ***Background/Objectives: Although a transcutaneous electrical nerve stimulation (TENS) pulse duration of 100–150 μs has been used conventionally to stimulate sensory nerve fibers, this pulse duration is not sufficient for stimulating motor nerve fibers. Therefore, this study was designed to test a new TENS protocol for stimulating motor nerve fibers. Methods/Statistical analysis: Fifteen males in their twenties with no lower back or pelvic orthopedic abnormalities and no contraindications for TENS participated in this study. A variable pulsation TENS machine was used. Using a high pulsating current of 250 μs, as in acupuncture-like TENS, each segment of the longissimus and iliocostalis muscles on both sides was contracted as much as possible, without causing pain. Afterwards, a stainless steel goniometer was used to measure the hip joint range of motion (ROM) during an active straight leg raise (ASLR) test.***

Findings: Conventional TENS controls pain through the stimulation of sensory nerves and it is effective for diverse diseases, such as increase of blood flow and acute or chronic pain. The existing TENS that is being broadly used is not appropriate for stimulating motor nerve that has high threshold. In this study,ES-420 (ITO, Japan) was used where pulsation variables can be freely controlled. Using high pulsating current of 250us following the acupuncture-like TENS mechanism, each segment of longissimus and iliocostalis on both sides erector spinae muscles of the subjects were contracted as much as possible within the range of not causing pain. Afterward, The ASLR test results showed that the active straight leg raise test was left hip joint ROM increased conducted where the range of motion of left-side hip joint significantly, increased from 75.40±8.13˚ to 81.80±9.99˚ (p<0.05), and the right hip joint and the range of motion of right-side hip jointincreased significantly, increased from 70.53±10.92˚ to 81.00±12.97˚ (P<0.05). Not only electrical muscle stimulation (EMS), but also TENS with high pulse duration of 250us can stimulate motor nerve that has high threshold, which consequently produces effects of reducing muscle tension and enhancing muscle strength. Improvements/Applications: TENS with high pulse duration of 250us can stimulate motor nerves that have high threshold. TENS is expected to become a new protocol that promotes functional enhancement, such as reduction of muscle tension and enhancement of muscle strength muscle.

Keywords: ***transcutaneous electrical nerve stimulation, pulse duration, hip joint range of motion, sensory nerve fibers, motor nerve fibers***

I. INTRODUCTION

Transcutaneous electrical nerve stimulation (TENS) is one of the many physiotherapeutic methods that are used to relieve pain. Moreover, the TENS unit is a noninvasive, inexpensive, safe, and self-manageable device. [1] TENS works by way of two medical mechanisms. One is the gate control theory, which uses electrical stimulation that induces a "rubbing" feeling, while the other is endogenous opioid pain control, which induces uncomfortable tingly pain. At the spinal level, the former induces pain control using a signal delivered to the T cells of the substantia gelatinosa that is located in the gray matter of the dorsal horn of spine. At the supraspinal level, the mechanism of the latter stimulates the endogenous opioid material in the mesencephalic periaqueductal gray matter neurons by inducing pain in the nerves. The separation of the endogenous opioid material stops the painful stimulation applied to the C fibers from entering the T cells, while the activity of the substantia gelatinosa cells is restricted due to the activation of the enkephalins released from the nerve cells when painful stimulation (normally coming from tissue injury) is delivered along the lateral spinothalamic tract. [2,3]

Based on the two mechanisms above, TENS therapy comes in the form of conventional, acupuncture-like, or intense TENS. Conventional TENS therapy has a stimulation intensity that induces a feeling of comfort by stimulating the sensory nerves using short pain bursts with a relatively long stimulation time. Acupuncture-like TENS therapy has a stimulation intensity that induces muscle contraction by stimulating the motor nerves using long pain bursts with a short stimulation time. Intense TENS therapy induces a hypersensory stimulation level by stimulating nerve pain. In most cases, conventional TENS therapy controls pain through the stimulation of sensory nerves with a pulse duration of 100–150 μs [4].

Electrical muscle stimulation (EMS), which induces strong repeated muscle contractions by stimulating the motor nerves, is a type of exercise therapy that is used to relieve muscle pain and promote functional enhancement by increasing the blood flow within the muscles. Less than 10 sessions of resistance training at approximately 70% of one repetition maximum (1RM) from 4 to 16 weeks can increase the muscle length and enhance the force development rate in elderly individuals. However,

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resistance exercise is difficult for elderly people who cannot voluntarily carry out strong muscle contractions. Therefore, more studies involving the indirect improvement of muscle strength and function are required [5,6].

Most TENS units are not appropriate for stimulating the motor nerves. A low pulsating current of 100–150 μs can stimulate sensory nerves because they have low thresholds. However, motor nerves have high thresholds, so they require a higher pulsating current. [4] For this study, a new TENS protocol was designed to stimulate motor nerves by using a high pulsating current of 250 μs. [7] The ways in which this stimulation affected the physical functions of the body after muscle twitch or tetanus were examined.

II. MATERIALS AND METHODS

2.1. Research subject

Fifteen males in their twenties with no orthopedic abnormalities in the lumbar vertebrae, pelvis, or hip joints and no contraindication for TENS (such as an arrhythmias, cardiac disorders, cardiac pacemaker, thromboses, and emboli) were chosen for this study.

2.2.Stimulator and electrode

For the TENS therapy, an ES-420 variable pulse duration unit (ITO, Japan) [Figure 1] with 5 x 5-cm noninvasive carbon electrodes [Figure 2] was used. Several noninvasive electrode types are available, including metal, adhesive, carbon rubber, and special electrodes; however, carbon rubber electrodes were chosen because they have little skin impedance and maintain their adhesive properties, regardless of the muscle changes.

Figure 1. ES-420 transcutaneous electrical nerve stimulation unit

Figure 2. Carbon rubber electrodes

2.3.Stimulator and electrode

The muscle bellies of the longissimus [Figure 3] and iliocostalis [Figure 4] erector spinae muscles on both sides, which are connected to the pelvis, were chosen as the EMS targets. These muscles were used so that the changes in the hip joint ranges of motion (ROM) after the EMS could be observed. The origin and insertion of the longissimus muscle are the on transverse processes, while the origin and insertion of the iliocostalis muscle are on the sacrum and ribs, respectively. Each segment of the two muscles (L5, L1, T9, T5, and T1) underwent EMS simultaneously for 60 seconds. [Figure 5] Because the motor nerves that induce muscle contraction were stimulated, the EMS time was set at 60 seconds, which is shorter than the time used to stimulate the sensory nerves in conventional TENS therapy.

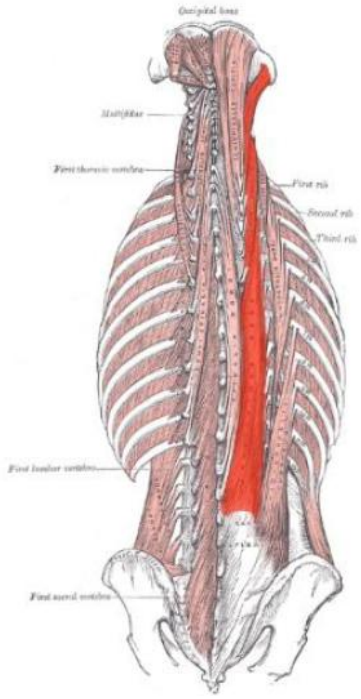

Figure 3. Longissimus muscle[8]

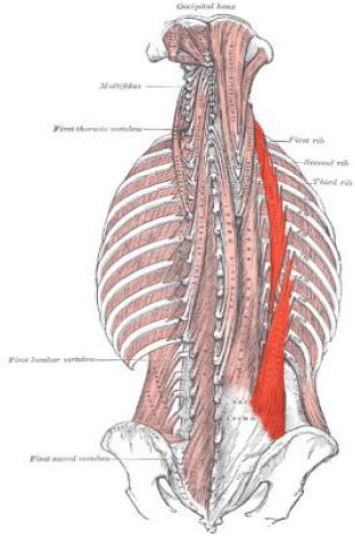

Figure 4. Iliocostalis muscle[9]

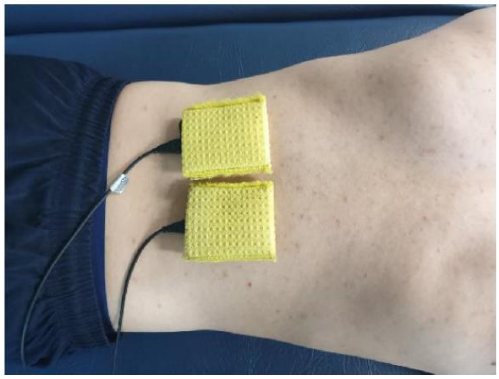

Figure 5. Electrical stimulation of the longissimus and iliocostalis muscles

2.4.Wave form, pulse duration, frequency, and amplitude

A biphasic symmetrical pulse current, in which the first and second phases cross the cathode and anode, was used as the wave form for the EMS. [10] The pulse duration was set at 250 μs. Aβ fiber is a nerve fiber that is stimulated within the shortest amount of time and at the lowest current intensity, followed by Aα fiber and C fiber. [4] Long pulse duration of 250us can sufficiently stimulate motor nerve of Aα. [Figure 6]

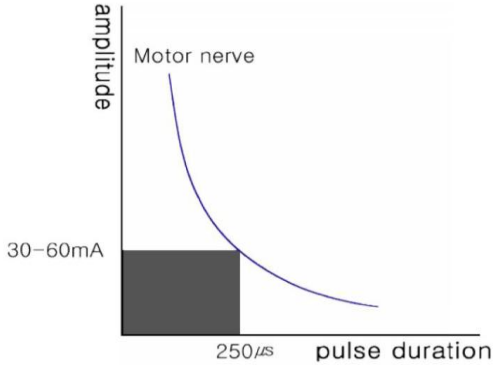

Figure 6. The amplitude and pulse duration used for the motor nerve stimulation

A low frequency of 1 Hz was used as the stimulation frequency. [11] The amplitude was set between 30 mA and 60 mA, with a maximum amplitude that induced strong twitch or tetanus responses in the subject without causing pain. [Figure 7]

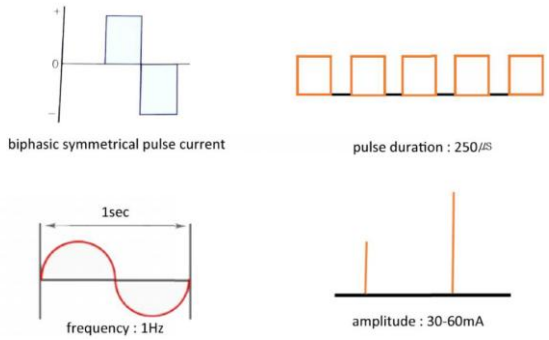

Figure 7. Wave form, pulse duration, frequency, and amplitude of the treatment

2.5.Goniometer

In order to measure the physical function changes, a stainless steel goniometer (7517; Saehan Corporation, Incheon, South Korea) was used to measure the hip joint ROM before and after the EMS. The goniometer had two gradations of 180º in opposite directions, with angle measurements in units of 10º. [Figure 8]

Figure 8. Stainless steel goniometer

2.6.Hip joint ROM measurements

In order to measure the hip joint ROM, each subject placed his stationary leg on the lateral centerline of the pelvis and his moving leg on the lateral centerline of the femur while lying in a supine position. In this position, the hip joint ROM was measured with the goniometer while using the lateral side of the hip joint as an axis. The original hip joint flexion exercise was performed with a bent knee in order to release the tension in the hamstring muscles. However, in this study, an active straight leg raise (ASLR) test was used, in which the hip joint was flexed while keeping the knee straight, in order to measure only the hip joint flexion. [Figure 9] The ASLR test captures the functional factors that show the tension and stability of the lower back, [12] and it is an indicator that can visually express and compare the hip joint ROM before and after the EMS.

Figure 9. Active straight leg raise test

2.7.Analysis method

IBM SPSS Statistics for Windows (version 20.0; IBM Corp., Armonk, NY, USA) was used for the statistical analysis, and each measured value was expressed as the mean and standard deviation. The paired t test was used to determine the ROM changes from before to after the EMS. The significance level was set at p=0.05.

III. RESULTS AND DISCUSSION

After contracting the hip joint muscles using the 250 μs pulse duration, the ROM of the left hip joint increased significantly, from 75.40±8.13º to 81.80±9.99º ($p<0.05$), and the ROM of the right hip joint increased significantly, from 70.53±10.92º to 81.00±12.97º ($p<0.05$). [Table 1]

Table 1: Differences in the hip joint ranges of motion(ROM)

	Pre-ROM	Post-ROM	p
Left hip joint	75.40±8.13°	81.80±9.99°	0.004
Right hip joint	70.53±10.92°	81.00±12.97°	0.003

IV. CONCLUSION

Conventional TENS, which can be used to control muscle pain, joint pain, nerve pain, myospasms, and multiple sclerosis by stimulating the sensory nerves within a comfortable range that does not induce pain, has been perceived as the representative TENS therapy. Similar to EMS, TENS therapy using a long pulse duration of 250 μs can stimulate the motor nerves to contract the muscles. This can improve physical function by increasing the nerve mobilization ability of the muscles, ultimately increasing the ROM of the hip joint. Variable frequency TENS therapy with a long pulse duration of 250 μs is expected to become a new protocol that promotes functional enhancement (reducing muscle tension and enhancing muscle strength) in elderly individuals who cannot voluntarily contract their muscles.

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