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Basic Science

Verification of an optimized stimulation point on the abdominal wall for transcutaneous neuromuscular electrical stimulation for activation of deep lumbar stabilizing muscles

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Abstract

BACKGROUND CONTEXT: Transcutaneous neuromuscular electrical stimulation (NMES) can stimulate contractions in deep lumbar stabilizing muscles. An optimal protocol has not been devised for the activation of these muscles by NMES, and information is lacking regarding an optimal stimulation point on the abdominal wall.

PURPOSE: The goal was to determine a single optimized stimulation point on the abdominal wall for transcutaneous NMES for the activation of deep lumbar stabilizing muscles.

STUDY DESIGN: Ultrasound images of the spinal stabilizing muscles were captured during NMES at three sites on the lateral abdominal wall. After an optimal location for the placement of the electrodes was determined, changes in the thickness of the lumbar multifidus (LM) were measured during NMES.

METHODS: Three stimulation points were investigated using 20 healthy physically active male volunteers. A reference point R, 1 cm superior to the iliac crest along the midaxillary line, was used. Three study points were used: stimulation point S1 was located 2 cm superior and 2 cm medial to the anterior superior iliac spine, stimulation point S3 was 2 cm below the lowest rib along the same sagittal plane as S1, and stimulation point S2 was midway between S1 and S3. Sessions were conducted stimulating at S1, S2, or S3 using R for reference. Real-time ultrasound imaging (RUSI) of the abdominal muscles was captured during each stimulation session. In addition, RUSI images were captured of the LM during stimulation at S1.

RESULTS: Thickness, as measured by RUSI, of the transverse abdominis (TrA), obliquus internus, and obliquus externus was greater during NMES than at rest for all three study points ($p<.05$). Transverse abdominis was significantly stimulated more by NMES at S1 than at the other points ($p<.05$). The LM thickness was also significantly greater during NMES at S1 than at rest ($p<.05$).

CONCLUSIONS: Neuromuscular electrical stimulation at S1 optimally activated deep spinal stabilizing muscles, TrA and LM, as evidenced by RUSI. The authors recommend this optimal stimulation point be used for NMES in the course of lumbar spine stabilization training in

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patients having difficulty initiating contraction of these muscles.

Keywords: Neuromuscular electrical stimulation; Lumbar stabilizing muscle; Real-time ultrasound imaging; Optimal stimulation point; Transverse abdominis; Lumbar multifidus

Introduction

Low back pain (LBP) is a common medical problem, and previous studies have reported a lifetime prevalence ranging from 54% to more than 80% [1]. Disability is often associated with LBP and leads to numerous socioeconomic problems [2].

Loss of spinal stability is an important factor in chronic LBP [3,4]. Panjabi [3] suggested that spinal stability is achieved when all components of the articular, muscular, and neural systems are well coordinated. Several previous studies have reported that people with LBP appear to have different recruitment patterns for the control of spinal muscles [5–9]. Some patients with LBP cannot effectively activate deep lumbar stabilizing muscles, such as the transverse abdominis (TrA), the obliquus internus (OI), and the lumbar multifidus (LM), when stabilizing the lumbopelvic region [5,6,10]. If this state of disrupted muscle recruitment is not addressed and corrected after the acute phase, chronic LBP will persist [7]. Corrective training of the deep lumbopelvic stabilizing musculature is considered an important component of LBP management and rehabilitation [11–14]. Traditional muscle-specific exercise of deep lumbar stabilizing muscles is labor and time intensive for therapists and patients.

Neuromuscular electrical stimulation (NMES) is widely used to enhance muscle strength and help retard muscle atrophy [15,16], and it has been used to reeducate and strengthen superficial and deep abdominal muscles for many years [17–23]. Recently, researchers demonstrated that NMES can preferentially stimulate contractions in deep lumbar stabilizers [19], and those changes in muscle activation induced by NMES are associated with clinically significant reductions in self-rated pain scores in LBP patients [20]. However, few studies have been undertaken to determine an optimal protocol for the effective activation of deep lumbar stabilizing muscles by NMES. Abdominal muscles are large enough to cover the entire abdominal wall; thus, the identification of a suitable standardized NMES point on the abdominal wall would be useful in providing optimal rehabilitative training of lumbar deep stabilizing muscles.

In the present study, we attempt to determine an optimal NMES electrode placement on the abdominal wall for the stimulation of deep lumbar stabilizing muscles using real-time ultrasound imaging (RUSI).

Methods

Sample size determination and participants

To determine the sample size, a power analysis was performed using test of mean difference from the constant for one sample (effect size=0.8, alpha=0.05, and power=0.9). The sample size was calculated for 19 subjects. We applied a drop rate of 0.1 giving a final sample size of 21 patients. One subject dropped out after reviewing the informed consent form resulting in 20 men in the study. Twenty physically active healthy men between the ages of 24 and 32 years volunteered for this study. Inclusion criteria were no history of LBP, body mass index between 21 and 29 kg/m^2, and good general health. Exclusion criteria included history of a neurologic or respiratory disease or if they had sought medical advice for a possible back pathology during the preceding year. Participants were provided comprehensive oral and written information about all the aspects of this study and provided written informed consent. Study approval was granted by our institutional review board.

NMES intervention

Electrical stimulation was delivered through a set of four hydrogel surface electrodes (5×5 cm) located on both sides of the anterolateral abdominal wall; this small electrode size allowed site-specific effects to be identified. Three stimulation points were investigated using a reference electrode 1 cm superior to the iliac crest along the midaxillary line: stimulation point S1 was located 2 cm superior and 2 cm medial to anterior superior iliac spine; stimulation point S3 was placed 2 cm inferior to the lowest rib in the same sagittal line as S1, and S2 was located midway between S1 and S3 (Fig. 1). Each stimulation was performed at S1, S2, or S3 using the ipsilateral R electrode. The stimulation pulses were generated using a portable research stimulator (CMMX-001A; Cybermedic Corp., Iksan, Republic of Korea). This unit delivers a constant current and a symmetrical biphasic waveform. Biphasic symmetrical pulses of 200 microseconds with an interphase delay of 100 microseconds were employed. These pulses were delivered via the surface electrodes at a frequency of 50 Hz to produce tetanic isometric contractions. The overall contraction-relaxation cycle was ramp up for 1 second, contraction 8 seconds, ramp down 1 second, and relaxation 10 seconds. Current intensities were controlled by the participants and investigators. Participants were instructed to use the unit at an intensity that elicited maximum muscle contraction without discomfort, such as, a burning sensation or severe tetanic pain. The average mean stimulation intensity was (±standard deviation [SD]) 18.35 (±3.2) mA for abdominal muscles.

Ultrasonography

The RUSI (Logiq 6 Expert; GE Healthcare, UK) unit was used to measure the thickness changes in deep and