A study of therapeutic ultrasound and exercise treatment for muscle fatigue in patients with chronic non-specific low back pain: A preliminary report

Safoora Ebadi*a, Noureddin Nakhostin Ansari*a, Soofia Naghdi*a, Ehsan Fallahb, Darioush M. Barzi*c, Shohre Jalaiae and Hosein Bagheria

*aDepartment of Physiotherapy, Rehabilitation School, Tehran University of Medical Sciences, Tehran, Iran
bEmam Reza Hospital, Army University of Medical Sciences of IR Iran, Tehran, Iran
cMostafa Hospital, Shahed University, Tehran, Iran

Abstract.
AIM: The aim of this study was to investigate the effect of continuous ultrasound (US) plus exercise on the endurance of paravertebral muscles of patients with chronic non-specific low back pain (CNSLBP).
METHODS AND MATERIALS: In this pilot, pretest-posttest study, 22 patients with CNSLBP participated. Patients received 10 sessions of treatment, including continuous US plus exercise therapy, over a period of four consecutive weeks. Median frequency slopes of Iliocostalis and Multifidus muscles as well as holding time during Biering-Sorensen test were measured using surface electromyography. In addition, function and pain were measured using Functional Rating Index (FRI) questionnaire and VAS.
RESULTS: Five females and 15 males with a mean age of 31.7 years completed the treatment. Descriptive data showed a decrease of 0.01 and 0.02 mean in median frequency slope of right and left Iliocostalis respectively and a mean of 0.08 decrease for both right and left Multifidus muscles. Endurance time increased 1.8 seconds mean. Both function (17%) and pain (24%) improved post treatment.
CONCLUSION: Larger population studies in the context of high quality, randomized clinical trial are needed to validate the results.

Keywords: Chronic low back pain, fatigue, endurance, ultrasound, exercise

1. Introduction

Low back pain (LBP) is one of the most common musculoskeletal problems that has caused socioeconomic implications in different countries, and affects 80–85% of people over their lifetime [1]. LBP is a common health and socioeconomic problem in Iran as well [2–4].

Chronic non-specific low back pain (CNSLBP) refers to a period of activity-limiting LBP that lasts for 3 months or more which is not linked to any underlying tissue damage [5]. Different physical agents alongside exercise therapy are the cornerstone of treating patients with CNSLBP [6].

Therapeutic ultrasound (US) is commonly used during physical rehabilitation in conjunction with exercise therapy to decrease pain, increase tissue extensibility, and accelerate healing [7]. The therapeutic effects of
US are classified as thermal and nonthermal. Ultrasonic energy increases molecular motion that rises tissue temperature, which in turn affects tissue in different ways; such as changing nerve conduction velocity and increasing pain threshold, increasing collagen extensibility, increasing local blood flow and reducing muscle spasm [8]. Nonthermal or mechanical effects of US are the result of cavitation and microstreaming that can alter cell membrane permeability and thus facilitate soft tissue healing [9]. The most recent evidence-based guidelines for the treatment of LBP cannot recommend US because of a dearth of evidence based on high quality clinical trials [10]. Nevertheless, US is commonly used in routine clinical practice for musculoskeletal problems, including LBP [11].

In addition to US, stretching and strengthening exercises are frequently administered in LBP rehabilitation [12]. Exercise programs for patients with LBP usually include muscle strengthening exercises, aerobic exercises, and range-of-motion exercises. It has been documented that lumbar extensor strengthening exercises administered alone or with co-interventions is more effective than no treatment and most passive modalities for improving pain, disability, and other patient-reported outcomes in chronic LBP [13].

The aim of this pilot study was to determine whether a commonly used physical therapy treatment routine consisting of continuous US plus exercise could affect paravertebral muscle endurance as shown by median frequency slope and endurance time in patients with CNSLBP.

2. Method and material

The protocol of this study was approved by the Research Council of Rehabilitation Faculty and the Ethical committee of Tehran University of Medical Sciences (TUMS). Oral and written information about the study were provided to the patients. If agreed to be enrolled in the study, patients were asked to sign a consent form.

The assessment of back muscle fatigue plays an important role in the evaluation of lumbar dysfunction [14]. Muscle fatigue refers to the decreased force/power generating capacity during and following prolonged or repeated muscle activity. Numerous factors influence muscle output during prolonged exercise, from oxygen transport capacity to metabolic substrate availability, from efferent motor command from the brain to contractile protein interaction within the muscle fibers [15].

Regardless of the causal factors of CLBP, the body of evidence supports the notion that LBP is associated with muscle impairment or deconditioning. Evaluation of the efficacy of any therapeutic intervention in the treatment of LBP requires objective measures to quantify the alteration in the natural history of the patient’s condition [16]. There are various kinds of objective outcome measures available for monitoring patients with LBP in clinical practice. One of the procedures that is declared to have a reliable correlation with LBP complaint is back muscle endurance capacity tests [17,18].

Surface electromyography and specifically power spectral analysis of EMG signals, has become an increasingly common method for the assessment of lumbar muscle activity and localized muscle fatigue. Assessment of paraspinal muscle by surface EMG has been suggested as an objective, safe, easy and non invasive measure for the evaluation of the status of patients with LBP. It has been reported that SEMG analysis is a useful method to evaluate treatment outcome for LBP therapies with adequate long-term test-retest reliability [19].

Numerous studies have identified an association between LBP and easily fatigued back muscles based on the changes in the power spectrum of SEMG and endurance time [20]. Accordingly, one goal in active low back rehabilitation is to improve the paraspinal muscle endurance [17]. The assessment of fatigue based on SEMG techniques during a fatiguing contraction can be demonstrated by a trend of the power spectrum to lower frequencies usually measured by the decrease in median frequency. Many studies have shown that better endurance would exhibit a less precipitous decay rate of the median frequency [21].

2.1. Participants

Twenty-two patients with CNSLBP who were referred to physiotherapy clinic of the Rehabilitation School of TUMS were admitted consecutively. Patients with known underlying systemic disease and specific conditions, those taking medication for specific psychological problems and pregnant patients were excluded.

2.2. Intervention

Patients received 10 sessions of treatment over a period of four consecutive weeks. Treatment included continuous US plus exercise.
2.3. Ultrasound therapy

Patients received 8 minutes of continuous US at a frequency of 1 MHz and an intensity of 1.5 W/cm² [22] using Enraf Nonius Sonoplus 434, Netherlands. Slow circular movements were applied by the transducer head over the painful paravertebral low back region.

2.4. Exercise therapy

We administered exercises, which were routinely prescribed in clinical practice and were supported in the reviews [23]. Patients were provided with a pamphlet describing exercises with related pictures. The patients were encouraged to perform the exercises at home correctly as taught by the first author.

The exercise program consisted of daily walking for at least 15 minutes (warm up). The patients were asked to perform the stretches daily before the strengthening exercises. The stretching exercise program included: 1) hamstring stretches in supine position; 2) cat and camel position for stretching back and front trunk muscles; 3) lower back and gluteal stretches with knee to chest movement. Patients were instructed to perform 2 to 3 stretches of all muscles daily and hold the stretch for 20 seconds unless it hurts.

Strengthening exercises included: 1) posterior pelvic tilts to strengthen abdominals; 2) sit ups (crunches); 3) bridging which strengthens several muscle groups including gluteals, back muscles and abdominals; 4) exercises in the quadruped position that begins with arms and legs on the floor and progresses to lifting opposite arm and leg together. Exercises in this position aims at strengthening paravertebral as well as hip and gluteal muscles.

Strengthening exercises in this study started with 5 repetitions and progressed to reach to 3 sets of 10 repetitions.

2.5. Outcome measures

2.5.1. Surface electromyography

Median frequency slope of Iliocostalis and Multifidus muscles along with endurance time during a Biering-Sorensen test were measured at baseline and after treatment using surface electromyography.

The Biering-Sorensen test is a method for evaluating paravertebral muscle fatigue, which was first introduced by Hansen and then modified by Biering-Sorensen [24]. Sorensen test and the electromyography recordings performed during its performance is a widely used test to evaluate the back muscle endurance, which has been said to be valid and reliable in both discriminating back patients and assessing rehabilitation [17,24]. The change in median frequency of the power spectrum to lower frequencies is used as an objective and non invasive assessment to evaluate localized back muscle fatigue during the Biering Sorensen test [14].

In this test, the subject’s upper trunk is positioned in an unsupported prone horizontal position from ASIS (anterior superior iliac spine) as long as possible, while their legs and hips are fixed to a bed. We used a two part hydraulic bed in which the segment under the upper body could be brought down slowly by pressing on an electronic button.

During the Biering-Sorensen test, the EMG activity of Iliocostalis Lumborum and Multifidus muscles was recorded bilaterally using an eight-channel surface EMG recorder (DATA Log Biometrics Ltd, UK). One channel was connected to a digital goniometer. The end point of holding time was when the patient failed from the horizontal position by more than 5 degrees as recorded by the digital goniometer. Data acquisition and analysis were performed using the built in software (DATA LOG PC software version 7.5) which applied Fast Fourier transformation to calculate median frequency. The software gave the rate of decline in median frequency (MF slope) by trend lines which were calculated using Linear Regression Analysis based upon the least squares method to produce a slope \( m \) and an intercept of the Y-axis. Preamplified bipolar Ag-AgCl electrodes (Type NO.SX230, Biometrics Ltd, UK, 10 mm in diameter) with fix center to center inter electrode distance of 20 mm, were used. The signal was gathered at a sample rate of 1000 and a gain of 1000. After shaving, abrading and cleansing the skin with alcohol, electrodes were attached based on the recommendations of De Foa et al. [25]. The digital goniometer was positioned on the lumbar region according to the manual instruction of the apparatus. Surface EMG of the isometric activity of all muscles were recorded during holding time.

2.5.2. Function and pain

Functional disability and level of pain were measured by Persian Functional Rating Index (FRI) questionnaire [26] and visual analog scale before and after treatment. The FRI is a reliable and valid 10-item questionnaire consisting of 5-point Likert scales. The patient ranks his or her perceived disability at the present time by selecting one of the five points of the scale (0 –
### Table 1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Before treatment</th>
<th>After 10 sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right ilio-costalislumborum</td>
<td>−0.19 (0.12)</td>
<td>−0.18 (0.09)</td>
</tr>
<tr>
<td>MF slope</td>
<td>−0.29 (0.25)</td>
<td>−0.21 (0.08)</td>
</tr>
<tr>
<td>Left ilio-costalislumborum</td>
<td>−0.17 (0.9)</td>
<td>−0.15 (0.06)</td>
</tr>
<tr>
<td>MF slope</td>
<td>−0.27 (0.29)</td>
<td>−0.19 (0.09)</td>
</tr>
<tr>
<td>Endurance time (in seconds)</td>
<td>120.6 (34.1)</td>
<td>122.4 (38.7)</td>
</tr>
<tr>
<td>FRI*</td>
<td>44.5 (12.6)</td>
<td>27.5 (9.9)</td>
</tr>
<tr>
<td>VAS**</td>
<td>48.3 (11.3)</td>
<td>24.3 (10)</td>
</tr>
</tbody>
</table>

*Functional Rating Index, **Visual Analogue Scale.

“no pain or full ability to function”; 4 – “worst possible pain and/or unable to perform this function at all”). The total score is obtained by summing the item scores and expressed as percentage from zero (no disability) to 100% (severe disability) [27,28].

The visual analogue scale (VAS) was used to assess pain intensity during last week. A visual analogue scale is a valid means to measure pain intensity. It is a 100 mm horizontal line, where 0 mm indicates “No pain” and 100 mm indicates “Unbearable pain”.

3. Results

Twenty patients completed the protocol. Two patients did not continue the treatment because of traveling. Five patients were female and fifteen male. The mean age of all participants was 31.7 (SD 10.5) years with a mean pain history of 4.5 (SD 2.9) years. The mean of BMI was 23.4 (SD 3.5). Mean and standard deviation of all outcome measures are summarized in Table 1.

Due to this study being a pilot one, encompassing only 20 subjects, we sufficed to descriptive data reporting. Median frequency slope of right and left Iliocostalis muscles showed a decrease of 0.01 (SD 0.03) and 0.02 (SD 0.02) mean respectively. The median frequency slope of both right and left Multifidus muscles showed an average of 0.08 (SD 0.04) decrease. Meanwhile, endurance time during Biering-Sorensen test increased by an average of 1.8 (SD 6.2) seconds. Mean improvement for function was 17% (SD 20.4%) and for pain was 24% (SD 13.2%).

4. Discussion

We witnessed that delivering continuous 1 MHz US combined with the specific exercises prescribed in this study, decreased the median frequency slope of back paravertebral muscles slightly and increased holding time during the Biering-Sorensen test to some extent. In addition, function and pain improved almost considerably.

It has been indicated that trunk muscle endurance can be increased by using specific exercises [29,30] and that US plus exercise can be an effective treatment for patients with chronic low back pain regarding function and pain [28–30].

The improvements might be attributed to the thermal and mechanical effects of US as well as the specific exercises prescribed [33]. Morisset showed that Continuous 1 MHz US given at either 1.5 W/cm² or 2.0 W/cm² intensity has the capability of heating lumbar periartricular tissue, to the degree to be sufficient to produce the theoretical therapeutic effects proposed with an elevation in temperature including pain reduction, decreased joint stiffness, tissue healing, and alterations in collagen extensibility [34]. It is possible that the exercises used in the present study were not sufficient as well as specific to provide an obvious effect on the patient’s endurance ability to hold the horizontal position for longer durations. It would be reasonable to exercise the patients in the same task specific position of the Biering Sorensen test to be able to see significant changes in fatigue indices. Besides, other ultrasound dosages might have different effects on the parameters. Moffroid described a series of exercises that increased static mechanical endurance of trunk extensors in healthy women over a 6-week period but did not significantly alter the median frequency measure [29]. In another study, Mohseni et al. found no significant change in MF slope of Iliocostalis and Multifidus muscles in a group of patients with CLBP who were treated with US and exercise, but witnessed a significant improvement in function and pain [22].

This preliminary study lacks a control group with no US and no exercise to compare the effects of these interventions and establish their relation to muscle endurance and functional improvement individually. Since the sample size was small and no statistical conclusion could be derived from the data, it is reasonable to have in mind that changes in outcomes could be the result of the natural history of the disease and non treatment factors.

5. Conclusion

This study was a pilot attempt to investigate the effects of a common physiotherapy treatment routine of
continuous US and exercise on paravertebral muscles endurance in patients suffering from Chronic Non Specific Low back pain. The descriptive results showed a slight decrease in MF slope of Iliocostalis and Multifidus muscles along with a few seconds increase in holding time. Meanwhile pain and function showed an almost considerable improvement. The study should be expanded in a randomized clinical trial to include larger sample size and control groups in order to make it possible to explore the significancy of changes and investigating the efficacy of treatment.

References


