

The Effects of Active Therapeutic Exercises on the Electromyographic Activity of Lumbopelvic Muscles during Prone Hip Extension in Patients with Chronic Non-Specific Low Back Pain

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ABSTRACT

Purpose: LBP is one of the most common health issues throughout the world and has multiple causes which one of them is the defect in motor patterns. This study compared the effectiveness of stability, general and mixed exercises on the electromyographic activity of ipsilateral erector spinae muscle (IES), contralateral erector spinae muscle (CES), gluteus maximus (GM) and medial hamstring (MH) during prone hip extension (PHE) in patients with nonspecific chronic low back pain (NSCLBP).

Methods: The study used an interventional quasi-experimental design. Thirty patients with NSCLBP between the ages of 20 to 40 years were randomly divided into 3 groups (each with ten patients) including stability, general and mixed groups. The study was conducted in Spring and Summer of 2014 in Amir Physical Clinic in Isfahan. MVEA of the muscles was measured using surface electromyography (EMG) prior and after exercises during PHE. Exercises were done for 10 sessions and 3 times per week. The obtained data by SPSS (version 22) and using the Kolmogorov-Smirnov test, Independent t-test Paired t test and ANCOVA were analyzed.

Results: MVEA of GM ($P=0.036$) significantly increased in the group who practiced with mixed exercises. Also, the exercises decreased MVEA of IES, MH and CES. Besides, this decrease for IES ($P=0.024$) was significant but for MH ($P=0.973$) and CES ($P=0.111$) were not. However, the statistical results did not show any significance among any two and or all three groups.

Conclusion: The findings of this study revealed that mixed exercises are more effective than stability and general exercises on the EMG activity of lumbo-pelvic muscles and could alter the electrical activity pattern of these muscles.

1. Introduction

Low Back pain is one of the most common health problems worldwide; about 70% to 80% of people complain from LBP at least once in their lifetime [1,2]. The first symptoms of LBP usually appear between the ages of 30 and 40 years [3] In the USA, LBP was recognized as the fifth most common cause

of visiting a doctor [4]. The high cost of its treatment causes less productivity in the workplace and finally LBP disables individuals [2].

Meanwhile, LBP is considered as a multi-factorial condition. The defects in movement patterns could be considered as one of the causes which plays a crucial role in the development of skeletal muscle dysfunction [3]. If synergistic muscles are activated properly, they

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PHYSICAL TREATMENTS

Figure 1. MT8 Electromyography device

have a major role in the proper performance of the vertebral column [5]. Increase or decrease in muscle activity can alter normal movement pattern [6,7]. Thus, the main focus of recent therapies is on the correction of defected movement patterns in patients with musculoskeletal pain [6,8,9]. A large number of studies have explained changes of movement pattern of the lumbopelvic muscles during different tasks in patients with LBP [10,11].

Arab et al (2010), Sakamata et al (2009) and Oh et al (2007) found that active exercise therapy alters the patterns of lumbo pelvic muscle activities in patients with non-specific chronic low back pain [16,33,33].

There are several clinical tests, which are used for assessment of the altered movement patterns in people with LBP. One of the most convincing assessments is Prone Hip Extension (PHE) test developed by Janda [6].

PHE is significant as it produces muscular activity pattern similar to functional movement patterns such as walking [7,8]. It has been assumed that changes in the activity of involved muscles during PHE may reduce lumbopelvic stability during gait [12]. This test could

be used to evaluate the patterns of muscular activities in musculoskeletal disorders using surface EMG [13,14].

To our knowledge, no study has investigated effective therapeutic exercises on the amplitude of lumbopelvic muscles activity in people with NSCLBP.

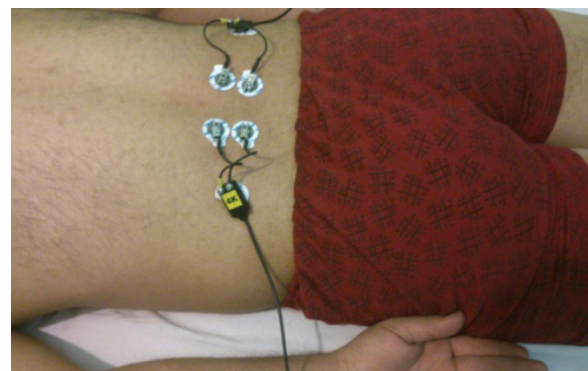
Therefore, this study aimed to determine and compare the altered EMG activity pattern of lumbopelvic muscles through dynamic stability of the lumbar spine in patients with NSCLBP under 3 experimental conditions. Stability exercises, General exercises, and Mixed exercises. It was hypothesized that mixed exercises would be more effective in changing muscular EMG activity in gluteus maximus (GM), medial hamstring (MH), ipsilateral erectorspiane (IES) and contralateral erector spinae (CES) compared to the effects of stability and general exercises.

2. Materials and Methods

This is an interventional quasi-experimental study. The patients with NSCLBP between the ages of 20 to 40 years were selected through a simple non-probability sampling method and were randomly divided into 3 exercise groups from a Amir Physical Therapy Clinic. Each group (n=10) consisted of 6 men and 4 women.

Patients were included if they suffered from back pain for 6 weeks or more and those with recurrent back pain of 3 times over the previous year, each time lasted for at least one week [15].

The patients participated in the study were referred by two orthopedic surgeons and a number of older than 40 years old; having history of trauma or injury to the hip joint, history of arthritis, spine abnormalities, neuromuscular lesions, central nervous system disorder or inability to perform active range of motion without back



PHYSICAL TREATMENTS

Figure 2. Electrode location of ES muscle.



PHYSICAL TREATMENTS

Figure 3. Electrode location of GM muscle

and hip pain ;having length discrepancy of their two limbs more than 1 cm, having ankle sprain, or short hip flexors diagnosed by the Thomas test; having positive neurological symptoms such as tingling, sensory loss, motor weakness or positive nerve root tension in foot; having history of lumbar spine surgery, injury to their back or lower extremities that prevents them from doing normal activities for at least one day during the past 3 months [5,6].

In this study, the dominant leg was selected for the investigation. The muscle activity of GM, MH, IES, and CES during PHE was collected with an MT8 radio telemetry EMG system (MIE Medical Research Ltd) ,which is shown at Figure 1.

The accuracy of EMG electrode placement was verified by asking the participant to contract the muscle of interest while the investigator monitored online EMG activity. Then, the electrodes were secured by hypoallergenic tape and a ground electrode was placed ipsilateral over the lateral malleolus. A preamplifier with a gain of 4000, band pass filtered at 6-500 Hz, sampling rate at 1000 Hz was used.

Patients were asked to lie in prone position while the arms were alongside the body and head was located in the midline. Surface EMG was recorded from the GM, MH, IES and CES muscles using bipolar Ag/AgCl disposable surface electrodes with an interelectrode distance of 2 cm (measured from the center of the electrodes) and parallel to alignment of muscle fibers [7].

To ensure of a good surface contact and low skin resistance, a standard skin preparation procedure of shaving, cleaning and abrading was performed for each electrode site [18,19]. The electrode locations were determined based on anatomical landmarks and also observation

of muscle responses in the testing position (PHE) They were as follows :

Two centimeter out of L3 spinous process for erector spinae muscles (Figure 2).

In the middle of the line that connects great trochanter to S2 for gluteus maximus (Figure 3).

The inner edge of the mid distance between gluteal and popliteal fold for medial hamstring (Figure 4) [4,16].

The maximum voluntary electrical activity (MVEA) of each muscle is initially calculated for normalization purposes. The method for calculating MVEA was similar to that of manual muscle test introduced by Kendall [20].

To calculate the MVEA of the erector spinae muscle, the patients were asked to lift the body against the maximum applied resistance to the sub scapular area and For gluteus maximum, they have to flex hip joint 90° and keep the knee in extended position and then apply the maximum resistance to portion of posterior distal femur. For MH, the hip was placed in the extension position, and the knee was placed at an angle of 70° flexion and the maximum resistances was applied to distal portion of the posterior of the leg.

Every contraction was repeated twice, each time being maintained for 5 seconds. One-minute break was given between each contraction. They were also familiarized with the standard movement position before conduction of the tests.

All patients were asked to raise chosen leg off the bed to 10° extension while the knee was kept straight as soon as they heard the order lift. An adjustable bar was placed in the 10 degree extension level and the partici-



PHYSICAL TREATMENTS

Figure 4. Electrode location of MH muscle.

pants were asked to do extension of hip until the heel hit the bar. This was repeated 3 times for each patient [16].

The EMG signals obtained during PHE were explained as percentage of calculated mean RMS of MVEA (%MVEA). The onset of the action was determined by electrogoniometry. The statistical analysis was performed by SPSS (version 22).

Stability exercises set

By specific active exercises in this study, We meant the separate performance and movement each of the following muscles: transverse abdominal muscles, oblique abdominal, lumbar multifidus, gluteus maximus, as well as correct use of the pelvic muscles. The exercises in this study are performed in the following steps:

1. Segmental controlling exercises emphasized the isolated contraction of abdominal muscles and lumbar multifidus with low contractile force.
2. Segmental controlling exercises were performed through simultaneous contraction of the abdominal muscles and lumbar multifidus in the supine sleeping and creep position.
3. Segmental controlling exercises were performed through simultaneous contraction of the abdominal muscles and lumbar multifidus in the close kinematic chain.
4. The progress in segmental controlling exercises was performed through simultaneous contraction of the abdominal muscles and lumbar multifidus with applying low energy by adding the leverage of muscles during the exercises in the kinematic chain [21,34].

These exercises were done in quadruped, sitting and bridging positions for 10 sessions 3 times per week. The exercises were ordered from easy to more complicated .In case the patient was successful in doing the previous exercises in each session, one or two additional exercises were added to the routine .It should be mentioned that all exercise sessions were monitored by the exam-

iner. Each exercise was repeated for 10 times and the participant was given 30 seconds of rest between each exercise.

General exercises set

General active exercises were a set of exercises that activate abdominal and paraspinal muscle groups. Regarding this, the following steps were taken in the current study:

1. Activating abdominal and paraspinal muscles
2. Activating paraspinal muscles in the closed kinematic chain
3. Activating abdominal muscles in the open kinematic chain
4. Activating paraspinal muscles and external abdominal oblique muscles

These exercises were done in the supine, prone, bridging, and quadruped position. These exercises include strengthening and stretching exercises for the body muscles and lower extremities which were done in 10 sessions, 3 times a week. The exercises were progressed from simple to complex.

In case the participant was successful in doing the previous exercises in each session, one or two additional exercises were added to the intervention. The sessions were monitored by examiner. Each exercise was repeated for 10 times and the participant was given 30 seconds of rest between each exercise [21].

Mixed exercises set

These exercises comprised both stability and general exercises and were done in quadruped, sitting, and bridging positions for 10 sessions 3, times per week. The exercises were progressed from simple to complex. In case the participant was successful in doing the pre-

Table 1. Demographic data of the 3 groups.

Variable	Stability exercise group	General exercise group	Mixed exercise group
Age (Y)	31±5.011	29.70±6.056	30.90±5.109
Height(cm)	165.90±8.950	171±11.721	169.80±9.875
Weight(kg)	71±14.298	65.90±9.875	67.20±9.461
BMI ^a (Kg/m ²)	25.87±5.04	22.56±3.73	23.32±2.711

a BMI=body mass index, b Values are presented as means± standard deviations.

Table 2. Comparison between the EMG activities of each muscle among 3 groups.

Group	Muscle	Muscle activity before Treatment (%MVE) (mv)	Muscle activity after Treatment (%MVE) (mv)	P-Value
Stability	GM	27.88(8.14)	31.74(32.10)	0.239
	MH	54.47(5.07)	54.18(6.14)	0.923
	IES	58.31(10.90)	56.84(12.82)	0.638
	CES	61.82(18.29)	85.14(19.93)	0.450
General	GM	31.87(8.34)	31.45(5.67)	0.239
	MH	60.41(7.60)	58.49(12.31)	0.923
	IES	66.01(7.38)	60.35(13.45)	0.638
	CES	58.26(10.52)	53.00(12.42)	0.450
Mixed	GM	36.31(10.52)	41.20(7.89)	0.036
	MH	53.18(11.30)	53.08(10.71)	0.973
	IES	60.50(7.84)	54.91(10.67)	0.024
	CES	85.26(7.38)	53.00(12.42)	0.111

PHYSICAL TREATMENTS

vious exercises in each session, one or two additional exercises were added to the intervention.

The sessions were monitored by the examiner. Each exercise was repeated for 10 times and the participant was given 30 seconds of rest between each exercise [21,35].

3. Results

Normal distribution of variables was tested using the Kolmogorov-Smirnov test. The paired t-test was conducted to compare the means before and after exercises in each group. Independent t test was also conducted to compare the means of the two groups. On the other hand, ANCOVA test was used to compare means among three groups. Statistical significance for all test was accepted below 0.05 level.

Demographic variables had a normal distribution. There were no statistically significant differences among the groups regarding age, height, weight and BMI. The patients' demographic data are listed in Table 1.

MVEAs of IES muscle, CES muscle, GM, and MH using Paired t test were obtained individually for each group and are shown in Table 2.

There were significant differences in MVEAs of GM (P=0.03) and IES (P=0.02) after treatment compared with pretreatment score in mixed exercise group.

However, no significant differences in MVEAs of MH (P=0.97) and CES (P=0.11) were found in mixed exercise group. There was no significant difference in MVEA of all tested muscles in stability and general exercise groups.

Statistical analysis of data revealed that the electrical activity of each muscle, which was measured using independent t test, when comparing the groups two by two, showed no significant difference. Furthermore, when comparing these variables for each of the muscles among the 3 groups using ANCOVA, no significant difference was found either.

4. Discussion

The findings of this study showed that MVEA of GM muscle significantly increased in the group practiced with combination of stability and general exercises. Also this combined exercise decreased MVEAs of IES, MH, and CES during PHE in patients with NSCLBP.

The results in the present study revealed a significant decrease in MVEA of IES. This was not the case for MH and CES, which only showed a trend (non-significant decrease). These findings indicated that the effect of mixed exercises on the electrical activity of lumbo-pelvic muscles and improvement of motor pattern during PHE was more than that of stability and general exercises.

These findings are consistent with some other studies reported equivocal results or even decreased amplitude signal [22,23].

Arab et al (2011) mentioned that "Increased activity of the MH in women with LBP may be due to high fatigability and poor endurance of the lumbar ES muscles. Also, increased MH activity is an adaptive mechanism following lumbar muscles fatigue and possibly weakness in the muscles.

Tolerance reduction of ES in patients with LBP may loosen sacrotuberous ligament (This ligament is considered as the main stabilizing structure in sacroiliac joint) and hamstring muscles can affect sacrotuberous ligament by connecting to its proximal part. It is perceived that the increased hamstring activity in patients with LBP may be due to the compensation of functional mechanism of these conditions.

The concept of lumbar stabilization was introduced in the last decade in the field of physiotherapy to prevent musculoskeletal injuries, through rehabilitation and improvement of performance. Lumbar stabilization refers to the internal stabilization that is achieved through isometric contractions of the lumboabdominal muscles. The current issue was considered by Panjabi, who believes that stabilization of the vertebral column depends upon 3 subsystems: passive (vertebral column), active (vertebral muscles) and control (neural control) [24].

Changes in motor recruitment patterns are due to spinal instability resulting in muscle dysfunction [25]. Coordination between local and global muscle system has changed in LBP [26]. Coordinate activity between two muscle systems (global and local) to maintenance of spinal stability is necessary [9].

The two deep muscles, transverse abdominal and lumbar multifidus are essential in segmental stabilization. These muscles can increase body stabilization through simultaneous contraction. Another explanation can be the fact that like trans versus abdominis muscle, other local stabilizing muscles initially contract and then the global muscles such as erector spinae acts as a synergist to increase the stability that is timely required. Injury or other pathologies can create abnormal pattern of stabilization. Coordinated muscular activity seems to be important in preventing and treating low back pain [27].

Anderson and Pandy (2003) reported that "Gluteus maximus has a major functional role in the early stance of walking and generates most of the support and pre-

vents the collapse of the hip, knee, and ankle". "The inappropriate activation of GM in gait is thought to be cause of low back pain, resulting in a deficiency in the shock absorption at the sacroiliac joint" [28].

In contrast, a number of studies showed increased EMG amplitude of trunk muscles in patients with LBP during functional activities such as gait and trunk flexion and extension [29,30]. Also, significant increased amplitude of lumbar paraspinal muscles after exercises was recorded [32].

These differences may be related to the types of therapeutic exercises used in these studies or they may be due to difference in methodological issues including differences between the methods of EMG normalization. To obtain a pure signal, free of these factors, electromyographic amplitude must be normalized according to the obtained amplitude by Maximum Voluntary Contraction (MVC). However, this method may not be appropriate for patients with LBP since they are not usually willing or able to do maximum contraction due to the pain or fear of pain [16]. In this study, the maximum isometric contraction was used since most participants had no pain during the PHE test. Therefore, motor training is useful for creating appropriate coordination in both muscular systems [26].

Results of this study showed that patients with NSCLBP who were treated by both general and stability showed significantly increased electrical activity of the gluteus maximus muscle and significantly decreased electrical activity of the medial hamstring muscle. However, the electrical activity of IES and CES muscles also decreased though this exercises which were not significant. These results imply that the combination of exercises alters the electrical activity of lumbopelvic muscles during PHE. Furthermore, these findings are useful and significant in treating patients with chronic non-specific low back pain.

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Conflict of interest

None declared.

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