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Evaluation of Lumbar Paravertabral Muscle Activity under Different Conditions with Surface Electromyography in Low Back Pain Patients

Ali Cimbiz, Ulku Manisaligil and Feride Beydemir

[1]Department of Physical Therapy and Rehabilitation, Dumlupinar University,
Health Institution of Higher Education, 43100 Kutahya-Turkey

Abstract: The paraspinal muscles are responsible for initiating and controlling all movements of the vertebral column. The aim of study was to evaluate the Lumbar Paravertabral Muscle Activity (LPMA) during different daily living postures and exercises in lower back pain (LBP) patients. Thirty two subjects with nonspecified LBP (F:16, M:16) longer than 3 months and 28 healthy volunteers (F:14, M:14) from Dumlupinar University students were participated to the study. Surface electromyography (µV) signals were measured during the rest positions, body movement, strengthen and stretching exercises. No statistically differences were found between group's LPMA in resting positions, body movement, strengthen and stretching exercises ($p>0.05$). Male subjects were performed higher LPMA than female subjects in standing with arms 90^0 flexion, trunk hyperextension and strengthen exercises in prone positions ($p<0.01$). Although no statistically differences between LBP and Control groups, we were observed LPMA during resting, body movement and stretching exercises increased and during the stabilization and strengthen exercises decreased in LBP group. LBP patient paravertabral muscles are not enough relaxed and/or effort muscle force during daily living activities. Thus LBP patients may open to microinjuries and reinjuries. Further studied needs which are investigated the LPMA during in daily living activities.

Key words: Body movement, Low Back Pain, Resting positions, Strengthen exercises, Stretching exercises, Surface Electromyography

INTRODUCTION

Muscular injuries are a common cause of disability in the population and they are the most common cause of Low Back Pain (LBP)[1]. Surface Electromyography (sEMG) is a noninvasive technique for assessing muscle function that has played a major role in our basic understanding of the function of trunk muscles in both normalsubjects and LBP patients during specific postures and movements[2-5]. sEMG analysis has shown advantages for fatigue assessment and has been applied for classifying healthy subjects and LBP patients[3], trained and non-trained subjects[5], subjects under rehabilitation treatments[4]; moreover, surface EMG provided evidence of physiological phenomena related to the back musculature[6] and myoelectric manifestations of muscle fatigue were shown to be predictor of the trunk extensor endurance time[7], thus reflecting mechanical fatigue.

The paraspinal muscles are responsible for initiating and controlling all movements of the vertebral column[8]. In recent years, many studies have documented an association between back muscle 'insufficiency' and the presence of LBP[1-5]. However, despite much investigation, no more studies were evaluated the paravertabral muscle activity during different daily living postures and exercises. The aim of study was to evaluate the Lumbar Paravertabral Muscle Activity (LPMA) during different daily living postures and exercises in LBP patients.

MATERIAL AND METHODS

Subjects: Thirty two subjects with nonspecified LBP (F: 16, M:16) longer than 3 months and 28 healthy volunteers (F: 14, M: 14) participated to the study. The study was approved by the Local Ethics Committee and written informed consent was obtained from all participants prior to inclusion. Subjects with lumbar discus prolepses and systemic disorder were excluded from the study. All subjects completed a pain and general health history, as well as general medical, neurologic and musculoskeletal examinations. Patients were asked to provide an average pain on Visual Analog Scale (VAS, 0-10 cm)[9].

Surface electromyography (sEMG) recordings: sEMG signals were detected with four surface electrodes by the Myomed 932 (Enraf Nonious, Netherlands) electrotherapy tool. The surface arrays were placed over the lumbar erector spine muscle at the level on L2 and L4 lumbar

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Corresponding Author: Ali Cimbiz, Department of Physical Therapy and Rehabilitation, Dumlupinar University Health Institution of Higher Education, 43100 Kutahya-Turkey E-mail: alicimbizphd@hotmail.com

vertebra, on the right and left side, as suggested by Roy *et al.*[3]. The part of the skin where the arrays were placed was slightly abraded with abrasive paste and conductive gel for each electrode of the array was used to assure proper electrode-skin contact and was inserted into the electrode cavities of the individual contacts of the arrays. Alcohol wipes were used for cleaning the surface of the skin before electrode placement. Preamplified, 10-mm contact area Ag-AgCl disposable electrodes with an interelectrode distance of 2 cm were used.

Body positions for measurement: Backlying (supine lying with the legs extended), pronelying, hooklying (supine position with knees bending), sidelying and long sitting (the knees are extended and the weight of trunk is partially supported on the arms) positions were used for measurement resting LPMA. In addition during the erect, arms flexed 90^0 and holding 1 kg on hands, trunk flexion, lateral flexion, rotation and hyperextension, squat and holding 1 kg on hands, kneeling on one leg and in the crawling positions were calculated the LPMA. Subjects first were getting the calculation position and than holds this position minimally 5 seconds. The highest sEMG signals were recorded as µVolts (µV).

Straightening and stretching exercise positions for treatments of LBP patients were chosen for measurement LPMA[10]. Abdominal curls up (arms at sides), straight-leg raising, cycling and posterior pelvic tilt in supine position (subjects were instructed to contract the lower part of abdominal muscles to rotate the pelvis posteriorly so that the lumbar spine became flat against the table); trunk extension and hip hyperextension in prone position were used as straightening exercise positions. All straightening positions were performed by the subjects and holding in this positions minimally 5 seconds.

Hip flexors (in position kneeling on one leg and leaning the trunk forward, toward the front foot until the abdomen is against the thigh), hamstrings (in position straight-leg raising) and lumbar extensors (in position getting the knees to the chest and keeping the knees together) muscles were used as stretching exercise. All stretching positions were performed by examiner and held in these positions for 5 seconds.

Statistical Analyses: A statistical analysis of these sEMG parameters was carried out using the SPSS to calculate the descriptive statistics and analysis of variance. Independent t test were used for comparing the control and LBP groups and Mann whithney U test were used for comparing the gender differences. P<0.05 were deemed significant. Datas' were presented SD±mean[11].

RESULTS AND DISCUSSION

Demographic and pain features of the subjects were shown in Table 1. No statistically differences were found in age between groups (p>0.05). Male subjects were found taller and heavier than female subjects (p<0.001). No statistically differences were observed in pain between male and female subjects in LBP groups (p>0.05).

In addition in manuel muscle testing no statistically differences were found in each group's male and female and between groups (p>0.05) except left Gluteus maximus strength (LBP group F: 4.5 ± 0.7 versus Control group M: 5.0 ± 0.0) (p<0.05).

LPMA results in resting positions: No statistically differences were found between group's LPMA in resting positions (p>0.05). The highest LPMA was found in Control group's female subjects in long sitting position

Table 1: Evaluation of demographic data and pain in subjects

	Group		LBP Group	
Control	Female (n:14)	Male (n:14)	Female (n:16)	Male (n:16)
Age, yr	21.3±0.8 (20-23)	21.6±1.5 (19-24)	21.0±1.6 (18-25)	21.9±1.9 (19-26)
Height, m	1.63±5.2 (1.52-1.70)	1.78±6.5* (1.63-1.88)	1.64±6.5 (1.53-1.76)	1.78±6.0* (1.70-1.89)
Weight, kg	53.6±5.2 (47-62)	73.9±9.0* (61-88)	57.7±10.3 (49-88)	76.0±12.9* (55-105)
Dominant side (R/L)	14/0	14/0	14/2	16/0
Rest VAS	0	0	2.4±2.3 (0-7)	2.1±2.5 (0-8)
Activity VAS	0	0	5.7±2.2 (2-9)	4.1±2.6 (0-9)
Back Pain Duration (month)			12.4±10.3 (5 – 24)	11.7±9.5 (6 – 25)

Data is shown mean±SD (min – max), VAS: Visual Analog Scale (0 – 10 cm) *P=0.000

Table 2: Evaluation of LPMA under different positions [µV]

	Control Group		LBP Group	
Positions	Female(n:14)	Male(n:14)	Female(n:16)	Male(n:16)
Erect	18.5±9.8 (4-35)	19.8±10.8 (4-50)	19.4±15.4 (6-71)	26.0±20.2 (6-82)
Arms 90^0 Flexion	22.7±14.1 (7-63)	46.2±20.0* (24-78)	28.5±12.7 (13-54)	42.0±22.4* (16-85)
Arm 90^0 Flexion + holding 1 kg on hands	47.4±42.6 (17-186)	61.2±28.3 (24-118)	45.6±23.6 (19-106)	57.6±27.6 (22-110)
Trunk lateral flexion (R)	22.3±15.2 (4-58)	17.9±12.0 (7-51)	24.0±13.0 (9-58)	33.6±28.4 (11-94)
Trunk lateral flexion (L)	18.2±10.5 (8-41)	20.2±10.0 (8-39)	28.3±26.1 (2-106)	29.8±26.4 (5-88)
Trunk flexion	23.3±31.0 (4-123)	28.4±31.0 (2-107)	15.5±13.4 (6-60)	20.1±21.7 (5-80)
Trunk hyperextension	13.6±6.3 (4-23)	16.3±8.2 (4-29)	22.8±20.2 (4-83)	31.5±30.9 (7-108)
Trunk rotation (R)	21.6±9.2 (5-35)	46.2±25.5* (17-93)	20.4±12.0 (8-47)	38.4±25.5* (11-88)
Trunk rotation (L)	20.6±9.2 (7-37)	45.5±28.8* (9-106)	27.3±14.2 (10-57)	33.8±25.6 (9-92)
Squat	27.3±14.6 (7-63)	25.8±20.3 (4-79)	30.6±24.3 (8-101)	27.3±22.8 (2-91)
Squat+ holding 1kg on hands	43.7±26.1 (5-99)	35.8±26.6 (6-86)	43.8±34.9 (9-147)	37.6±25.0 (5-94)
Crawling	11.2±5.3 (4-20)	11.6±9.4 (2-32)	19.7±22.6 (1-98)	15.1±22.0 (2-96)
Kneeling on one leg (R)	25.0±17.2 (7-76)	31.8±19.4 (11-69)	29.7±19.5 (2-85)	36.1±43.1 (7-179)
Kneeling on one leg (L)	25.4±16.0 (2-56)	31.9±20.8 (8-70)	28.1±20.5 (5-92)	32.7±29.5 (12-124)

Data is shown mean±SD (min – max) * P<0.01 (Higher paravertabral muscle activity in male groups than female groups)

(25.0 µV). The lowest LPMA was found in LBP group's male subjects in hooklying position (8.4 µV).

LPMA results under different positions: The highest lumbarparavertabral muscle activity was found in control group males in standing position arm 90^0 flexion with holding 1 kg on hands (61.2 µV). The lowest muscle activity was observed in control group females in crawling position (11.2 µV). In standing arm 90^0 flexion and right trunk rotation positions, Control and LBP group's males were found higher LPMA than females ($p<0.01$). In the other hand left trunk rotation LPMA was found higher in control group males than control group females ($p<0.01$) but no statistically differences were found between control group's males and LBP group's males and females ($p>0.05$) (Table 2).

LPMA results during strengthen exercises in supine and prone positions: Male subjects were performed higher LPMA than female subjects. In supine position the highest LPMA was found in posterior pelvic tilt exercise in Control group's male subjects (27.2 µV). The lowest LPMA in this position was observed in abdominal curls up exercise in LBP group's female subjects (12.8 µV). In prone position the highest LPMA was found in trunk extension with arm stretched overhead in control group's male subjects (194.9 µV) and the lowest LPMA was observed in right hip hyperextension in control group's female subjects (47.2 µV). No statistically differences were found between groups in supine position exercises ($p>0.05$). Control group males were performed higher LPMA than control and LBP group's females in trunk extension with arm stretched overhead and right hip hyperextension exercises ($p<0.05$). In addition control group males were performed higher LPMA than LBP group females in all prone position exercises ($p<0.05$). However only the exercise trunk extension with arm stretched overhead was found higher LPMA in LBP group males than females ($p<0.05$) (Table 3).

Table 3: Evaluation of LPMA during strengthen exercises in supine and prone positions [μV]

	Control Group		LBP Group	
Supine Positions	Female(n:14)	Male(n:14)	Female(n:16)	Male(n:16)
Abdominal Curls up (arm at sides)	15.4±9.3 (2-39)	22.1±20.3 (6-82)	12.8±7.1 (2-26)	13.3±6.4 (6-28)
Straight-leg raising (R)	17.1±5.4 (12-32)	19.5±8.6 (9-37)	17.1±6.2 (6-28)	18.9±6.8 (11-33)
Straight-leg raising (L)	16.0±6.3 (8-29)	20.4±11.6 (5-43)	17.1±8.1 (5-31)	19.9±7.8 (12-37)
Cycling	17.1±7.1 (9-36)	19.9±10.1 (7-42)	17.3±7.7 (7-34)	22.7±17.1 (11-69)
Posterior pelvic tilt	20.1±31.7 (4-127)	27.2±31.8 (2-126)	15.8±18.7 (1-74)	13.1±10.9 (2-48)
Prone Positions				
Trunk Extension, (arms at sides)	86.9±30.6 (43-148)	143.0±84.2[b] (36-289)	82.7±36.5 (25-170)	121.3±62.5 (34-270)
Trunk Extension, (arms in reverse T)	108.3±42.5 (52-204)	151.9±69.0[b] (49-274)	97.4±48.0 (25-224)	119.9±58.6 (38-260)
Trunk Extension, (arms stretched overhead)	126.6±55.5 (15-219)	194.9±97.1[a,b] (62-390)	113.1±53.6 (2-235)	169.1±77.2[c] (57-363)
Hip hyperextension (R)	47.2±25.7 (9-92)	100.9±59.9[a,b] (25-226)	54.3±31.6 (9-120)	65.1±38.4 (22-184)
Hip hyperextension (L)	60.7±36.1 (21-140)	81.1±33.3[b] (20-136)	47.8±29.7 (6-93)	64.8±31.3 (24-136)

Data is shown mean±SD (min – max),

[a] $P<0.05$ (Lumbar paravertabral muscle activity higher in males than females)

[b] $P<0.05$ (Lumbar paravertabral muscle activity higher in Control group's males than LBP group's females)

[c] $P<0.05$ (Lumbar paravertabral muscle activity higher in LBP group's males than LBP group's females)

LPMA results during stretching exercises: The highest LPMA was found during stretching left hip flexors in control group's male subjects (51.2 mV) and the lowest LPMA was found during stretching lumbar extensors in control group's females (15.9 mV). Control group's male was performed higher LPMA during stretching left hip flexors than control and LBP females ($p<0.05$). No statistically differences were found in LPMA during stretching exercises between both group's male subjects ($p>0.05$).

In LBP patient with a bulging or herniated disc with pain is radiating down into the hip and leg[12]. Any movements, active or passive, of the lower extremity lead to an activation of the erector spine muscles. In our study, although no statistically differences in groups, LBP group male's LPMA was higher than Control males in pronelying (73.4%) and long sitting (26.5%) positions. Because of increases the normal curves in the neck and the low back resulting in additional nerve compression and stress to the guiding joints or facets of the vertebrae prone position is not suitable as a resting position for patients with LBP[12].

Gallagher[13] demonstrated that the angle-specific activation of the erector spinae muscle is strongly influenced by the hip and pelvis position and rotation. Combined spine and hip-extension exercises, such as trunk extension with fixed trunk or fixed legs, demonstrated synchronized activation of all dorsal chain muscles[14].

In our study no statistically differences were found in LPMA between LBP and Control groups except the gender differences. In addition erect, trunk lateral flexion and hyperextension, squat, crawling and kneeling on one leg positions were found higher LPMA in LBP group than Control (2.9 - 93.2%). Elevation in LPMA is reflected to erector spinal spasms. Trunk hyperextension and lateral flexion are increased in LPMA and muscle soreness. Thus, the patients with LBP should avoid from this positions. Although the trunk hyperextension and lateral flexion positions, in trunk flexion (M: 2.9%, F: 33.5%) and rotation (M: 16.9%, F: 5.6%) LPMA were decreased in LBP group. Epidemiologically, trunk rotation has been associated with over 60% of low back injuries; and, it has been ascribed as the sole factor in causation of back injuries in 33% of cases[15]. Andersson *et al.*[16] observed that the highest activity observed in quadratus lumborum and deep lateral erector spinae occurred in ipsilateral trunk flexion in a side-lying position and for superficial medial erector spinae during bilateral leg lift in a prone position.

Nouwen *et al.*[17], studied on bilateral paraspinal EMG at levels L1-L2 and L4-L5 and abdominal EMG of a group of 20 low-back pain patients were compared to those of a group of 20 pain-free controls during flexion, extension, lateral bending to right and left and rotation to right and left. The results showed no significant left-right differences in paraspinal EMG levels between low-back pain patients and pain-free controls during any of the movements. In more recent study Lariviere *et al.*[18], compared the EMG activity of the trunk muscles between normal subjects and chronic LBP patients during standardized trunk movements. The EMG amplitude analysis revealed significant differences between groups for some muscles (left lumbar and thoracic erector spine). The abnormal (asymmetric) EMG patterns detected among chronic LBP patients not explained by postural asymmetries.

Strengthening exercises for the abdominal muscles are frequently used in the rehabilitation of low back pain. Kankaanpaa *et al.*[19] reported that the chronic LBP patients are weaker and fatigued faster than the healthy controls. However, the duration of gluteus maximus activity shorter in the back pain patients than in controls during the trunk flexion and it ended earlier during extension[20]. In another study Suter and Lindsay[21] showed that the golfers with chronic LBP reduced back endurance associated with significant inhibition of the knee extensors, indicating that this muscle group cannot be activated to a full extent.

In our study, although no statistically differences in groups, during the strengthen exercises in supine position LPMA were decreased in LBP group (2.5 - 51.8%) than Control group. Straight-leg raising exercises did not increase in paravertabral muscle tonus. In the other hand we find higher standard deviation in posterior pelvic exercises. Allison *et al.*[22] demonstrated that pelvic tilting causes substantial recruitment of global muscles such as the rectus abdominus and external obliques. It may be unwise to recommend this exercise during the early phases of rehabilitation for some patients with severe low back injuries because of preloading of the spinal structures[22]. During the posterior pelvic tilt exercises many subjects' in our study contract abdominal and paravertabral muscles together. These results demonstrate the importance of teaching patients the posterior pelvic tilt exercise. Strengthen exercises in prone position LPMA were decreased in LBP group's male (13.2 - 35.5%) and females (4.8 - 15.0%). Differences in low back muscle fatigability, indicated as a decrease in EMG signal of the lumbar back muscles, have been demonstrated between groups of back pain patients and healthy control subjects[3,23,24]. Furthermore, high fatigability of paraspinal muscles has been shown to be associated with the presence as well as the risk of developing LBP[25]. A decrease in EMG signal has been associated with muscle metabolic correlates to fatigue, most notably the accumulation of H^+ ions at the sarcolemma as lactic acid is produced and disassociated[2,26,27]. Leinonen *et al.*[20] reported that the activity of the gluteus maximus muscle during the flexion-extension cycle reduced in patients with chronic low back pain. In our study gluteus maximus muscle's strength in manuel muscle testing and LPMA was decreased in LBP groups. Although no statistically differences were found between groups, the male subjects performed higher LPMA than females. Because of our subjects young and with lower pain muscle strength were found similar in groups. As shown in strengthen exercises LPMA were decreased during stretching exercises in LBP groups male (9.9 - 33.8%) and female (1.4 - 9.0%).

Our opinion while muscle weakness may be caused by immobilization after injury, or as the cumulative effect of poor motor habits and decreased activity. The condition may include atrophic loss of muscle cross-sectional area, inefficient vascularization and compromised biochemical and physiological function. There may also be a change or diminution in neural drives which accompany changes in muscle tissue. The patterns of dysponetic sEMG activity may include decrements in peak torque, power deficits (i.e., inability to sustain force through ROM arcs) and impaired fatigue resistance. Maximal effort sEMG activity will probably be decreased on the involved side. Muscle physiology studies generally demonstrate a higher muscular endurance in women[28]. This could be explained by the greater capacity of women to use oxidative phosphorylation to produce ATPs, given that muscle composition in terms of muscle fiber proportion type (type I vs type II) is the same in both genders for back muscles and that the absolute load produced is apparently unrelated to gender differences[28-29]. The healthy subjects showed higher peak extension moment at L5/S1 than chronic LBP subjects and men generated a significantly higher extension moment than women. However, higher values (more efficient muscle contractions) were obtained for the chronic LBP and female groups[30].

In our study in most of positions and exercises LPMA were decreased in female than male subjects in both groups. Gender differences were observed significant in standing with arms 90^0 flexion, trunk rotations and strengthen exercises in prone positions. These results are related muscle mass and force.

The interestingly were found in our study during resting, body movement and stretching exercises LPMA increased and during the stabilization and strengthen exercises LPMA were decreased in LBP group. Consequently LBP patient paravertabral muscles are not relaxed and/or effort enough muscle force during daily living activities. Thus LBP patients may open to microinjuries and reinjuries. Further studied needs which are investigated the LPMA during in daily living activities.

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