ORIGINAL ARTICLE

Nr 2023;13 (1):148-155

Electromyographic Activity of Posterior Oblique Sling Muscles During Gait in Subjects with Chronic Non-Specific Low Back Pain *versus* Healthy Controls

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DOI:
10.32098/mltj.01.2023.17

LEVEL OF EVIDENCE: 3

SUMMARY
Objective. To measure the surface electromyographic (EMG) activity of gluteus maximus (GMax) and latissimus dorsi (LD) muscles during walking and to measure the scapular upward rotation at different ranges of shoulder abduction in subjects with chronic nonspecific low back pain (CNSLBP) *versus* healthy controls.
Methods. Twenty-six subjects with unilateral CNSLBP with a mean age (y) of 25.15 ± 4.11 and 26 age-matched healthy controls with mean age (y) of 23.88 ± 2.64 were recruited through direct referrals for this cross-sectional, comparative analysis. EMG activity of the GMax and contralateral LD muscles were recorded during treadmill walking using surface electrodes. Scapular upward rotation was measured using bubble inclinometers at 0°, 45°, 90°, 135°, and end range abduction. Analysis of variance (ANOVA) was used to analyze the difference between the two groups.
Results. No statistically significant difference existed between the two groups regarding the recorded EMG activity of GMax and LD muscles during walking. Also, there was no statistically significant difference between the groups in scapular upward rotation measured at the different ranges of shoulder abduction.
Conclusions. EMG activity of GMax and LD muscles and scapular upward rotation does not seem to be different between subjects with CNSLBP and healthy controls.

KEY WORDS
Low back pain; posterior oblique sling muscles; electromyography; motor control; regional interdependence.

INTRODUCTION
The concept of regional interdependence is important in musculoskeletal physical therapy, and it indicates that a dysfunction in one body area can be caused by abnormalities in remote regions (1, 2). Following this concept, chronic nonspecific low back pain (CNSLBP) can be viewed as dysfunction that can be caused by abnormalities in the upper, and lower limbs and/or the spine (1, 3-5). Although CNSLBP is widely prevalent, the nature of the condition is still elusive with no specific cause reported in about 85% of cases (6-8).
A more accurate diagnosis of CNSLBP has been the target of research with more objective methods of assessment that have proven to be essential to better treat the condition. The change in muscle recruitment patterns and motor control strategies have been linked to the causes of CNSLBP (9). Patients with CNSLBP have been shown to inappropriately activate lumbopelvic and trunk muscles which can cause more dysfunction (10, 11).
The posterior oblique sling muscles including the erector spinae (ES), hamstrings, gluteus maximus (GMax), and latissimus dorsi (LD) play an important role in stabilizing the trunk and driving motor control strategies in patients with low back pain (12). Through its connection to the LD through the thoracolumbar fascia, the GMax muscle plays a major stabiliz-

ing force on the spine and unloads some of the load placed on the spine by dispersing it to the lower limbs. In addition, it has an important function during walking to extend the hip and prevent the excessive forward flexion of the trunk (13, 14).

While the GMax muscle is usually inhibited and the LD muscle is usually facilitated, the dysfunction between these two muscles can contribute to the dysfunction seen in patients with CNSLBP. When the GMax is inhibited which can result in a decrease in lumbopelvic stability, the contralateral LD muscle is facilitated to compensate for its insufficiency. This may also result in excessive scapular upward rotation since the LD muscle is a scapular upward rotator (15).

Although previous studies (15-23) have tried to investigate the relationship between the GMax and LD muscles during static tasks such as prone hip extension, no study has investigated the relationship between EMG activity of GMax and LD muscles during gait in subjects with CNSLBP and healthy control to the authors' knowledge. Therefore, the primary objective of this study was to measure the EMG activity of GMax and LD muscles during walking. A secondary purpose was to measure the scapular upward rotation at different ranges of shoulder abduction in subjects with CNSLBP *versus* healthy controls. Since there are contradictory data in the published literature, it was hypothesized that there will be no significant difference between the EMG activity of GMax and LD muscles during walking in subjects with CNSLBP *versus* healthy controls. Also, it was hypothesized that there will be no significant difference between the two groups regarding the degree of scapular upward rotation measured at different ranges of shoulder abduction.

METHODS

Study design and setting

This was a cross-sectional and comparative analysis conducted at the EMG laboratory of the Faculty of Physical Therapy, Cairo University. The study was approved by the institutional review board (IRB) of the Faculty of Physical Therapy, Cairo University (approval number: P.T.REC/012/003643 – Date of approval: February 27, 2022).

Sample size calculation

To detect an effect size of Cohen's d = 0.82 with 80% power (alpha = 0.05), G*power software (version 3.1.9.7; Franz Faul, Universitat Kiel, Germany) suggested we need 50 participants (25 in each group) using an independent sample t-test (two-tailed). The effect size was calculated based on a standard deviation of 16 points in a group of subjects with CNSLBP and an expected mean difference of 9 points from a previous similar study (24).

Participants

Out of 69 subjects who were screened for eligibility, 52 met the inclusion criteria. These were 26 subjects with unilateral CNSLBP (group A) and 26 age-matched healthy controls (group B). Those with unilateral CNSLBP were recruited through direct referrals from their orthopedic physician and they had to meet the following inclusion criteria: age ranges between 20 and 40, unilateral CNSLBP for more than three months, at least a score of 3 out of 10 on the visual analog scale (VAS), body mass index (BMI) less than 30, and symptoms confined to the lower back with no radiation. Subjects were excluded if they have non-mechanical low back pain, lower limb deformities, any neurological disorders, any shoulder dysfunctions, age younger than 20 or older than 40, any physical dysfunction affecting the lower limb that restricts walking, and BMI higher than 30.

Assessment procedure

After eligible subjects signed the informed consent form, their demographic data were collected. After a detailed explanation of the study and assessment protocol, their height and weight were taken using a universal height and weight scale (Model Number: Zt-120 Dial Body Scale, Perlong Medical Equipment Co., Ltd., Shanghai, China). Their BMI was then calculated using the following formula: BMI = body weight (Kg)/squared height (m^2). Then the subjects were prepared for recording EMG activities and for measuring scapular upward rotation.

The procedure for recording EMG activity

The EMG activities of the GMax and LD muscles were measured. For subjects in group A with unilateral CNSLBP, EMG activity of the ipsilateral GMax and contralateral LD muscles was recorded (*i.e.*, if the subject has a right CNSLBP, the right GMax and left LD activities were recorded). For subjects in group B, the dominant GMax and contralateral LD muscle activities were recorded. An EMG unit (Neuro-MEP.NET, Neurosoft, Ivanovo, Russia) using two EMG channels and version 4.1.7.0 software was used (**figure 1**).

The amplifier has two electrically isolated channels with an impedance of less than 10 m ohms. It also has up to 10 traces gain with a resolution of 1,000 per trace. Disposal adhesive electrocardiography (ECG) electrodes measured 44 × 28 mm were used. The EMG unit bandwidth was 5-500 Hz, and the sample rate of the EMG signal was 2,000 samples/second.

Before placement of surface electrodes over the muscles, the skin was cleaned with 70% alcohol and shaved if needed. For GMax electrode placement, the active electrode was placed halfway between the greater trochanter and the second sacral vertebra, the reference electrode was placed lateral to the active one at distance equal to the size of the

Figure 1. Neuro-MEP.NET EMG Surface apparatus.
(1) Screen, **(2)** Printer, **(3)** Amplifier, **(4)** Keyboard, **(5)** Computer processing unit, **(6)** Foot switches.

electrode (**figure 2**). For LD muscle, the active electrode was placed over the muscle belly halfway between the midaxillary line and the T9 spinous process 4 cm below the inferior angle of the scapula. The reference electrode was placed medial and slightly below the active electrode at the level of the T10 spinous process at a distance equal to the size of

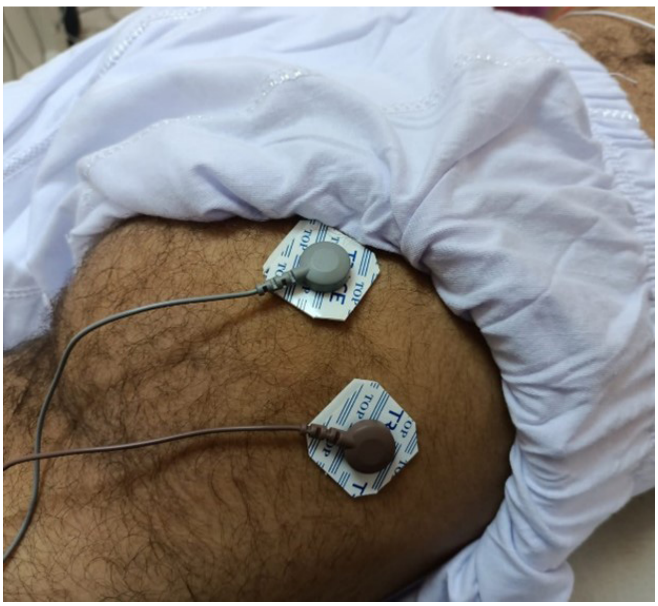

Figure 2. Electrode placement for GMax muscle.

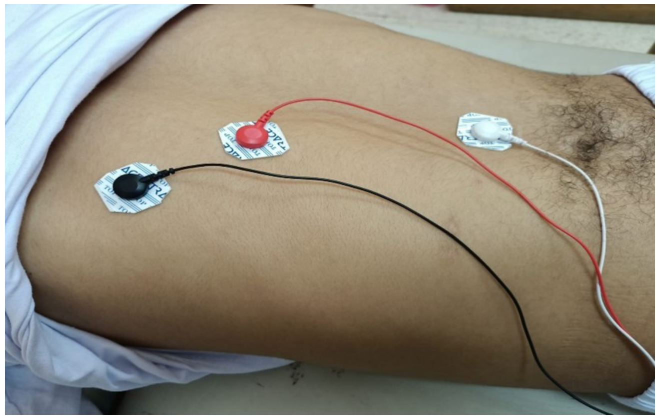

Figure 3. Electrode placement for latissimus dorsi muscle.

the electrode. The ground electrode for both muscles was placed on the spinous process of L2 (17, 24) (**figure 3**).
The muscle activity of GMax and LD muscles was recorded during walking on a treadmill at 3 km/hour which was standardized for all subjects regardless of their conditions (25). After 3 minutes of walking familiarization on the treadmill, the EMG signal from both muscles was collected for 30 seconds and the first and last 5 seconds were discarded (26). Patients were also familiarized with walking on the treadmill without any wires attached to them to practice and to explain how to safely stop the treadmill in case of an emergency. A regular treadmill (via delle pesche, 12547023 Cesena (FC), Italy) with zero inclination was used.
To normalize the EMG activity for the recorded muscles, the root mean square (RMS) value was obtained using the maximum voluntary isometric contraction (MVIC) from the corresponding positions used for the muscle test. It was recommended, however, to get a submaximal isometric contraction for the GMax muscle because a maximum contraction may produce pain which would invalidate the use of the RMS value for normalization (27).
Using the same electrode placement as before, the subject was asked to lift both knees off the table from a prone position to produce bilateral hip extension with the knee flexed to 90 degrees and hold them for 5 seconds for GMax muscle (**figure 4**). For normalization of the RMS value of the LD muscle, the subject was asked to produce MVIC against the therapist's hands placed on the distal posterior surface of the arm. The subject was asked to extend the shoulder while the arm was aligned at the edge of the table, forearm hung outside the table, elbow flexed to 90 degrees and hold the contraction for 5 seconds. The scapula and the contralateral pelvic were supported on the table by a research assistant (27) (**figure 5**).
The signal obtained during walking on the treadmill was amplified and the average RMS of the recorded EMG

Figure 4. Submaximal voluntary isometric contraction for normalization of GMax muscle.

Figure 5. MVIC method for normalization of LD muscle.

activity during walking was calculated and expressed as a percentage of the normalized value. The average percent normalized value of three walking trials was used for data analysis.

Measurement of scapular upward rotation

A standardized method of measurement was used (28). This involves the use of two bubble inclinometers for measurement (Baseline® Bubble Inclinometer, Fabrication Enterprises INC, White Plains, New York 10602, USA). One inclinometer was fixed using straps on the distal humerus for measuring shoulder abduction, and the other was placed on the spine of the scapula. Measurement was taken in the resting position (0-degree abduction), then

Figure 6. Measuring scapular upward rotation using bubble inclinometers.

the subject was asked to abduct the arm to 45, 90, and 135 degrees, to end range abduction, and the scapular upward rotation was recorded (**figure 6**) at each of the ranges. Upward rotation of the scapula on the same side of the tested LD muscle was measured.

Data analysis

Data were analyzed using the statistical package for social science (SPSS) program, version 27 (SPSS Inc, Chicago, IL, USA). Data were tested for normality using the Shapiro-Wilk test and showed normal distribution. An independent sample t-test was used to compare the demographics between the two groups for continuous variables (age, weight, height, and BMI) and the Chi-squared test was used to compare the sex distribution between the two groups. Analysis of variance (ANOVA) was used to compare the mean values between the two groups. The significance level was set at $p \leq 0.05$.

RESULTS

In group A there were 18 (69%) females and 8 males (31%), while in group B there were 17 females (65%) and 9 males (35%). There was no significant difference between groups for sex distribution with χ^2 value = 0.08 and $p = 0.76$. **Table I** summarizes the basic characteristics of the participants. No statistically significant difference between the two groups was found for any of these variables.

There was no statistically significant difference in the EMG activity of the GMax and LD muscles between the two groups with $p > 0.05$ (**table II**). Similarly, there was no statistically significant difference between the two groups for the mean scapular upward rotation measured at different angles of shoulder abduction ($p > 0.05$) (**table III** and **figure 7**).

Table I. Basic characteristics of participants.

	Subjects with CNSLBP	Control group	P-value
	Mean ± SD	Mean ± SD	
Age (years)	25.15 ± 4.11	23.88 ± 2.64	0.19
Weight (kg)	67.5 ± 9.71	69.15 ± 9.32	0.53
Height (cm)	166.96 ± 9.33	166.34 ± 9.91	0.81
BMI (kg/m²)	24.22 ± 3.28	24.92 ± 2.53	0.38
Sex, n (%)			
Females	18 (69%)	17 (65%)	0.76
Males	8 (31%)	9 (35%)	

SD: standard deviation; P-value: level of significance.

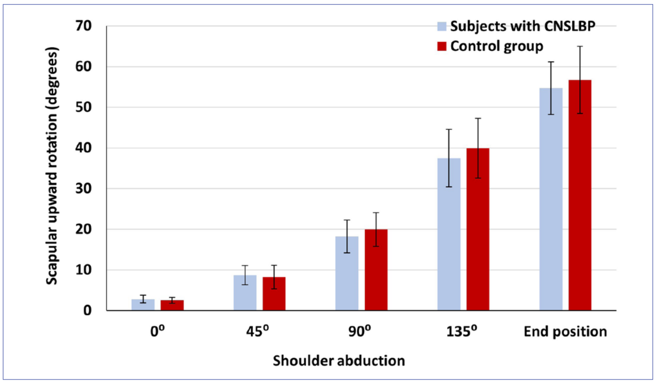

Figure 7. Mean scapular upward rotation of subjects with CNSLBP and control group.

Table II. Comparison between EMG of GMax and LD muscles in subjects with CNSLBP and control group.

EMG (%MVIC)	Subjects with CNSLBP	Control group	MD	F- value	P-value
	Mean ± SD	Mean ± SD			
Gluteus maximus	69.64 ± 25.09	77.42 ± 21.49	-7.78	1.44	0.23
Latissimus dorsi	57.46 ± 19.76	51.41 ± 18.51	6.05	1.29	0.26

SD: standard deviation; MD: mean difference; F-value: Fisher statistics value; P-value: probability value.

Table III. Comparison of scapular upward rotation between subjects with CNSLBP and control group.

Shoulder position	Subjects with CNSLBP	Control group	MD	F-value	P-value
	Mean ± SD	Mean ± SD			
0° abduction	2.85 ± 0.93	2.53 ± 0.72	0.32	1.86	0.17
45° abduction	8.72 ± 2.39	8.25 ± 2.88	0.47	0.41	0.52
90° abduction	18.21 ± 4.02	19.95 ± 4.14	-1.74	2.35	0.13
135° abduction	37.49 ± 7.06	39.93 ± 7.35	-2.44	1.49	0.22
End range abduction	54.68 ± 6.47	56.73 ± 8.22	-2.05	0.99	0.32

SD: standard deviation; MD: mean difference; P-value: probability value.

DISCUSSION

While previous studies (15-23) have primarily focused on muscle activity during static tasks (*e.g.*, prone hip extension), this study targeted a more functional approach and investigated the EMG activity of posterior oblique sling muscles during walking. The researchers of the current work were interested in detecting the changes that may happen during functional activities such as walking and how subjects with CNSLBP recruit the posterior oblique muscles *versus* healthy controls. Although the muscle activities were tested during a short walking period (30 sec), it may provide insight for future research to further investigate the same muscle activities during longer walking tasks or even during more complex tasks such as running.

Although there was no statistically significant difference between subjects with CNSLBP and healthy controls in the recruitment of the GMax muscle, subjects in the CNSLBP group showed a slightly lower activity pattern of GMax muscle during walking than those healthy subjects. The GMax muscle plays an important role in controlling the lumbosacral spine and if weak, it can contribute to the development of low back pain (14, 29-32). Previous literature, however, showed contradictory results regarding the recruitment of GMax muscle in patients with CNSLBP. Some studies reported that the GMax muscle showed higher activation patterns in subjects with CNSLBP as compared to healthy controls (15-17). While others found that the muscle has a decreased recruitment pattern in subjects with CNSLBP as compared to healthy controls (18-23). It is important to note, however, that the EMG activity of GMax in these studies was recorded during static positions and not during gait as in the current study.

The EMG activity of the LD muscle, on the other hand, was slightly higher in subjects with CNSLBP as compared to the healthy controls although statistical significance was not present as well. This can be explained by that subjects with CNSLBP may activate the trunk muscles as a compensatory mechanism to achieve lumbopelvic stability. The contradiction between the result of this study and previous studies (15-23) may arise from the fact that muscle activation patterns are different in static *versus* dynamic tasks. Since previous studies used static tasks such as prone hip extension and we used walking tasks, it is possible that subjects with CNSLBP use different activation patterns to compensate for the presence of pain or mobility deficits or use different motor control strategies. This may result in higher or lower activation patterns which need to be further investigated in future research.

The result of the current study is consistent with the result of the work by Mohamed *et al*. (24) who found increased activation of LD and decreased activation of GMax muscles in subjects with chronic low back pain as compared to controls. Their study, however, measured the activation of muscles on both sides of the body, unlike our study. Also, the major difference between this study and their work is that they measured the EMG muscle activity during prone hip extension while in this study we measured the same muscle activities during walking on a treadmill.

Increased scapular upward rotation was reported in subjects with chronic low back pain as compared to healthy controls by the work of Mohamed *et al*. (24). Our study, however, did not find a statistically significant difference between groups with a slight increase in the degree of scapular upward rotation measured at 0 and 45 degrees of abduction in subjects with CNSLBP. This is consistent with the work of Taghizadeh *et al*. (33) who found increased scapular upward rotation at zero- and 40-45-degrees abduction in subjects with CNSLBP as compared to healthy controls. They used, however, the lateral scapular slide test for assessment, while in our study, we used an inclinometer-based assessment. They justified that the increase in scapular upward rotation may be due to the anatomical attachment of the LD muscle to the inferior angle of the scapula, but it was not clear why the upward rotation would increase in some ranges while others did not.

The current study can be viewed within the scope of several limitations. First, the EMG activity of only two muscles was measured, and only one pair of the muscles were tested *i.e.*, ipsilateral GMax and contralateral LD muscles in subjects with CNSLBP, the dominant GMax and contralateral LD muscles in healthy controls. It is useful that future research considers measuring the muscle activities bilaterally and compares between them to obtain a better picture of the muscle recruitment patterns in subjects with CNSLBP *versus* healthy control during walking.

Second, we recommend that future research takes it a step further and investigate EMG muscle activities during more complex tasks such as running and compare their results to ours. It is important to know how the muscles behave when the demands of a task increase. This will give an insight into how patients with long-standing low back pain and who may be more physically active such as runners cope with their conditions and how much stabilizing activity of GMax and LD muscles is needed when the task intensity increases.

Third, the small sample size may have contributed to the findings of no statistically significant difference between the groups. A larger sample size could have shown different results. It is recommended that future research increase the sample size and find out whether or not this can be a factor for different results.

CONCLUSIONS

Based on the results and considering the limitations, EMG activity of GMax and LD muscles and scapular upward rotation does not seem to be different between subjects with CNSLBP and healthy controls.

FUNDINGS

No funds were available for this study.

DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

WA, MA: study design, providing intervention participation, data collection and analysis. MA, SA, HE: editing.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

ACKNOWLEDGMENTS

The authors would like to thank the participants in this study.

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