Assessment of Gastrocnemius Muscle Activity in Patients with Chronic Mechanical Low Back Pain

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ABSTRACT
Background: One of the most common musculoskeletal conditions that impair quality of life and cause functional impairment is chronic mechanical low back pain (CMLBP). **Objective:** The purpose of this study was to assess the gastrocnemius electro-myographic activity when compared to healthy controls in patients with CMLBP.
Patients and Methods: Fifty-two male and female participants were invited to participate in this study, divided as the following: group (A) (Study group) involved 26 participants with chronic mechanical low back pain, and group (B) (Control group) involved 26 age-matched healthy volunteers. **Results:** There were no significant differences between study group (A) and control group (B) in the electro-myographic activity of gastrocnemius muscle (amplitude and frequency). In addition, there were no significant correlations between gastrocnemius muscle activity and pain intensity measured via visual analogue scale (VAS), static balance measured via single leg stance test and dynamic balance measured via Y balance test. **Conclusion:** Electro-myographic activity of gastrocnemius muscle seems to be not affected in chronic mechanical low back pain patients.
Keywords: Balance, Gastrocnemius, Low Back Pain, Muscle activity.

INTRODUCTION

One of the most common musculoskeletal conditions that interferes with functioning and lowers quality of life is low back pain (LBP) **(1)**. It also causes significant problems in both the personal and professional lives of individuals **(2)**. Its prevalence ranges from 22 to 65% **(3)**. Based on how long it had been present, it was divided into three groups: acute (0–6 weeks), sub-acute (7–12 weeks), and chronic (> 12 weeks) **(4)**. The most common type of chronic pain in the world is mechanical LBP which leads to functional disability and affects quality of life **(5)**. According to definitions, it is characterized by back discomfort that is mechanical and last for more than three months and is felt between the gluteal fold and the last rib **(6)**. When it comes to maintaining postural stability, individuals with LBP employ a more rigid method compared to healthy people, who adopt a multi-segmental strategy. Instability may result from this strategy as postural control demands increase **(7)**.

All muscles of the human body work as one unit. As they are connected by a wide network of myofascial chains acting as linking components **(8)**. The recognition of soft tissue as a pain generator in CLBP is not a new concept. Consideration has been given to the back fascia in relation to the pathophysiology of LBP **(9)**. The Superficial Back Line (SBL), which is suggested to be most related to injuries of the lumbar spine, is a fascial line that runs from the base of the foot to the top of the head, connecting and shielding the entire posterior surface of the body **(10)**.

Static balance may be impacted by calf muscle fatigue when standing on one leg with both eyes open or closed **(11)**. Altered muscle activation pattern of lower extremity musculature such as gastrocnemius muscle which acts as a two-joint muscle for both ankle and knee joints **(12)**. It could disrupt normal sagittal spine–pelvis–leg alignment and alter the lumbar–pelvic rhythm **(13)**. This can lead to excessive lumbar tissue loading and lumbar intra-discal pressure, predisposing individuals to LBP **(14)**.

The study aimed to investigate the electro-myographic activity of gastrocnemius muscle relation to pain and postural stability when individuals with chronic low back discomfort are contrasted with healthy controls.

PATIENTS AND METHODS

Study participants

Fifty-two male and female subjects took part in the study. This study extended from February 2023 to January 2024.

Study design

The study used a cross-sectional observational design. There were two groups of participants. Study group A had 26 individuals suffering from CMLBP. Group B (control group): included gender- and age-matched 26 healthy volunteers. All patients in group A were diagnosed and referred by an orthopedic surgeon. The study was carried out at Delta University in Egypt's Faculty of Physical Therapy.

To be a participant in this study, subjects were evaluated using the following criteria: patients diagnosed and referred by an orthopedic surgeon with CMLBP (met the criteria of The ACR Appropriateness, have a history of LBP without known cause, and last for more than 3 months in a persistent form **(15)**, their BMI was from 20 to 25 **(16)**. Age of patients ranged from 20 to 30 years. If a participant did not match the inclusion criteria, or if they had any neurological symptoms, history of previous surgery in the back, inflammatory arthritis, any systemic diseases, radicular pain, spinal fractures, or uncorrected vision impairment, vestibular dysfunction, and auditory deficits, they were not allowed to participate in this study.

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Outcome measures:

1. Pain assessment by VAS: A horizontal line measuring 100 mm is anchored at both ends by word descriptors, "no pain" on the left and "worst imaginable pain" on the right. It is a valid and reliable assessment tool for pain intensity [17].
2. Electromyography (EMG): Surface EMG signals with a high density were obtained from the gastrocnemius muscle by (Neuro-EMG-Micro 153032, Russia) 2/4 channels with electronic unit dimentions140×190×150 mm was utilized to capture, store, and evaluate all the information pertaining to each subject's muscle activity, figure (1).

Figure (1): Electromyography device.

3. The single-leg stance test evaluates a person's ability to balance by having them stand on one foot with their eyes open and then closed, greatly lowering their base of support [18].
4. The Y balance test was used to assess the leg's dynamic balance capacity. It demonstrated strong interrater correlation (0.85–0.91) and interrater correlation (0.99–1.00) in a prior study [19].

METHODS

The severity of the pain was measured by the visual analog scale. The patient was instructed to mark the position on the line that best reflected how they felt about their current state of pain [20].

In the single-leg stance test, the participants were asked to stand barefoot on a level surface, with one leg lifted so that it was close to but not touching their weight bearing limb's ankle. For the entire eyes open test period, each participant was instructed to fix his attention on a place at eye level on the wall in front of him. The individual was instructed to fold his arms across his chest before raising the affected limb. To find out how long the person could stand on one limb, the investigator used a stopwatch.

Y balance test was used. Each participant stood barefoot with toes positioned at a landmark. Next, the participants reach their non-weight bearing LE into one of the three components of the “Y” [anterior (ANT); posteromedial (PM); posterolateral (PL)]. The anterior reach trials were performed three on the right[19].

Gastrocnemius muscle activity was recorded using high-density surface electromyography (EMG) signals. Electromyography: high-density surface EMG signals were measured from gastrocnemius muscle by (Neuro-EMG-Micro 153032, Russia) 2/4 channels with electronic unit dimensions 140×190×150 mm. Conductive paste (Every, Italy) was used to fill the electrode cavities and attached to the subject's skin after the skin had been shaved and rapped with abrasive paste and water to measure the right gastrocnemius muscle activity. Ag/AgCl surface electrodes with a 20 mm diameter and a 25 mm gap between them were used as the EMG electrodes. The muscle's belly, or the most noticeable bulge/calf, was where the electrode was placed. Based on SEMG to evaluate muscles in a non-invasive manner, the SEMG system was configured during the measurement [21]. Two quasi-isometric tiptoe standing calf workouts were performed, with each subject clutching a 10-kg disk until the exercise was completed. The first trial stopped when the heels touched the ground, and the individuals continued to stand on their tiptoes until they failed. Following a minute of rest, the participants carried out the second trial [22]. For both trials, the average was determined. Examiner encouragement was used to perform to the best of one's abilities. The main outcome measures (amplitude and mean power frequency) were recorded in the data sheet [23].

Sample size calculation:

The G*POWER statistical program (version 3.1.9.2; Franz Faul, Universität Kiel, Germany) was utilized to calculate the sample size expecting a large difference between groups and showed that 26 patients per group were the necessary sample size for this investigation. The following parameters were used in the calculations: α=0.05, power=80%, effect size=0.8, and allocation ratio N2/N1 = 1. The calculation yielded a sample size of 52 participants.

Ethical approval

The Ethical Committee for Human Research at Cairo University's Faculty of Physical Therapy in Egypt gave its approval to the study (NO: P.T.REC/012/004634). After being informed of all the details, each participant provided written consent. Throughout the course of the investigation, the Helsinki Declaration was adhered to.

Statistical analysis

Version 25.0 of the statistical SPSS package application for Windows was used to do the statistical analysis. The Shapiro-Wilk test was used to determine whether the data were regularly distributed or not. These results made it possible to perform both parametric and non-parametric analyses. Quantitative data for clinical general characteristics (age, weight, height, pain measured via VAS, dynamic balance measured via Y-balance and static balance measured via single leg stance test), amplitude, frequency, and VAS were reported as mean and standard deviation. Gender-specific categorical data were presented as frequency and percentage, and the Chi-square test was used to compare the two groups. The investigated major dependent variables of interest were compared using the one-way Multivariate Analysis of Variance (MANOVA) test (amplitude, frequency, VAS, Y-balance and single leg stance test) at different tested groups (study group vs. control group). Pearson simple correlation coefficient was performed to investigate the relation and direction between the gastrocnemius muscle activity (amplitude and frequency) with pain intensity, static and dynamic balance in CLBP patients. At the probability level, every statistical analysis was significant if P was < 0.05.

RESULTS

In this current study, a total of 52 volunteers from both genders (28 males and 24 females) participated and divided into two equal groups as the following: study group A (n = 26) suffering from CLBP with mean values of VAS = 6.49 ±1.61. Normal healthy age and gender-matched volunteers (n = 26) in control group B. The results of clinical general demographic data (Table 1) showed no significant differences in mean values of participant's age, weight, height, and BMI, and gender between the study and control groups.

Table (1): Clinical general characteristics in both groups

Variables	Groups (Mean ±SD)		*P*-value
	Experimental group (n=26)	Control group (n=26)	
Age (year)	25.50 ±4.25	24.50 ±2.92	0.328
Weight (kg)	75.38 ±11.32	75.77 ±11.66	0.904
Height (cm)	169.69 ±9.24	174.14 ±11.24	0.126
BMI (kg/m^2)	26.08 ±2.66	24.87 ±2.61	0.106
VAS	6.49 ±1.61	-----	-----
Gender (males: females)	12 (46.20%): 14 (53.80%)	16 (61.50%): 10 (38.50%)	0.266

Quantitative data (age, weight, height, BMI, VAS, Oswestry) are reported as mean ± standard deviation and compared statistically by one-way MANOVA test.

Qualitative data (gender) are reported a frequency (percentage) and compared statistically by Chi-square test.
P-value: probability value, P-value > 0.05: non-significant

The statistical comparison for main outcome variables between both groups is illustrated in table (2). No significant statistical changes were observed between the experimental and control groups in amplitude, frequency, ANT, PM, PL, equation, and single leg stance test.

Table (2): Between groups comparison for outcome variables

Variables	Groups (Mean ±SD)		Mean difference (95% CI)	*P*-value
	Experimental group (n=26)	Control group (n=26)		
Amplitude	43.63 ±26.62	38.91 ±21.26	4.72 (-8.69 – 18.14)	0.483
Frequency	193.58 ±81.95	190.46 ±71.41	3.12 (-39.71 – 45.93)	0.885
ANT	87.83 ±12.33	86.58 ±9.63	1.25 (-4.92 – 7.41)	0.687
PM	75.67 ±14.12	69.76 ±13.20	5.91 (-1.70 – 13.52)	0.125
PL	76.52 ±17.44	78.68 ±13.34	2.16 (-6.48 – 10.81)	0.617
Summation Equation	88.60 ±11.12	84.35 ±8.83	4.25 (-1.34 – 9.84)	0.133
Single-leg stance test	31.61 ±10.95	35.53 ±11.74	3.92 (-2.41 – 10.24)	0.220

Data are reported as mean ± standard deviation (SD) and compared statistically by one-way MANOVA test
P-value: probability value, P-value > 0.05: non-significant

Pearson correlation coefficients in bivariate analysis were calculated between gastrocnemius muscle activity (amplitude and frequency) with VAS, Y-ANT, Y-PM, Y-PL, summation equation and single leg stance test in CLBP patients (Table 3). These correlational studies' findings showed that there were no significant relationships between each of amplitude and frequency with VAS, Y-ANT, Y-PM, Y-PL, summation equation, single leg stance test in CLBP patients.

Table (3): Correlation between gastrocnemius muscle activity (amplitude and frequency) with pain intensity, functional activity level, and postural stability or balance in CLBP patients

Variables	Amplitude		Frequency	
	r-value	P-value	r-value	P-value
VAS	-0.053	0.798	-0.068	0.741
Y-ANT	-0.099	0.630	-0.024	0.909
Y-PM	0.119	0.561	0.156	0.556
Y-PL	0.032	0.875	0.159	0.439
Summation Equation	-0.024	0.907	0.076	0.710
single leg stance test	-0.153	0.456	-0.199	0.329

r: Pearson correlation coefficient. P-value: probability value, *Significant: (P<0.05)

DISCUSSION

The study aimed to investigate the electro-myographic activity of gastrocnemius muscle in CLBP patients compared to healthy controls. The results accepted the general hypothesis that there was no statistically significant difference between gastrocnemius muscle activity (frequency and amplitude), static and dynamic balance in CMLBP compared to age/gender-matched healthy volunteers. In addition, there was no significant correlation between gastrocnemius muscle activity and pain intensity in CMLBP patients. This was supported by the finding of the previous studies, they found there was no significant difference in the activity of erector spinae muscles in CLBP patients compared to healthy volunteers [(24)].

In addition, it is possible that the sample selected for this study had a normal flexible gastrocnemius muscle with no shortening or tightness, and this so caused unchanged muscle activity. In addition, the patient age in this study is relatively younger than in previous studies.

The study also found no significant difference in (static and dynamic balance) postural control in CMLBP patients and controls. The results were consistent with previous studies, including **Johanson *et al.*** [(25)] who, after causing back muscular fatigue, discovered no discernible variations in postural control between the groups. **Joudeh *et al.*** [(26)] found that calf muscle activity had no appreciable impact on the balance of standing. The study's findings are supported by **Marcolin *et al.*** [(23)], who discovered that the global dynamic postural balance performance was unaffected by the calf muscle's decreased EMG activity during dynamic balance exercises. Moreover, it was proved that exercise-inducing fatigue in the calf muscles had no effects on both static and dynamic balance [(27)]. It was suggested that there were compensatory mechanisms developed to counteract calf muscle fatigue (i.e., enhanced muscle spindle reflex activity) to maintain balance [(12)]. While in this study, the sustained EMG activity of the gastrocnemius may indicate a greater contribution from the soleus muscle [(24)].

The impact of aging on balance has been the subject of numerous research. According to **Zettel *et al.*** [(28)]**,** older persons had reduced attentional demands associated with balance recovery. Several authors reported that, in older patients, there was a significant decline in balance after fatigue compared with baseline circumstances, suggesting that aging had a deleterious impact on dynamic standing balance [(29,30)].

On the other hand, we observed that fatigue had no discernible impact on standing balance in our sample of young adults. Furthermore, the present study used male participants, whereas other research demonstrating a noteworthy distinction in the impact of fatigue on balance had female participants [(29)]. Gender differences in body muscle mass could be the cause of this. Males have more skeletal muscle mass than females, according to studies. In one study involving 468 males and females, the average muscle mass for men was 33 kg, while the average muscle mass for girls was 21 kg. Males exhibited a 40% increase in upper-body muscular mass and a 33% increase in lower-body muscle mass [(31)]. Males may have superior standing balance than females due to their higher muscle mass [(26)].

There was no significant difference between LBP patients and controls. This may be due to previous studies reporting that antigravity muscles such as gastrocnemius had a fatigue-resistant morphological structure and a high proportion of slow twitch fibers [(32)].

In addition, there are numerous methodological variations in the approach and measurement timing between the current and earlier investigations. While our study used young people, earlier studies looked into comparatively older participants.

Lee and Chang [(33)] indicated that calf tightness had a detrimental impact on gait and balance and that measuring muscle tightness should be taken into account when exercising and receiving treatment.

CONCLUSION

There was no significant difference between gastrocnemius activity/amplitude in CMLBP patients compared to control. In addition, there were no significant correlations between gastrocnemius muscle activity and pain intensity, balance, both static and dynamic, in individuals with persistent mechanical LBP.

- **Declaration of conflicting interests:** NIL.
- **Funding:** NIL.

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