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Chronic Low Back Pain in Women: Muscle Activation during Task Performance

Fernanda G Santos[1)], Carolina M Carmo[1)], América C Fracini[1)], Rita R P Pereira[1)], Kelly S Takara[1)], Clarice Tanaka[1)]*

[1)] *Department of Physiotherapy, Communication Science and Disorders, Occupational Therapy, Faculty of Medicine, University of São Paulo: Avenida Doutor Enéas de Carvalho Aguiar, 255. Prédio dos Ambulatórios, 4°andar, Bloco 2. Serviço de Fisioterapia, Brazil*

Abstract. [Purpose] The aim of this study was to compare the activities of the trunk and hip muscles in chronic low back pain (CLBP) women and asymptomatic subjects during the kneeling to half-kneeling task. [Subjects] Twenty-nine CLBP women and thirty asymptomatic subjects (C) participated in this study. [Methods] Electromyography activity (EMG) of the obliquus internus abdominis (OI), the lumbar erector spinae (LES) and the gluteus medius (GM) muscles was recorded bilaterally. The peak amplitude, the time of peak amplitude and the integrated linear envelope EMG for each muscle were obtained. [Results] The C group bilateral OI and GM muscles displayed higher peak amplitudes and earlier times of peak amplitude. They also had higher integrated linear envelope EMG values. The CLBP group bilateral LES muscles had higher peak amplitudes and earlier times of peak amplitude. They also showed an increased integrated linear envelope EMG values. [Conclusion] The CLBP women activate the LES muscles in the kneeling to half-kneeling task, showing different patterns of motor planning activity.

Key words: Low back pain, Postural balance, Abdominal muscles

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INTRODUCTION

Low back pain (LBP) is one of the most prevalent musculoskeletal disorders. It can cause disability and adversely impact the economy[1)]. LBP is a complex disorder with multifactorial causes and much research has focused on clarifying certain aspects of the condition while others still remain unclear. Greater knowledge of LBP might help to improve its negative impacts, such as patient pain, functional disability and work absenteeism[2–5)]. The natural history of LBP tends towards spontaneous resolution either with or without treatment. However, in a subset of patients, the development of chronic low back pain (CLBP) is debilitating and unpredictable[6)]. The determination of which patients will progress to a prolonged and disabling course is currently unknown.

CLBP patients display reduced endurance and strength of the muscles of the spine (e.g., the lumbar erector spinae) and the hip (e.g., the gluteus maximus), and decreased flexibility of the back as a result of prolonged inadequate posture, which may be responsible for the pain[7)]. A variety of CLBP treatment programs have addressed the musculoskeletal alterations responsible for the pain with protocols that address strengthening[8)] and flexibility[9)] of trunk muscles, electrotherapy with low laser therapy[10)], or alternative therapy as yoga[11)] or acupuncture[12)]. In general, good outcomes for self-reported pain, disability and improved quality of life have been reported.

The studies of motor control alterations in CLBP patients have brought new insights. People suffering from CLBP adopt different movement strategies compared to asymptomatic subjects[13–17)]. A common alteration is delay in the activation of deep muscles (e.g., the transversus abdominis and the obliquus internus abdominis) during voluntary limb movements[18–20)]. CLBP subjects also exhibit higher and constant activation of the lumbar erector spinae muscle during tasks such as walking[21)]. In CLBP patients, the change in motor planning activity might be associated with other levels of the neurologic system. Tsao et al. correlated the alterations in the pattern of transversus abdominis activity to the cortical map reorganization of the motor cortex in CLBP subjects. Later, Tsao et al. showed that the deep and superficial fascicles of the erector lumbar spinae muscles had increased overlap of motor cortical representation, suggesting that it might reduce the selection of activation between deep and superficial fascicles. In support of this theory, reeducation of the transversus abdominis delayed pattern of contraction showed shifting of the muscle cortical representation and improvement in the level of pain[24)]. Therefore, in CLBP patients it is crucial to understand the movement pattern and muscle activation during the performance of a specific task.

Tasks involving asymmetrical lower limb movements, e.g., running or climbing steps or stairs, primarily require

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*Corresponding Author. Clarice Tanaka (E-mail: cltanaka@usp.br)

lumbopelvic control for balance[25)], motor coordination, and adequate synergy of the trunk and hip muscles[26)]. In the clinical setting, the kneeling to half-kneeling task has been a useful tool for assessing lumbopelvic control in balance, due to minimum interference of the lower limbs, and it is commonly used in the treatment of neurologic patients[27)]. The task starts from the kneeling position, and the patient supports the body on one side (knee) while flexing the contralateral hip until reaching the ground with his/her foot to the final half-kneeling position.

The purpose of this study was to compare the activity of the trunk and hip muscles in CLBP patients and asymptomatic subjects during the kneeling to half-kneeling task. We chose the obliquus internus abdominis and lumbar erector spinae (trunk muscles), due to the function of the obliquus internus abdominis in stabilizing the pelvis and the spine during voluntary lower limb movement[28, 29)], and the function of the lumbar erector spinae in controling the excessive movements of the trunk in the sagittal and frontal plane[30, 31)]. The gluteus medius muscle (hip muscle) plays an important role in stabilizing the hip during unipedal dynamic tasks[32–34)]. We hypothesized that the CLBP patients would have different lumbopelvic control, tested during the asymmetrical movement of the lower limbs, showing different utilization of the trunk and hip muscles compared to asymptomatic subjects.

SUBJECTS AND METHODS

Participants

Twenty-nine women with a history of non-specific chronic low back pain [CLBP, age=45.8±5 years; Body Mass Index (BMI)=23.9±1.7 kg/m^2] and thirty healthy, pain-free women (C, age=44.5±5 years; BMI=23.7±1.5 kg/m^2) were the subjects of this study. The CLBP subjects were recruited from the Orthopedic and Traumatology Department of the Hospital das Clínicas, the University of São Paulo, and were included if they were diagnosed with non-specific low back pain (e.g., low back pain not attributable to a recognizable known specific pathology), and had experienced low back pain for at least 3 months with intensity sufficient to limit daily activity. The exclusion criteria for both groups were pregnancy, neurological conditions, obesity (body mass index: BMI>30), previous spine or abdominal surgery or any rheumatological disease. The participants did not regularly engage in physical activities. The Ethics Committee of the Clinics Hospital in São Paulo, Brazil approved the study (1174/09).

Electromyographic Recordings

Electromyography activity (EMG) was recorded using an 8-channel EMG system (EMG810C, EMG System do Brasil® Ltda, São José dos Campos SP/Brazil) and surface electrodes with 10-mm diameter Ag/AgCl discs set at an inter-electrode distance of 20 mm (EMG System do Brasil® Ltda, São José dos Campos SP/Brazil). Following skin preparation (shaved and cleaned with 70% alcohol) to reduce electrode impedance, surface electrodes were placed bilaterally (right, R, and left, L) over the obliquus internus abdominis (ROI, LOI) 2 cm inferior to the anterior superior iliac spine (ASIS), and midway between ASIS and the symphysis pubis[35)]. Electrodes were also placed on the lumbar erector spine (RLES, LLES), 30 mm directly lateral to the L2 spinous process[36, 37)], and the gluteus medius (RGM, LGM), midway between the iliac crest and the greater trochanter[38)]. A ground electrode was placed on the ulnar styloid process. The EMG signals were converted to a digital format using a 12-bit analog-to-digital converter (EMG System do Brasil® Ltda, São José dos Campos SP/Brazil). Each electrode was connected to a preamplifier (20x) and further amplified (50x) for a total gain of 1000. The raw EMG signals were recorded within a bandwidth of 20 to 500 Hz at a sampling frequency of 2 kHz. A force platform (BIOMEC400, EMG System do Brasil® Ltda, São José dos Campos SP/Brazil) was synchronized with the EMG system to determine the onset and the end of movement. All subjects were instructed to wear adapted gymnastics clothing to facilitate the attachment of the electrodes and to allow them to perform the movement as naturally as possible.

Procedure

The participants were instructed to initiate the task by kneeling on the force platform with their knees apart (at pelvis width) while maintaining the trunk in the upright position and keeping the arms free beside the body. The acquisition of the EMG data began in the kneeling position. The instructor asked each participant to perform the task: move to a half-kneeling position by flexing the right hip and then bringing the right foot forward at a comfortable pace while maintaining the left knee on the force platform to support the body weight. Task and data acquisition were completed when a stable half-kneeling position was reached and the body weight was supported on the right knee and left foot. Before the data collection commenced, the task was explained to the patients, and they were allowed to perform one attempt to familiarize themselves with the movement. The CLBP subjects were pain-free on the day of data collection, and the task did not provoke any pain. Postural reactions for balance, e.g., abduction of the arms during the task, were allowed; however, the trials in which the participants needed hand support on the ground for any moment during the task or trials in which the participant was not able to bring the right foot straight forward to the final position without interrupting the movement to support the right foot on the ground were excluded. Three EMG trials of approximately 10 seconds each were collected.

Data Process and Statistical Analysis

Raw EMG data were first converted to ASCII format with EMG System software (EMG System do Brasil® Ltda, São José dos Campos SP/Brazil) and then transferred to Origin 8 software (OriginLab Corporation, Northampton, MA, USA). The raw EMG signals were full-wave rectified and low-pass filtered using a fourth-order Butterworth filter with a cutoff frequency of 5 Hz. The EMG amplitudes were normalized with the average of the filtered values of the activity of the muscles during the task[39, 40)].

The onset and end of the task were identified using the

Table 1. The mean ± standard deviation of the anthropometric characteristics of the participants

	C group** (n=30)	CLBP group** (n=29)
Age (y)	44.57±13.6	45.8±14.3
Weight (kg)	61.27±7.1	64.72±10.8
Height (cm)	1.60±0.07	1.64±0.07
BMI (kg/cm^2)	23.77±2.1	24.15±3.9

**C group= asymptomatic subjects, CLBP group= chronic low back pain patients
*p<0.05

Table 3. The median and interquartile time (%) intervals (Q1–Q3) of the peak EMG amplitudes of the muscles analyzed

Muscles#	C group**	CLBP group**
ROI	0.42 (0.07–0.88)	0.69 (0.10–0.97)*
LOI	0.42 (0.03–0.97)	0.59 (0.08–0.90)*
RLES	0.59 (0.11–1.00)	0.36 (0.03–0.89)*
LLES	0.77 (0.13–1.00)	0.24 (0.01–0.97)*
RGM	0.44 (0.07–0.74)	0.68 (0.11–0.94)*
LGM	0.21 (0.05–0.83)	0.86 (0.13–1.00)*

#Right and left (R, L) obliquus internus abdominis (OI), the lumbar erector spinae (LES) and the gluteus medius (GM)
**C group= asymptomatic subjects, CLBP group= chronic low back pain patients
* p<0.05

force platform data, and the time of the execution of the task was normalized as a percentage so that the data could be compared between the groups. The normalized EMG data were processed, and the EMG parameters used in the analysis were the averages of peak amplitude, time of peak, and the integrated linear envelope EMG.

The age, weight, height, and BMI were compared between the groups using Student's t-test. The distribution of each variable was compared between the groups using the Mann-Whitney U-test (Minitab 15, State College, PA, USA). The alpha-level was chosen as 0.05 for all of the analyses.

RESULTS

Table 1 shows the descriptive analysis of the CLBP and C groups of age, weight, height and BMI.

There were significant differences between the groups for all of the EMG parameters analyzed, except for the integrated linear envelope of LOI. The C group right and left OI and GM muscles displayed higher peak amplitudes (RLOI, p=0.001; LOI, p=0.014; RGM, p=0.007; LGM, p<0.001) (Table 2) and earlier times of peak amplitude (RLOI, p=0.002; LOI, p=0.026; RGM, p=0.001; LGM, p<0.001) (Table 3) during the task than the CLBP group. The CLBP group right and left LES muscles showed higher peak amplitudes (RLES, p=0.003; LLES, p<0.001) (Table 2) and earlier times of peak amplitude (RLES, p=0.003; LLES, p<0.001) (Table 3) than the C group. The integrated linear envelope EMG was higher in the C group for the right OI (p<0.021) and the bilateral GM muscles (RGM, p=0.004; LGM, p=0.001) (Table 4), while the CLBP group showed increased integrated linear envelope EMG for the bilateral LES muscles (RLES, p<0.001; LLES, p<0.001) (Table 4).

Table 2. The median and interquartile intervals (Q1–Q3) and peak amplitudes of the muscles analyzed

Muscles#	C group**	CLBP group**
ROI	1.84 (0.78–2.18)	1.23 (1.00–2.44)*
LOI	1.53 (1.00–2.08)	1.28 (1.05–1.80)*
RLES	1.11 (0.99–1.32)	1.52 (1.05–8.07)*
LLES	1.13 (0.64–2.00)	1.36 (1.09–5.28)*
RGM	1.60 (1.00–2.10)	1.25 (1.00–2.16)*
LGM	1.81 (1.02–2.11)	1.19 (1.04–2.31)*

#Right and left (R, L) obliquus internus abdominis (OI), the lumbar erector spinae (LES) and the gluteus medius (GM)
**C group= asymptomatic subjects, CLBP group= chronic low back pain patients
* p<0.05

Table 4. The median and interquartile intervals (Q1–Q3) of the integrated linear envelope EMG of the muscles analyzed

Muscles#	C group**	CLBP group**
ROI	0.96 (0.12–2.00)	0.68 (0.20–1.00)*
LOI	1.00 (0.53–2.00)	1.00 (0.18–1.00)
RLES	1.00 (0.10–1.00)	1.00 (0.79–2.00)*
LLES	0.94 (0.11–1.00)	1,00 (1.00–2.28)*
RGM	1.00 (0.35–1.48)	0.66 (0.17–1.00)*
LGM	1.00 (0.87–2.00)	1.00 (0.57–1.00)*

#Right and left (R, L) obliquus internus abdominis (OI), the lumbar erector spinae (LES) and the gluteus medius (GM)
**C group= asymptomatic subjects, CLBP group= chronic low back pain patients
* p<0.05

DISCUSSION

This study was conducted to test the hypothesis that compared to asymptomatic subjects; CLBP women would have poorer lumbopelvic control, as tested during asymmetric movement of the lower limbs. The results reveal that the lumbopelvic control of an asymmetrical lower limb task is different in CLBP women compared to asymptomatic subjects. CLBP women recruit the LES muscles, while the execution of this task in pain-free women is based on the recruitment of the abdominal and hip muscles. The kneeling to half-kneeling task involves load transfer from double to single support and requires adequate motor control of the trunk and the hip. This task is not as functional as stair or step climbing, which might better represent daily living activities of trunk and hip motor control; however, it was chosen to minimize interference of the distal lower limbs joints. The alteration of the activity pattern of the trunk and hip muscles has been described during internal perturbation evoked by voluntary movement and external perturbation elicited by unexpected environmental perturbation in CLBP subjects[41, 42]. The kneeling to half-kneeling task combines internal perturbation (voluntary movement of lower limb) with hip instability (asymmetric lower limb movement).

The main finding of our study was that CLBP women mainly activate the back muscles, while asymptomatic subjects displayed activation of the abdominal and hip muscles to accomplish the kneeling to half-kneeling task. This finding is evidenced by the higher and faster peak amplitudes (time of peak), with higher muscular activity (integrated linear envelope EMG) of the LES muscles in CLBP patients, and of the OI and GM muscles in the asymptomatic subjects. This finding suggests that the core stabilization of the CLBP group is anchored in the back muscles, and in the asymptomatic subjects it is distributed between the trunk (abdomen) and the hip muscles.

Similar muscular behavior has been reported in the literature for tasks with asymmetrical demands of the lower limbs: the OI and GM muscles reportedly play an important role in stabilizing the lumbar spine and the hip in the stance phase during the gait of asymptomatic subjects[43]. Increased activity of the LES muscles was reported during walking and running by CLBP subjects[44, 45]. It seems that the CLBP subjects adopt the strategy of increased activation of the LES muscles to maintain the stiffness and stability of the spine[46–48]. However, the increased activity of the LES muscles seems to be an improper strategy that reduces endurance and alters the proper function of the lower limbs after an external perturbation[49, 50].

In our study, the CLBP patients did not acknowledge pain during the task, which shows that they adopted an improper strategy of muscular recruitment, activating the back muscles even in the absence of symptoms. The elevated activity of the back muscles might produce compressive forces in the spine and predispose CLBP patients to be vulnerable to injury and the recurrence of pain[51]. The alteration of the back muscle activity (LES and multifidus) and the abdominal muscles (TrA) has been previously associated with changes in how the cortical map of these muscles is organized in the motor cortex[22, 23]. Also, there is a change in inputs of corticomotor excitability in the trunk muscles[52]. Therefore, in agreement with Tsao and Hodges and MacDonald et al., we recommend that intervention for CLBP subjects should include symptom control or musculoskeletal alterations such as strength or flexibility, and it should also emphasize the motor control recovery of the trunk and the hip in different dynamic activities.

A limitation of this study was that subjects kept their arms free beside the body during the kneeling to half-kneeling task. Perhaps the subjects should have kept their arms crossed to control their movements, since the OI muscle activates during arm movements[18]. This study revealed important findings about the activities of muscles of the abdomen and hip during a task with minimum interference of the lower limbs in chronic low back pain population. Future studies are needed to verify the activities of the abdominal and hip muscles during asymmetrical lower limb tasks, such as climbing stairs.

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