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Association between abdominal muscle activity and lumbar muscle morphology, and their role in the functional assessment of patients with low back pain: A cross-sectional study

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Abstract

Objectives: The study aims to investigate the relationship between abdominal muscle activity and the cross-sectional area (CSA) of the lumbar muscles and assess their role in the functional assessment of patients with chronic non-specific low back pain (CNSLBP). **Methods**: 142 patients with CNSLBP were included in this study. Disability levels were evaluated with the Roland-Morris Low Back Pain and Disability Questionnaire. The functional assessments of the participants were evaluated with a 6-minute walk test. Abdominal muscle activity was measured using a pressure biofeedback unit. The CSA of the bilateral multifidus, erector spinae, and psoas muscles were measured T2-weighted MRI images at the L2-L5 levels. **Results**: Significant correlations were found between the abdominal muscle activity during the posterior pelvic tilt movement and the CSA of the erector spinae muscle at the L4 and L5 levels, and the psoas muscle at the L2−L5 levels (correlation coefficient range from 0.32 to 0.48). Abdominal muscle activity yielded a significant additional contribution to the variance on the functional assessment (R^2 change=0.101). **Conclusions**: The relationship of abdominal muscle activity with lumbar muscles and the contribution of muscle activities to functional assessment should be considered in the management of patients with CNSLBP.

Keywords: Abdominal Muscles, Low Back Pain, Magnetic Resonance Imaging, Pain Management, Paraspinal Muscles

Introduction

Spinal movements are initiated and controlled by the trunk muscles, which also support the spine and maintain its stability[1]. It has been reported that parameters such as strength, endurance, histopathological features, and activity of the trunk muscles are impaired, and because of

these reasons, spinal stability and function deteriorate in patients with low back pain (LBP)[2-4]. Trunk muscle activities in patients with chronic LBP alternate from healthy controls in order to maintain the stability of the spine, and the muscle activities are associated with morphological characteristics of trunk muscles, especially when movements and in upright posture[5-7].

Also reported that, co-contraction of trunk muscles plays a role in maintaining spinal stability by regulating internal and external loads at the spine and is important for exercises performed in the patient with LBP[8,9]. Hides et al. reported good agreement between the transversus abdominis and multifidus muscles, being two deep stabilizers that are involved in segmental stability but that have antagonistic functions[10]. In an experimental study by Raschke et al., a distributed moment histogram − a neurophysiology based approach − revealed the presence of coactivation of the
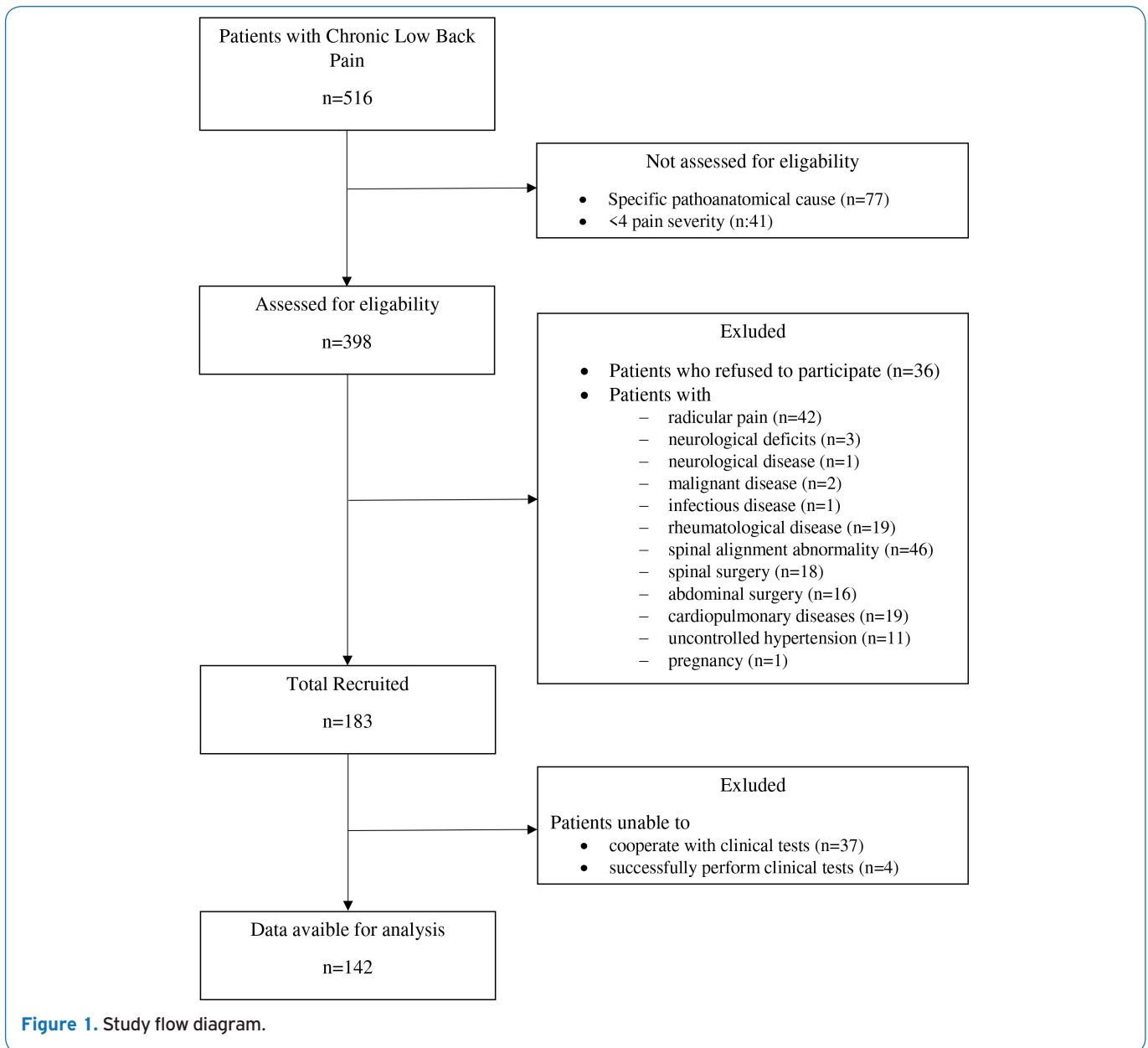
Figure 1. Study flow diagram.

erector spinae, latissimus dorsi, rectus abdominis, and abdominal external oblique muscles during dynamic trunk extension movements[11], although the relationship between abdominal wall muscle activity and the morphological features of the paravertebral muscles has not been studied in detail yet.

Motor control exercises such as posterior pelvic tilt and abdominal draw-in maneuver, which are corner exercises in the management of patients with LBP, are applied according to the principle of coactivation of trunk muscles in clinical practice. But the theoretical background of coactivation in motor control exercises has not been investigated in detail.

To our knowledge, there is only a study on this subject and this research has shown that the transversus abdominis muscle contraction ability is associated with the multifidus muscle contraction ability assessed by palpation, but not with the multifidus cross-sectional area at the L5 level[10]. However, in this study, only the deep spine stabilizer muscles were focused, and global stabilizers, another muscle group involved in motor control exercises, were not evaluated. Evaluation with posterior pelvic tilt movement with the participation of rectus and abdominal oblique muscles, which are global stabilizer muscles, may contribute to the knowledge in this field.

One of the issues that should be focused on in patients with chronic LBP is functional assessments and disability since people suffering from chronic pain have a poor physical status[12,13]. These evaluations can be made through questionnaires such as Short Form-36 or with performance-based methods such as timed up and go test, 6-minute walking test (6MWT), and fast stair descent performance[13,14]. Although the common purpose of the 6MWT is to evaluate functional aerobic capacity, the American Thoracic Society's 6MWT guideline and some studies state that it can be used as functional status in musculoskeletal diseases[13,15]. Since the trunk muscles are located in the center of the upper and lower extremity kinetic chain, trunk muscles play a role in functional activities[1,16]. However, there are few studies investigating the relationship between the characteristics of trunk muscles and functional parameters in individuals with LBP[14,17].

In the light of the findings of the above studies, the primary purpose of the present study is to investigate the relationship between abdominal muscle activity (AMA) during posterior pelvic tilt movement and abdominal draw-in maneuver and the cross-sectional area (CSA) of the lumbar muscles measured by Magnetic Resonance Imaging (MRI) in patients with chronic non-specific LBP (CNSLBP). As a further aim, the study seeks to reveal the contribution of AMA and lumbar muscle size to 6MWT distance in patients with CNSLBP. It is known that there are some changes in the activity patterns and morphological features of the trunk muscles, such as decreased activation speed but increased percentage of maximum voluntary isometric contraction of the multifidus and transversus abdominis muscles, increased activity of the erector spinae and rectus abdominis muscle, delayed activation in transversus abdominis muscle but earlier contraction in erector spinae muscle, decreased CSA but increased fatty degeneration of paravertebral muscles in individuals with LBP compared to healthy controls[3,4,7,10,14,18]. Our primary hypothesis is that muscle activity during posterior pelvic tilt movement and abdominal draw-in maneuver are related to lumbar muscle cross-sectional area in patients with CNSLBP. Our secondary hypothesis is that the muscle activities obtained from both movements and the cross-sectional area measurements of the lumbar muscles contribute to 6MWT of patients with CNSLBP.

Materials and methods

Participants

142 patients aged 18–65 years who presented to the Physical Medicine and Rehabilitation clinic of a university hospital between 1 September 2016 and 31 August 2017 with LBP lasting for more than three months, with no specific pathoanatomical cause identified by clinically, laboratory, or radiological examinations, and who had pain severity of ≥4 according to visual analog scale (VAS) were included in the study. Patients with radicular pain; neurological deficits; a history of neurological, malignant, infectious, or rheumatological disease; a spinal alignment abnormality; a history of spinal or abdominal surgery; cardiopulmonary diseases limiting exercise capacity; uncontrolled hypertension; and those who were pregnant were excluded from the study. Patients who were unable to cooperate during AMA measurements or in whom successful measurements could not be performed were also excluded (Figure 1). The participants were informed about the purpose and scope of the study and written, and verbal consents were provided. The study protocol and informed consents form were approved by the local ethics committee before the study (2016-571), and the study was conducted following the Declaration of Helsinki.

Demographic data such as age, sex, height, weight, body mass index (BMI), and the severity and duration of the LBP were recorded. The participants were clinically assessed, including the identification of functional status and disability due to LBP. Trunk muscle activity was assessed by an experienced physiatrist, and the morphological features of the paravertebral muscles were assessed by a radiologist and a physiatrist who were blind to the clinical findings and who had experience in musculoskeletal radiology.

Clinical Assessment

Before the clinical assessment, all participants were provided with basic information about the anatomical, biomechanical, and functional properties of the abdominal and back muscles, as well as the nature of the tests. The participants were not allowed to exercise before the test, or to consume solids or liquids for two hours prior to the test. To avoid any effect of environmental conditions, all tests were performed in the same room in a quiet environment.

The mean severity of pain felt by the participants within the last week prior to the assessment date was measured on a 0–10 cm VAS[19].

The participants' levels of disability due to low back pain were assessed using the Roland-Morris Low Back Pain and Disability Questionnaire (RMLBPDQ) – a 24-item self-administered questionnaire assessing the effect of LBP on daily life that is valid and reliable in the Turkish population. Higher scores indicate greater levels of disability[20,21].

The functional assessments of the participants were evaluated with a 6MWT, performed along a 30-m corridor. After resting, the participants were asked to walk as fast as possible at their regular walking pace for six minutes. It was explained prior to the initiation of the test that they would be allowed to rest in the event of dyspnea or extreme fatigue, although the time for rest would be included in the test period. During the test, the elapsed time was announced at one-minute intervals, and the distance walked by the participant was recorded in meters after 6 minutes[22].

Abdominal Muscle Activity Assessment

AMA was measured using a pressure biofeedback unit (PBU) (Stabilizer®, Chattanooga Group Inc.; California, USA) involving the performance of an abdominal draw-in

maneuver in the prone position, and a posterior pelvic tilt movement in the supine position. These movements are not specific to the abdominal muscles due to the nature of the motor control exercises[10]. However, it has been shown that the measurement scores of the abdominal draw-in maneuver and posterior pelvic tilt movement by PBU reflect the activity of the abdominal muscles[23,24]. The PBU is an inexpensive, reliable, non-invasive instrument for the accurate measurement of muscle activity during specific movements and is a simple pressure transducer that includes a three-chamber cuff, a catheter, and a manometer[4,25]. The cuff is 6.7−24 cm in size and is made of non-elastic material, and the manometer features a scale ranging from 0 to 200 mmHg, measuring intervals of 2 mmHg. Different movements and positions on the cuff lead to changes in the pressure values recorded on the manometer[26].

The activity of the transversus abdominis muscle is assessed using a PBU and involves the patient making the abdominal draw-in maneuver in the prone position[10,27]. For this purpose, the cuff of the PBU was placed between the midpoint of the line connecting both anterior superior iliac spines and the umbilicus of the participant while in the prone position. The participant was asked to perform abdominal breathing in a relaxed manner. The manometer valve was closed, and the cuff was inflated to a pressure of 70 mm Hg. All participants were given the standardized verbal command: "Draw in your abdomen without moving your spine or pelvis and hold this position for 10 seconds". The pressure reduction indicated on the manometer was recorded. To avoid potential muscle fatigue, the measurement was performed in three repetitions with 2-minute rest periods between, and the average was calculated. This measurement has been shown to have concurrent validity with transversus abdominis surface electromyography and satisfactory reproducibility in patients with CNSLBP[23,28].

The activities of the rectus abdominis, external and internal abdominal oblique muscles were assessed during a posterior pelvic tilt movement in the supine position[24,29]. For this purpose, the cuff of the PBU was placed between the midpoint of the line connecting both iliac crests of the participant while in the supine position. The participant was asked to perform abdominal breathing in a relaxed manner. The manometer valve was closed, and the cuff was inflated to a pressure of 40 mm Hg. All participants were given the standardized verbal command: "Push your waist down without moving your head, shoulders, or knees, and hold this position for 10 seconds without holding your breath." The pressure increase measured on the manometer was recorded. The measurement was performed in three repetitions with 2-min rest periods between, and the average was calculated[29]. This measurement has been shown to have concurrent validity with surface electromyography in patients with CNSLBP[24], while there have been no studies to date assessing its intra-rater reproducibility. Consequently, the measurements of the first 20 patients were repeated in random order at 7-day intervals under the same environmental conditions, without the participants knowing about their previous scores, and the
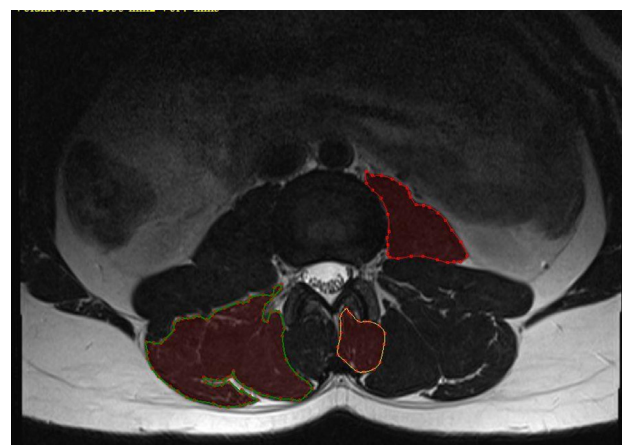
Figure 2. Demonstration of the cross-sectional area measurement of the lumbar muscles.

intra-rater intraclass correlation coefficient was found to be 0.86 (95% CI 0.81−0.89).

Radiological Assessment

Radiological assessments were performed on routine MRI sections obtained during the diagnostic procedures of the patients. MRI was acquired in T2-weighted axial sections, perpendicular to the spinal canal at the inferior plateaus of the L2, L3, L4, and L5 vertebral corpuses using a 3T Magnetom Avanto (Siemens, Erlangen, Germany) device with a repetition time/echo time of 2100 ms/91 ms, a matrix of 256×156, a field of view of 400×325 mm and a slice thickness of 5 mm. On the sections obtained through the picture archiving and communication system (Extreme PACS Client, Ankara, Turkey), the CSA of the bilateral multifidus, erector spinae, and psoas muscles were measured separately on the right and left sides within the fascial borders using a free drawing technique (Figure 2) and the averages were calculated. CSA measurements were performed at different times and in different rooms by a radiologist and physiatrist, with 20 years of experience in musculoskeletal and spinal radiology who were unaware of the sociodemographic and clinical data of the patients and each other's measurements. The inter-rater intraclass correlation coefficients were found to range from 0.83 (95% CI 0.81−0.87) to 0.91 (95% CI 0.88−0.94) (Table 1).

Statistical analysis

IBM SPSS Statistics for Windows (Version 22.0. Armonk, NY: IBM Corp.) was used for the statistical analysis. The normality of the variables was tested using visual (histogram and probability graphics) and analytic methods. Descriptive analyses were presented as mean and standard deviation

Table 1. Inter-rater correlation coefficients analysis of radiological assessment.

		ICC	95% Confidence Interval	
			Lower Bound	Upper Bound
Multifidus muscle CSA	L2 level	0.85	0.82	0.87
	L3 level	0.85	0.82	0.89
	L4 level	0.90	0.88	0.94
	L5 level	0.83	0.81	0.87
Erector Spinae muscle CSA	L2 level	0.88	0.85	0.91
	L3 level	0.87	0.84	0.90
	L4 level	0.90	0.88	0.92
	L5 level	0.90	0.87	0.92
Psoas muscle CSA	L2 level	0.88	0.85	0.90
	L3 level	0.86	0.83	0.88
	L4 level	0.91	0.88	0.94
	L5 level	0.85	0.83	0.88
Abbreviations: CSA, Cross-sectional area.				

for numerical variables with normal distribution, and as frequency tables for ordinal variables. The Intraclass Correlation Coefficient (ICC), with a two-way mixt effect model and absolute agreement definition, was applied for the analysis of inter-rater reliability. The Pearson correlation measure was used to analyze the correlations between parametric variables. The contributions of AMA and lumbar muscles' CSA on 6MWT were examined through linear regression analysis with change statistics. Linear regression analyses were performed for the dependent variable, which was the results of the 6MWT. The independent variables were added to the analysis step by step in blocks. Model 1 was created by age, gender, BMI, disease duration, and severity. In the second step, the AMA scores during the posterior pelvic tilt movement and the abdominal draw-in maneuvers were added to model 1. The CSA of the psoas, erector spinae, and multifidus muscles at the L2–L5 levels were added to the model in the third, fourth, and fifth steps, respectively, and the final model was created in the fifth step. The contribution of the added variables to the variance was analyzed. To achieve a normal distribution of the residuals, three outliers from the dependent variables were excluded from the analysis. The p-value of <0.05 was considered statistically significant. The post-hoc power of the study was found to be 93.3% and 93.7% with α=0.05, according to the prevalence of low back pain in middle-income countries (21.4%) and the eastern black sea region of Turkey (18.1%), respectively[30,31].

Results

In this cross-sectional study, the 142 patients (mean age of 41.24±13.1 years) had CNSLBP with a mean severity of 5.6±1.7 and a mean duration of 76.4±25.6 months. The sociodemographic data of the participants are presented

Table 2. Sociodemographic and clinical data of the participants.

Variables	Statistic values
Age, years	41.24 ± 13.1
Sex, female	92 (64.7)
Height, cm	166.9 ± 9.8
Weight, kg	75 ± 15,5
Body Mass Index, kg/m^2	27.03 ± 5.7
Duration of low back pain, months	76.4 ± 25.6
Severity of low back pain, 0-10 cm VAS	5.6 ± 1.7
Values were presented with mean ± standard deviation for numeric variables, and frequency (percentage) for nominal variable. Abbreviations: VAS, Visual Analogue Scale.	

Table 3. Clinical test results of the participants.

Disability Measure	
Roland-Morris Disability Questionnaire	12.5 ± 5.3
Functional Assesment	
6 Minute Walk Test, m	433.4 ± 54.5
Abdominal Muscle Activity	
Posterior Pelvic Tilt Movement, mm-hg	62.1 ± 12.9
Abdominal Drawing-in Maneuver, mm-hg	9.1 ± 4.2
All variables were presented with mean ± standard deviation.	

in Table 2. The participants had a mean disability score of 12.5±5.3, and a mean functional capacity of 433.4±54.5 meters. The mean AMA of the participants was 62.1±12.9

Table 4. Cross-sectional Area Measurements of Lumbar Muscles.

		Mean	Standard deviation
Multifidus muscle CSA (mm²)	L2 level	338.6	242.6
	L3 level	444.4	188.7
	L4 level	655.2	160.9
	L5 level	924.6	182.8
Erector Spinae muscle CSA (mm²)	L2 level	1622.7	483.8
	L3 level	1652.1	445.7
	L4 level	1499.4	340.8
	L5 level	1253.6	337.1
Psoas muscle CSA (mm²)	L2 level	1622.7	483.8
	L3 level	1652.1	445.7
	L4 level	1499.4	340.8
	L5 level	1253.6	337.1
Abbreviations: CSA, Cross-sectional area.			

Table 5. Correlation Between Abdominal Muscle Activity and Cross-sectional Area Measurements of Lumbar Muscles.

	Multifidus muscle CSA				Erector Spinae muscle CSA				Psoas muscle CSA			
	L2 level	L3 level	L4 level	L5 level	L2 level	L3 level	L4 level	L5 level	L2 level	L3 level	L4 level	L5 level
Abdominal Drawing-in Maneuver PBU score	r=0.15	r=0.12	r=0.09	r=0.07	r=0.18	r=0.20	r=0.28	r=0.25	r=0.30	r=0.35	r=0.39	r=0.34
Posterior Pelvik Tilt Movement PBU score	r=0.20	r=0.29	r=0.19	r=0.13	r=0.28	r=0.28	r=0.32[a]	r=0.33[a]	r=0.37[a]	r=0.47[b]	r=0.48[b]	r=0.48[b]
[a]: $p<0.05$, [b] $p<0.001$ Abbreviations: CSA, Cross-sectional area, PBU: Pressure biofeedback unit.												

Table 6. Change statistics results of linear regression analysis showing the contribution of muscle activity and cross-sectional area measurements of lumbar muscles to functional assessment.

Model	R^2	Adjusted R^2	R^2 Change	p
Dependent Variable: Six-Minute Walk Test				
1	0.426	0.364	0.426	**<0.001**
2	0.527	0.446	0.101	**0.03**
3	0.598	0.468	0.071	0.26
4	0.672	0.502	0.074	0.22
5	0.674	0.520	0.002	0.99
Model 1: Age, sex, body mass index, disease duration, and disease severity *Model 2: Model 1 + abdominal muscle activity (both abdominal drawing-in maneuver and posterior pelvic tilt movement)* *Model 3: Model 2 + L2-5 Psoas muscle cross-sectional area* *Model 4: Model 3 + L2-5 Erector Spinae muscle cross-sectional area* *Model 5: Model 4 + L2-5 Multifidus muscle cross-sectional area*				

mmHg during the posterior pelvic tilt movement and 9.1±4.2 mmHg during the abdominal draw-in maneuver (Table 3). Table 4 shows the CSA of the multifidus, erector spinae, and psoas muscles at the L2–L5 levels.

There was no statistically significant correlation between muscle activity during the abdominal draw-in maneuver and the CSA of the lumbar muscles (Table 5). A statistically significant correlation was found between the muscle activity during the posterior pelvic tilt movement and the CSA of the erector spinae muscle at the L4 and L5 levels, and the psoas muscle at the L2–L5 levels ($r=0.32$, $P=0.03$; $r=0.33$, $P=0.03$; $r=0.37$, $P=0.01$; $r=0.47$, $P<0.001$; $r=0.48$, $P<0.001$; and $r=0.48$ $P<0.001$, respectively).

Table 6 shows the change statistics results of hierarchical linear regression analysis showing the contribution of muscle activity and cross-sectional area measurements of lumbar muscles to functional assessment. The variables in the first model explained 42.6% of the variance ($P<0.001$), while in the second model, the inclusion of muscle activities yielded a significant additional contribution of 10.1% to the variance ($P=0.03$). In the third, fourth, and fifth models, the CSA of the psoas, erector spinae, and multifidus muscles at the L2–L5 levels were included, and all four levels of each muscle yielded an independent additional contribution of 7.1%, 7.4%, and 0.02%, respectively to the variance, although these contributions were statistically insignificant. ($P=0.26$, $P=0.22$ and $P=0.99$, respectively).

Discussion

The present study investigates the relationship between anterior AMA and the CSA of the lumbar muscles, as well as the contributions of anterior AMA and the CSA of the lumbar muscles on functional assesment in patients with CNSLBP. The study has shown that the muscle activity during posterior pelvic tilt movement is associated with the CSA of the erector spinae muscle at the L4 and L5 levels, and the psoas muscle at the L2–L5 levels, and that muscle activity contributes to the functional assessment of patients. No relationship could be identified between muscle activity during the abdominal draw-in maneuver and the CSA of the lumbar muscles.

Co-contraction of synergist or antagonist muscles of the trunk during movement is critical in maintaining spinal stability and spinal control[9]. The co-contraction of the antagonist muscles was demonstrated to occur between the multifidus and transversus abdominis muscles in manual tests and by a PBU, and between the rectus abdominis and the erector spinae muscles using an electrophysiological method, and a moment histogram was developed by Raschke et al. to that end[10,11,32]. The relationship between AMA and the CSA of the paravertebral muscles was examined by Hides et al., who evaluated transversus abdominis muscle activity during the abdominal draw-in maneuver and the CSA of the multifidus muscle at the L5 level on real-time ultrasound images, but found no relationship, concurring with the findings of the present study[10]. Unlike in Hides et al.,

in the present study, we evaluated the CSA of the multifidus muscle at multiple levels from an MRI, and measured the CSA of the erector spinae and psoas muscles, but could find no significant relationship between the CSA of all three muscles and muscle activity during the abdominal draw-in maneuver. The fact that the transversus abdominis muscle indirectly controls spinal stabilization by regulating intra-abdominal pressure, which may play a role in this result[33].

On the other hand, there is a correlation between muscle activity during posterior pelvic tilt movement, and the CSA of the erector spinae muscle at the L4 and L5 levels and the psoas muscle at L2–L5 levels. The posterior pelvic tilt movement mainly involves abdominal flexor muscles, especially the rectus abdominis muscle[29,34,35]. The role of the psoas muscle in posterior pelvic tilt movements has not been studied electrophysiologically, since it is located anterior to the vertebrae and inside the pelvis, although it may act as an agonist during posterior pelvic tilt movements due to its role in the lumbopelvic rhythm and its anatomical location[36]. The erector spinae muscle has a more important function at the distal levels with greater spinal mobility and acts as an antagonist muscle in the control of flexor movements of the rectus abdominis and other anterior abdominal wall muscles[1,16]. The findings of the present cross-sectional study do not explain how the size of agonist and antagonist muscles affects muscle activity. We believe that fascial kinetic chains play a role in this force transmission, as these structures are surrounded by fascia that is included in the anterior and posterior superficial myofascial kinetic chains[37,38].

Although there have been several studies examining the role of the core muscles in lumbar stabilization, their function in lumbopelvic movements and their role in lower and upper extremity tasks, their relation with disability and functional assessment have been evaluated in relatively few studies[10,14,18,39-43]. The studies investigating this relation have tended to utilize the CSA measurement of the lumbar muscles based on previously documented information, suggesting a relationship between the CSA of the lumbar muscles and muscle strength – the size of the CSA is a predictor of muscle strength[44,45]. Unlike in the present study, previous researches have tended to be conducted based on a "single-level single muscle" choice, and the vast majority of these studies have failed to establish any association between the CSA of the lumbar muscles with disability level and functional status[10,14,18,39-43]. Chen et al., who obtained results that partially disagreed with our findings, assessed the CSA of the psoas and multifidus muscles only at the L5 level and identified only the psoas CSA as a predictive factor[46]. However, they involved a patient group with spinal stenosis, and used the Japanese Orthopedic Association Score as its measure of functional status. Different patient populations and different outcome measures may result in conflicting results. Despite the established association between the CSA of the lumbar muscles and muscle strength, findings related to other morphological and histological characteristics, such as the fatty degeneration of the lumbar muscles, changes in the muscle fiber-type ratio, and

enzymatic activity differences should be considered relating to functional status and disability in patients with LBP[41-43]. These points fell outside the scope of the present study and so were not addressed, and we also did not make a level-by-level assessment of the muscles, although the cross-sectional area of the upper levels were included in the study due to the lower morphological change.

The present study is the first to identify a significant 10% contribution of AMA to functional assessment in patients with CNSLBP. This finding is actually not surprising considering the concept of "proximal stability for distal mobility" in biomechanics[1,16]. It is well known that the trunk is central to distal segment movements, and the trunk muscles aid spinal stability as well as force generation and transmission and maintain postural balance during kinetic chain movements of the upper and lower extremities[16]. Impaired motor control of the abdominal muscles in patients with CNSLBP is associated with a loss of physical function. From another point of view, impairments in physical function due to LBP affect the motor control of abdominal muscle. To break the resulting vicious circle, exercises and practices aimed at increasing activity in the abdominal muscles should be included in treatment regimes.

There are some limitations of the present study, the first of which relates to the use of a PBU rather than an electrophysiological examination, which is considered the optimum approach to the assessment of AMA. Although the validity of the pressure biofeedback unit has been shown for both abdominal movements, the fact that it is an indirect measurement method should be considered. Also, the normal values, minimal clinically important difference values, and adjusted values for height, weight, and gender of the abdominal draw-in maneuver and posterior pelvic tilt movement measured with the PBU are unknown. In addition, the patients' pain level and motivation may also influence the optimization of muscle activity assessment. Moreover, although the sample size was in line with similar studies since the prevalence of chronic non-specific low back pain in the Turkish population is not known, the fact that it was not calculated before the study can be considered another study limitation.

In a conclusion, a relationship exists between muscle activity during posterior pelvic tilt movements and the CSA of the psoas and erector spinae muscles, and muscle activity during posterior pelvic tilt movements and draw-in maneuver are important in the functional assessment of patients with CNSLBP. Based on these findings, it is important to include exercises for abdominal muscle strengthening, core stabilization, and motor control in the rehabilitation programs established for patients with low back pain. Further clinical studies to be conducted in the future based on electrophysiology may provide additional contributions to literature by considering other morphological features of the lumbar muscles.

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