



Pain, function, contractile properties, and spinal kinematics in adult females with and without non-specific chronic low back pain: a comparative and correlational study

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Purpose: The purpose of this study was to compare pain levels, functional impairment, contractile properties of the erector spinae and spinal kinematics in females with and without non-specific chronic low back pain (NSCLBP), and to examine the interrelationships among these variables. **Methods:** All participants were assessed for pain levels and functional impairment. Tensiomyography was used to evaluate the contractile properties of the erector spinae, and all participants were assessed for spinal kinematics during a lift task. An independent *t*-test was performed to compare all variables between the control group and the NSCLBP group, and the Pearson correlation coefficient analysis was performed to examine the relationships among all variables. **Results:** We found significant differences between groups in pain levels, functional impairment, maximal radial muscle displacement, contraction velocity, and lumbar extension and rotation angles. Additionally, Pearson correlation analysis revealed a significant positive correlation between pain levels, functional impairment, and the lumbar extension angle, and a significant negative correlation was found between maximal radial muscle displacement and both pain levels and functional impairment. **Conclusions:** This study identified differences in pain level, functional impairment, contractile properties of erector spinae and spinal kinematics based on NSCLBP presence, along with correlations among these variables. Further research should explore other functional motor tasks.

Key words: non-specific chronic low back pain, erector spinae, muscle contractile properties, spinal kinematics, function

1. Introduction

Low back pain (LBP), one of the leading causes of musculoskeletal disorders worldwide, is a significant health issue that affects up to 80% of individuals at some point in their lives and can have substantial economic repercussions [36]. Non-specific chronic low back pain (NSCLBP) is characterized by pain lasting more than 12 weeks without an identifiable underlying pathology,

such as infection, tumor, osteoporosis, fracture or structural deformity [3]. Furthermore, NSCLBP may lead to functional alterations in the musculoskeletal system, potentially resulting in abnormal movement patterns, persistent pain and functional limitations [25]. Due to its complex and multifactorial nature, NSCLBP remains challenging to diagnose accurately, often leading to inadequate or suboptimal treatment [13].

Patients with NSCLBP often encounter challenges in maintaining lumbopelvic stability during lifting task,

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which involve trunk flexion and extension [30]. Specifically, in patients with NSCLBP, compensatory excessive muscle guarding through co-contraction of the lumbopelvic muscles occurs due to impaired lumbopelvic stability, which serves as a key factor in maintaining chronic low back pain by reducing trunk movement efficiency and inducing continuous stress [35]. These inefficient movement patterns can result in overactivation and increased stiffness of the lumbar extensor muscles [28].

Inefficient movement patterns in individuals with NSCLBP are closely associated with impairment of the flexion-relaxation phenomenon (FRP), a natural suppression of erector spinae activity during trunk flexion that contributes to spinal stability and reduces muscle fatigue [10]. Impairment of the FRP can lead to excessive tension and restricted range of motion in the lumbar muscles, resulting in structural changes such as chronic low back pain, atrophy of the erector spinae, fiber-type transformation, and intramuscular fat infiltration as well as functional alterations including muscle fatigue, abnormal activation patterns, and reduced neuromuscular control [5], [9], [11], [34].

To ensure appropriate diagnosis and intervention in patients with NSCLBP, it is essential to clarify the interrelationships among pain levels, functional impairment, the contractile properties of the erector spinae, and inefficient trunk flexion–extension movement patterns. Electromyography (EMG), which has been extensively utilized in previous studies, is limited to capturing the electrical activity of muscles and does not directly evaluate mechanical properties such as contraction velocity and stiffness [6], [26]. To overcome the limitations of conventional research methods, it is essential to incorporate Tensiomyography (TMG). This non-invasive tool allows for the quantitative assessment of muscle contractile properties, including contraction time and maximal radial muscle displacement [8]. Furthermore, few studies have examined the interrelationships among the multidimensional factors of NSCLBP, encompassing pain levels, functional impairment, the contractile properties of the erector spinae, and spinal kinematic variables during trunk flexion–extension movements.

Therefore, the primary objective of this study was to compare and analyze pain levels, functional impairment, static contractile properties of the erector spinae, and spinal kinematics during lifting tasks between adult females with and without NSCLBP. The secondary objective was to investigate the interrelationships among these variables, thereby providing fundamental evidence for designing rehabilitation exercise interventions aimed at reducing pain and improving functional outcomes in individuals with NSCLBP.

2. Materials and methods

2.1. Participants

This study employed a case-control design, determining that a total of 40 participants was necessary based on a priori power analysis using G*Power version 3.1.9.7 (Düsseldorf University, Düsseldorf, Germany). This analysis utilized an independent *t*-test (two-tailed, effect size $d = 0.91$, $\alpha = 0.05$, power = 0.80) as the reference. Accordingly, two groups of adult females aged 20–29 years were recruited: a control group ($n = 20$) consisting of healthy individuals without LBP and a NSCLBP group ($n = 20$) comprising of individuals with NSCLBP, characterized by the absence of identifiable pathological causes and a current pain score of 5 or higher on the visual analogue scale (VAS). Exclusion criteria for the NSCLBP group included individuals with a history of musculoskeletal or neurological disorders, those who had undergone surgery within the past three months, individuals with orthopedic conditions that may interfere with participation in the experiment, and those diagnosed with specific chronic low back pain with identifiable pathological causes. This study was approved by the Institutional Review Board of Incheon National University (INU-IRB No. 7007971-202108-005), and all participants provided informed consent prior to data collection.

2.2. Measurements

2.2.1. Index of pain and functional disability

To assess the level of LBP in participants, the VAS was utilized. The VAS consists of a 10 cm horizontal line on which individuals indicate their perceived level of pain. A mark exceeding 4 cm is considered indicative of moderate to severe pain and has been recognized as a valuable tool for diagnosing chronic low back pain [33]. Additionally, to evaluate the functional status of patients with NSCLBP, who are known to experience physical limitations, the Korean version of the Oswestry Disability Index (KODI) was used. This questionnaire assesses functional disability related to low back pain across 10 domains and has demonstrated reliability and validity for Korean patients through cross-cultural adaptation [16].

2.2.2. Contractile properties of erector spinae

To evaluate the contractile properties of the erector spinae, TMG was used under isometric conditions using the TMG-100 system (Electrostimulator, Ljubljana, Slovenia). This non-invasive technique measures the radial displacement of the muscle belly in response to a single electrical stimulus ranging from 0 to 100 mA [8]. TMG is recognized as a reliable and effective method for assessing low back pain, overall muscle contractile properties, and fatigue [24]. It provides both spatial and temporal data on the radial displacement of the muscle belly through variables such as maximal radial displacement (D_m), contraction time (T_c), delay time (T_d), sustain time (T_s), and half-relaxation time (T_r) (Fig. 1).

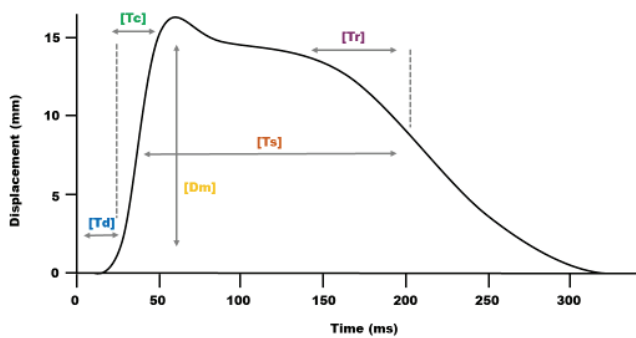


Fig. 1. Variables of tensiomyography: T_d – delay time, T_c – contraction time, D_m – maximal radial muscle displacement, T_s – sustain time, T_r – half relaxation time



Fig. 2. Measurement of TMG

Participants were instructed to refrain from caffeine intake, exercise, and myofascial release techniques for 24 to 48 hours prior to measurement [20]. All TMG measurements were conducted by a single examiner with over three years of experience. In addition, based

on the method described by Perotto et al. (2011), the measurement site was marked on the muscle belly of the erector spinae at its anatomical location, and the participants were positioned as shown in Fig. 2 during the measurement. Two electrodes (50×50 mm, T.Y. Sherry International Co., Ltd., Taiwan) were positioned with a 5 cm inter-electrode distance. The intensity of electrical stimulation and the interval between stimuli were determined based on the protocol from a previous study [20].

2.2.3. Box lift motion analysis

To analyze the box-lifting task, a total of eight motion capture cameras (6 Eagle and 2 Raptor-E systems, Motion Analysis Corp., USA) were used, and based on the Helen Hayes marker set, 41 reflective markers were attached. These included 28 standard markers (excluding the sacrum), three spinal markers placed on the 7th cervical (C7), 12th thoracic (T12), and 2nd and 4th lumbar vertebrae (L2 and L4) with three offset points between them. Additionally, bilateral markers were positioned on the posterior superior iliac spine (PSIS), greater trochanter, and the top of the iliac crest (Fig. 3). In addition, for the kinematic analysis of the box-lifting task, motion capture data were collected at a sampling rate of 120 frames per second using motion analysis software (Cortex 7, Motion Analysis Corp., USA). A box measuring 41 cm in width, 31 cm in depth, and 28 cm in height was used with a load equivalent to 15% of each participant's body weight. All participants performed dynamic stretching and warm-up exercises to prevent injury prior to measurement. They received instructions and practiced for the experimental task and completed five trials, from which the average of the three most successful performances was used to calculate the kinematic variables. In this study, the events for the analysis of the box-lifting task were defined as shown in Fig. 4, and two force plates (9260AA, Kistler, Switzerland) were used to identify Event 1 and Event 2 based

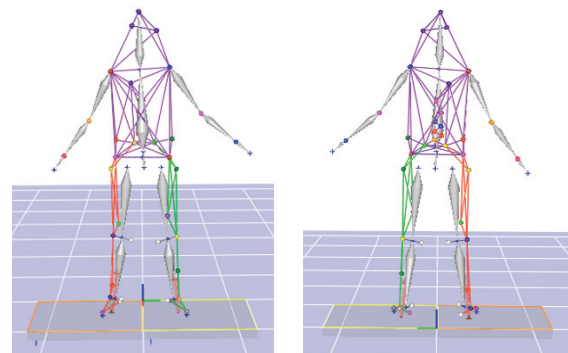


Fig. 3. Modified marker set

on the maximum vertical ground reaction force during the lifting movement.

ables during the box-lifting task. The significance level for all statistical tests was set at $p < 0.05$.

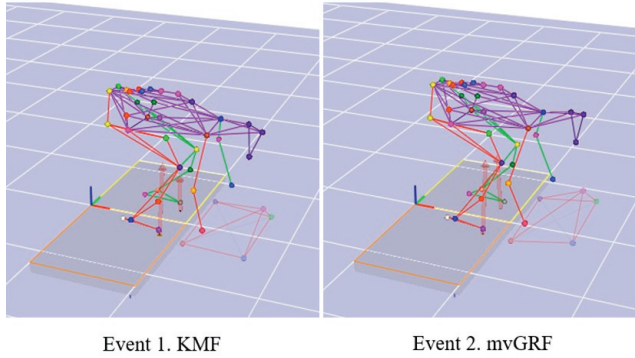


Fig. 4. Event: KMF – knee maximum flexion, mvGRF – maximum vertical ground reaction force

2.3. Statistical analysis

All statistical analyses were performed using SPSS version 28.0 (IBM, USA). The mean and standard deviation were calculated for each variable. To assess the normality of the data, the Shapiro–Wilk test was performed for all variables. An independent t -test was used to compare differences in VAS scores, KODI scores, static contractile properties of the erector spinae, spinal kinematic variables during the box-lifting task and maximum vertical ground reaction force. Additionally, Pearson correlation coefficient analysis was performed to examine the relationships among pain levels, functional impairment, static contractile properties of the erector spinae and sagittal-plane lumbar kinematic vari-

3. Results

3.1. Results of participant characteristics

As a result of participants characteristics, significant between-group differences were found in pain period ($t = -5.338, p \leq 0.000$). However, there were no significant differences between groups in age ($t = -0.877, p = 0.386$), height ($t = -0.458, p = 0.649$), weight ($t = -0.561, p = 0.578$) (Table 1).

3.2. Results of the pain and functional disability index

As a result of analyzing pain and functional impairment levels, significant between-group differences were found in VAS ($t = -24.778, p \leq 0.000$) and KODI ($t = -17.764, p \leq 0.000$) (Table 2).

3.3. Results of erector spinae contractile properties

As a result of analyzing the static contractile properties of the erector spinae, no significant between-

Table 1. Characteristics of participants

Variables	Control ($n = 20$)	NSCLBP ($n = 20$)	t	p
Age [years]	21.70 ± 2.08	22.22 ± 1.47	-0.877	0.386
Height [cm]	162.38 ± 5.90	163.12 ± 4.24	-0.458	0.649
Weight [kg]	53.36 ± 5.00	54.48 ± 7.40	-0.561	0.578
Pain period [month]	0.00 ± 0.00	46.90 ± 39.29	-5.338	$\leq 0.000^*$

Data are mean $\pm$ standard deviation, * $p < 0.001$.

NSCLBP – non-specific chronic low back pain, VAS – visual analogue scale, KODI – Korean Oswestry disability index.

Table 2. Results of the pain and disability index

Variables	Control ($n = 20$)	NSCLBP ($n = 20$)	t	p
VAS [cm]	0.35 ± 0.81	6.80 ± 0.83	-24.778	$\leq 0.000^*$
KODI [%]	1.78 ± 1.99	34.89 ± 8.10	-17.764	$\leq 0.000^*$

Data are mean $\pm$ standard deviation, * $p < 0.001$.

NSCLBP – non-specific chronic low back pain, VAS – visual analogue scale, KODI – Korean Oswestry disability index.

Table 3. Results of erector spinae contractile properties

Muscle	Variables	Control	NSCLBP	<i>t</i>	<i>p</i>
ES	T_c	15.47 ± 180	16.05 ± 3.10	-0.717	0.478
	D_m	3.79 ± 1.29	2.76 ± 1.76	2.114	0.041*
	V_c	0.11 ± 0.04	0.08 ± 0.05	2.048	0.048*

Data are mean ± standard deviation, * $p < 0.05$.

NSCLBP – non-specific chronic low back pain, ES – erector spinae, T_c – contraction time, D_m – maximum radial displacement, V_c – velocity of contraction.

group difference was found in T_c ($t = -0.717$, $p = 0.478$). However, significant differences were observed in D_m ($t = 2.114$, $p = 0.041$) and V_c ($t = 2.048$, $p = 0.048$) (Table 3).

3.4. Results of the kinematic variables of the spine

As a result of analyzing spinal kinematics during the box-lifting task, significant between-group differences were observed in L2–L4 extension and rotation at KMF (extension: $t = -2.273$, $p = 0.031$; rotation: $t = 2.212$, $p = 0.033$) and at mvGRF (extension: $t = -2.213$, $p = 0.035$; rotation: $t = 2.091$, $p = 0.043$). However, no significant differences were observed in the other kinematic variables. Additionally, there were no significant between-group differences in peak vertical ground reaction force across all events (Table 4).

3.5. Results of Pearson correlation

As a result of the Pearson correlation coefficient analysis, no significant correlations were found between D_m and the L2–L4 kinematic variables at any event (KMF: $r = -0.274$, $p = 0.087$; mvGRF: $r = -0.288$, $p = 0.072$). However, significant correlations were identified between VAS and the L2–L4 kinematic variables at both events (KMF: $r = 0.334$, $p = 0.035$; mvGRF: $r = 0.326$, $p = 0.040$). For the KODI, a significant correlation was observed only at the KMF event ($r = 0.313$, $p = 0.049$), with no significant correlation at mvGRF ($r = 0.308$, $p = 0.053$). Additionally, significant correlations were found between D_m and VAS ($r = -0.344$, $p = 0.030$), as well as between D_m and KODI ($r = -0.353$, $p = 0.026$) (Table 5).

Table 4. Results of kinematic and kinetic variables

Spine	Event	Kinematic variable	Control	NSCLBP	<i>t</i>	<i>p</i>
T12–L2	KMF	lateral flexion	0.99 ± 4.53	-0.73 ± 2.61	1.466	0.153
		extension	-5.45 ± 3.54	-5.72 ± 2.63	0.271	0.788
		rotation	2.16 ± 3.11	2.89 ± 4.45	-0.598	0.554
	mvGRF	lateral flexion	0.85 ± 4.62	-0.58 ± 2.65	1.199	0.238
		extension	-5.46 ± 3.91	-5.53 ± 2.87	0.057	0.955
		rotation	2.09 ± 3.11	2.41 ± 4.35	-0.268	0.790
L2–L4	KMF	lateral flexion	-0.80 ± 4.63	-1.14 ± 4.51	0.239	0.812
		extension	-2.57 ± 3.90	2.09 ± 8.29	-2.273	0.031*
		rotation	8.87 ± 6.05	4.94 ± 5.14	2.212	0.033*
	mvGRF	lateral flexion	-1.02 ± 4.81	-1.30 ± 4.76	0.185	0.854
		extension	-2.64 ± 4.07	1.97 ± 8.37	-2.213	0.035*
		rotation	8.33 ± 5.48	4.78 ± 5.26	2.091	0.043*
F_z	KMF		0.62 ± 0.12	0.60 ± 0.03	0.922	0.362
	mvGRF		0.76 ± 0.13	0.72 ± 0.03	1.563	0.133

Data are mean ± standard deviation, * $p < 0.05$.

Direction. Lateral flexion, (+) – left, (–) – right; Extension, (+) – extension, (–) – flexion; Rotation, (+) – left, (–) – right.

NSCLBP – non-specific chronic low back pain, T – thoracic, L – lumbar, F_z : ground reaction force of vertical, KMF – knee maximum flexion, mvGRF – maximum vertical ground reaction force.

Table 5. Results of Pearson correlation

Variables		r	p
D_m	KMF	-0.274	0.087
	mvGRF	-0.288	0.072
VAS	KMF	0.334	0.035*
	mvGRF	0.326	0.040*
KODI	KMF	0.313	0.049*
	mvGRF	0.308	0.053
D_m	VAS	-0.344	0.030*
	KODI	-0.353	0.026*

Note. * $p < 0.05$.

D_m – maximum radial displacement, VAS – visual analogue scale, KODI – Korean Oswestry disability index, KMF – knee maximum flexion, L – lumbar, mvGRF – maximum vertical ground reaction force.

4. Discussion

This study aimed to compare and analyze the levels of pain and functional disability, the static contractile properties of the erector spinae and the kinematic variables of the spine during a box-lifting task, based on the presence or absence of NSCLBP in adult females. Additionally, the study sought to examine the correlations among these variables. The results revealed significant between-group differences in D_m ($p = 0.041$) and V_c ($p = 0.048$) of the erector spinae, while no significant difference was observed in T_c . In the analysis of the box-lifting task, significant between-group differences were observed in the L2–L4 extension and rotation joint angles at the KMF ($p = 0.031$ for extension; $p = 0.033$ for rotation) and mvGRF ($p = 0.035$ for extension; $p = 0.043$ for rotation) time points. Pearson correlation analysis indicated no significant correlation between D_m of the erector spinae and the L2–L4 extension joint angle, whereas VAS and KODI (except for mvGRF) were significantly correlated with the L2–L4 extension joint angle. Furthermore, significant correlations were observed between D_m of the erector spinae and both VAS and KODI scores.

In the results concerning the static contractile properties of the erector spinae, no significant between-group differences were observed in T_c . T_c refers to the time required to reach 10% to 90% of D_m and is positively correlated with the proportion of Type I muscle fibers [4]. Previous studies indicate that individuals with NSCLBP tend to exhibit a shift toward Type I muscle fibers, which has been attributed to increased neuromuscular activity, such as heightened paraspinal muscle activation and elevated mechanical loading [1]. However, because the proportion of muscle fiber types

varies among individuals, muscular responses to identical external stimuli may differ, and the relationship between pain and fiber-type transformation remains unclear [1], [23]. This underscores the need for further research to elucidate the association between NSCLBP and muscle fiber characteristics. D_m was significantly lower in the NSCLBP group compared to the control group. D_m represents the maximum displacement during muscle contraction, and it is known to decrease under conditions of increased muscle tension and stiffness [29]. The erector spinae in individuals with NSCLBP have been reported to exhibit excessive tension and stiffness in the erector spinae, even at rest, due to abnormal activation [17]. Based on these findings, it is considered that the significantly lower D_m value observed in the NSCLBP group compared to the control group may be attributed to such excessive tension and stiffness. V_c , which reflects muscle contraction velocity and is recognized as an important variable for assessing muscle fatigue [18], was significantly lower in the NSCLBP group than in the control group. This may indicate a tendency toward slower muscle contraction in individuals with NSCLBP; however, it should be interpreted with caution because T_c did not differ between groups and V_c is mathematically derived from D_m/T_c . Therefore, the reduction in V_c may primarily reflect the smaller D_m observed in the NSCLBP group rather than an actual slowing of contraction velocity. Nevertheless, chronic overactivation and fatigue of the erector spinae in individuals with NSCLBP have been reported to induce physiological adaptations such as a shift toward Type I muscle fibers characterized by slower contraction [21], [22]. Thus, these mechanisms may partly contribute to the observed reduction in V_c , although further longitudinal or mechanistic studies are needed to confirm this relationship.

In the analysis of the box-lifting task, greater L2–L4 extension angles were observed in the NSCLBP group compared to the control group across all time points. This indicates that individuals with NSCLBP lifted the box with a more extended lumbar posture, in contrast to the flexed posture exhibited by the control group. This finding is consistent with previous studies that report individuals with NSCLBP tend to adopt a more extension-dominant and stiffened movement strategy during lifting tasks compared to controls [7], [27]. In patients with NSCLBP, loss of the FRP occurs due to a combination of pain-avoidance behavior and impaired neuromuscular control, leading to a rigid movement strategy that maintains lumbar extension through excessive activation of the erector spinae during trunk flexion [14], [28]. Such movement control characteristics in individuals with NSCLBP may lead to a tendency to maintain an

extended posture during actual lifting tasks, which may explain the consistently increased L2–L4 extension angles observed across all time points. Additionally, the NSCLBP group demonstrated smaller rotation angles compared to the control group at all time points. This suggests that the NSCLBP group minimized transverse plane movement during trunk flexion while lifting the box. This finding is consistent with previous studies reporting that the lumbar rotational range of motion during trunk flexion is significantly reduced in the NSCLBP group compared with the control group, and that such reduction is associated with pain-avoidance movement strategies linked to tension of paraspinal tissues, muscle stiffness, and mechanical instability [2], [12]. Additionally, the loss of FRP may further restrict rotational movement by diminishing erector spinae relaxation responses and promoting excessive co-activation of surrounding spinal muscles during trunk flexion [31]. These characteristics of NSCLBP may explain why the NSCLBP group demonstrated smaller rotation angles than the control group across all time points.

Pearson correlation analysis revealed no significant correlation between D_m of the erector spinae and the L2–L4 extension joint angle. This finding suggests that it is difficult to establish a clear relationship between D_m , a TMG-derived variable measured under static conditions, and joint angle variables that reflect complex neuromuscular control and coordination strategies during dynamic movements. Indeed, D_m has been reported to vary sensitively depending on dynamic conditions and may not fully represent muscle function during movement [19]. Consequently, D_m in this study may have shown only a limited association with the kinematic variables. A significant positive correlation was observed between VAS, KODI (except for mvGRF event), and the L2–L4 extension joint angle. This positive correlation between VAS and the L2–L4 extension angle indicates that higher levels of pain are associated with an increased tendency toward lumbar extension. Individuals with higher pain levels may tend to adopt a stiffer lifting pattern characterized by greater lumbar extension and erector spinae activation [11]. However, this association should be interpreted as correlational rather than causal, given the cross-sectional nature of the study. Future longitudinal or interventional studies are warranted to clarify the causal mechanisms underlying this relationship. The positive correlation between KODI and the L2–L4 extension angle indicates that higher levels of functional disability are associated with an increased tendency toward lumbar extension. The ODI is recognized as a measure that reflects not only physical functional limitations but also psy-

chological factors such as fear-avoidance and anxiety [32]. Individuals with higher levels of functional disability in NSCLBP tend to adopt a more rigid, extension-based strategy as a form of pain-avoidance behavior [15]. Consequently, the positive correlations observed between VAS, KODI scores, and L2–L4 extension angles in this study may suggest that higher levels of pain and functional disability are associated with the adoption of a rigid, extension-based movement strategy. A significant negative correlation was identified between D_m of the erector spinae and both VAS and KODI scores. This finding suggests that lower D_m values are associated with higher levels of pain and functional disability, as decreased D_m may indicate increased muscle tension or stiffness [29]. Previous studies have shown that elevated levels of muscle tension and stiffness can be critical factors in the development or persistence of pain and functional disability [37]. These findings may explain the negative correlations observed between reduced D_m values and both VAS and KODI scores.

5. Conclusions

This study aimed to compare pain and functional disability levels, static muscle contraction characteristics of the erector spinae, and spinal kinematic variables during a box-lifting in adult female with and without NSCLBP. Additionally, the study sought to analyze the correlations among these variables. The results indicated that the NSCLBP group exhibited significantly lower values of D_m and V_c in the erector spinae compared to the control group. Furthermore, during the box-lifting task, the NSCLBP group demonstrated greater L2–L4 extension angles and smaller rotation angles than the control group across all time points. Pearson correlation analysis revealed no significant correlation between D_m and the L2–L4 extension angle. However, a significant positive correlation was observed between VAS, KODI (except for mvGRF event), and the L2–L4 extension angle. Additionally, a significant negative correlation was found between D_m and both VAS and KODI scores. Future studies should incorporate a wider range of functional tasks commonly observed in daily life to further investigate pain management and functional improvement strategies for individuals with NSCLBP.

This study has some limitations. The sample included only young adult females, which restricts the generalizability of the results. In addition, the cross-sectional design limits causal interpretation, and the static nature

of TMG may not fully reflect dynamic muscle function. Despite these limitations, the findings provide valuable insights into the neuromuscular characteristics of individuals with NSCLBP.

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Conflict of interests

The authors declare that they have no conflict of interest.

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