

LOWER CROSS SYNDROME-RELATED MUSCULOSKELETAL IMPAIRMENTS IN PATIENTS WITH LOW BACK PAIN: A CROSS-SECTIONAL ANALYTICAL STUDY

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Low back pain; Lower Cross Syndrome; muscular imbalance; anterior pelvic tilt; lumbar lordosis; iliopsoas; gluteus maximus; gluteus medius; muscle strength; physical therapy.

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Abstract

Background: Low back pain (LBP) is a common musculoskeletal condition that may be associated with alterations in lumbopelvic muscle strength, muscle length, and pelvic alignment. Lower Cross Syndrome (LCS) describes a pattern of muscular imbalance involving weakness of selected abdominal and gluteal muscles together with shortening or tightness of hip-flexor and lumbar musculature. The present study investigated the relationship between LCS-related musculoskeletal characteristics and diagnosed LBP.

Objective: To determine the relationship between Lower Cross Syndrome and low back pain and to assess pelvic alignment, selected muscle tightness, and muscle strength among patients diagnosed with LBP.

Methods: A cross-sectional analytical study was conducted in the Physiotherapy Department of Pakistan Railway Hospital, Rawalpindi, Pakistan, from November 2024 to May 2025. Patients aged 15–55 years with diagnosed LBP were recruited using purposive sampling according to predefined eligibility criteria. Data were collected using a self-structured questionnaire incorporating demographic characteristics, Numeric Pain Rating Scale (NPRS), assessment of pelvic tilt, muscle length, and manual muscle testing. Iliopsoas, rectus femoris, and thoracolumbar muscle characteristics were assessed, while abdominal, gluteus maximus, and gluteus medius strength was evaluated using manual muscle testing. Data was analyzed using SPSS version 25. Categorical variables were presented as frequencies and percentages, continuous variables as mean $\pm$ standard

deviation, and associations were assessed using the Chi-square test. Statistical significance was set at $p < 0.05$.

Results: The reported mean age of participants was 38.2 ± 6.22 years, with a male-to-female ratio of 2:1. Eighty-two percent were married and 41.3% were housewives. An NPRS score of 5 was reported by 60% of participants, while approximately 38.1% reported a recent episode of LBP within the preceding 4–6 months. More than 65% demonstrated a lordotic lumbar curve and 50% demonstrated anterior pelvic tilt. Iliopsoas shortening was observed in all assessed participants, with 76.2% demonstrating more than 20° shortening. Thoracolumbar muscle tightness was present in 61.9%. Reduced abdominal, gluteus maximus, and gluteus medius strength was frequently observed, with only approximately 12%, 12.7%, and 11.1%, respectively, demonstrating normal strength. Significant associations were reported between several muscle characteristics and age, marital status, and occupation, whereas gender was not significantly associated with muscle length or muscle strength.

Conclusion: LCS-related musculoskeletal impairments, including iliopsoas shortening, thoracolumbar tightness, reduced abdominal and gluteal muscle strength, anterior pelvic tilt, and lordotic lumbar posture, were frequently observed among patients with diagnosed LBP. These findings support the clinical assessment of muscle length, muscle strength, and pelvic alignment as components of the physical therapy examination of patients with LBP. However, the cross-sectional design does not establish a causal relationship between LCS-related impairment and LBP. Further longitudinal and controlled studies are required to clarify the temporal and causal relationship between these muscular characteristics and low back pain.

INTRODUCTION

Low back pain (LBP) is one of the most prevalent musculoskeletal disorders worldwide and represents a major cause of disability, activity limitations, and reduced quality of life. It can occur across the lifespan and may arise from multiple interacting biological, mechanical, psychological, and social factors. Most LBP cases are classified as non-specific because a single pathological or anatomical source cannot be confidently identified. Current global estimates indicate that LBP affected approximately 619 million people in 2020 and remains the leading cause of disability worldwide (1). The substantial and increasing burden of LBP has consequently made its prevention, assessment, and rehabilitation an important priority within musculoskeletal and physical therapy practice (1, 2).

The musculoskeletal system plays an essential role in maintaining posture, providing stability, permitting movement, and transferring loads between different body segments. Efficient lumbopelvic function depends on coordinated activity of the lumbar spine, pelvis, abdominal musculature, hip extensors, hip abductors, and hip flexors. Alterations in the strength, flexibility, endurance, or activation of these muscles may influence lumbopelvic mechanics and movement control. Previous research has demonstrated that people with LBP may exhibit impairments in trunk and lower-limb muscle function, although the magnitude and clinical importance of individual impairments vary between populations and study designs (3, 4).

One clinical concept used to describe a characteristic pattern of lumbopelvic muscular imbalance is Lower Cross Syndrome (LCS). The

concept, traditionally associated with Janda's model of muscular imbalance, describes an interaction between shortened or overactive muscles and weakened or inhibited opposing muscles around the lumbar spine and pelvis. The commonly described pattern includes tight hip flexors and lumbar extensor muscles together with weakness or reduced activation of the abdominal and gluteal musculature. This imbalance may influence pelvic position, particularly by promoting anterior pelvic tilt and alterations in lumbar alignment (5, 6). The theoretical model therefore provides a clinically recognizable framework for examining the relationship between muscle length, muscle strength, pelvic alignment, and LBP.

The muscles commonly considered in the lower-crossed pattern include the iliopsoas, rectus femoris, thoracolumbar/lumbar extensor musculature, abdominal muscles, gluteus maximus, and gluteus medius. The iliopsoas and rectus femoris contribute to hip flexion and can influence the position of the pelvis, whereas the gluteus maximus contributes substantially to hip extension and pelvic control. The gluteus medius provides important frontal-plane pelvic stability during functional activities. The abdominal muscles contribute to trunk stabilization and control of pelvic position. Consequently, alterations in the length or strength of these muscles may affect the mechanical relationship between the lumbar spine and pelvis (5, 7).

The relationship between muscular impairment and LBP has been investigated in several observational studies. Nourbakhsh and Arab examined 17 mechanical factors in 600 participants and reported that back-extensor endurance demonstrated the strongest association with LBP among the factors examined. They also found associations involving back-extensor length and the strength of selected hip and abdominal muscles. However, their findings did not support a simple relationship between LBP and structural characteristics such as lumbar lordosis, pelvic tilt, or iliopsoas muscle length (8). These findings indicate that although muscle performance may be relevant to LBP, individual postural or structural

characteristics should not be interpreted as isolated causes of pain.

Similarly, Lee et al. conducted a five-year prospective study examining trunk muscle strength as a potential risk factor for LBP. Their findings indicated that individuals who subsequently developed LBP demonstrated a lower extension-to-flexion strength ratio, suggesting that an imbalance between trunk extensor and flexor strength may be associated with the development of LBP (9). These findings are relevant to the lower-crossed model because abdominal and spinal extensor muscle function represents an important component of lumbopelvic control. Nevertheless, the prospective nature of that study and the cross-sectional design of the present investigation address different questions, and causal interpretations should therefore be made cautiously.

Hip musculature has also received increasing attention in the study of LBP. The hip muscles provide a mechanical connection between the lower extremities and pelvis and contribute to the control of forces transmitted to the lumbar spine. A systematic review and meta-analysis reported evidence of lower-limb muscle impairment among individuals with LBP and emphasized the importance of hip and lumbopelvic muscle function in maintaining stability and coordinating movement (7). Deficits involving the gluteal musculature may alter pelvic control during weight-bearing and functional activities.

The gluteus medius is of clinical interest because of its role in controlling frontal- and transverse-plane pelvic motion. A systematic review involving more than 1,000 participants with LBP found that individuals with LBP tended to demonstrate reduced gluteus medius strength compared with individuals without LBP, although findings for other measures of muscle function were heterogeneous (10). Such findings support the clinical relevance of evaluating gluteal muscle performance in individuals with LBP, while also demonstrating that muscle dysfunction should be considered as part of a broader multifactorial presentation rather than as a single explanatory mechanism.

The association between hip extensor weakness and lumbar muscle characteristics has also been examined directly. Arab et al. studied 266 individuals with LBP and 215 matched controls and found differences in hip extensor strength between participants with and without LBP. Their analysis also identified an association between hip extensor weakness and shortened back extensor musculature in men with LBP (11). These findings provide some support for the concept of lumbopelvic muscular imbalance, particularly the coexistence of hip extensor weakness and altered back-extensor length. However, because these findings are derived from an observational study, they do not establish whether muscular impairment precedes LBP or develops because of pain and reduced activity.

The relationship between pelvic posture and LBP remains similarly complex. The traditional LCS model proposes that increased anterior pelvic tilt is accompanied by increased lumbar lordosis, thereby altering mechanical loading across the lumbopelvic region. The theoretical mechanism is that shortening of the hip flexors and lumbar extensors combined with reduced function of the abdominal and gluteal muscles may influence pelvic orientation (5, 6). However, empirical evidence has not consistently supported a direct causal relationship between static pelvic alignment and LBP. A systematic review and meta-analysis of lumbopelvic kinematics found substantial heterogeneity between studies and reported no consistent difference in standing pelvic tilt or lumbar lordosis across all individuals with and without LBP (12).

More recent evidence nevertheless suggests that pelvic alignment may differ statistically between people with and without LBP. A 2024 systematic review and meta-analysis of observational studies found that pelvic tilt was, on average, higher among participants with LBP than controls, although substantial heterogeneity existed between studies and the authors emphasized that firm conclusions regarding lumbopelvic mechanisms could not be made (13). This evidence is particularly relevant to the present study because it supports assessment of pelvic

alignment while simultaneously emphasizing that pelvic tilt should be interpreted in the context of the individual's overall clinical presentation.

The relationship between anterior pelvic tilt and muscular characteristics has also been questioned. A systematic review of non-surgical interventions for excessive anterior pelvic tilt concluded that the evidence concerning reduction of pelvic tilt and associated symptoms remains uncertain. The review highlighted that pelvic position is influenced by a complex sensorimotor system and that abdominal muscle strength alone may not explain variations in anterior pelvic tilt (14). Therefore, although the LCS model provides a useful clinical framework for examining patterns of muscle tightness and weakness, its components should not automatically be regarded as independent causes of LBP.

An additional consideration is the possibility that muscular impairments may develop because of LBP rather than being the original source of symptoms. Pain may reduce physical activity, alter movement strategies, and promote protective muscle behavior, potentially resulting in weakness, reduced endurance, or changes in muscle length. Conversely, pre-existing weakness or impaired lumbopelvic control may alter movement and loading and contribute to the persistence or recurrence of symptoms. Thus, the relationship between LBP and muscular imbalance may be bidirectional. Current approaches to LBP increasingly recognize the condition as multifactorial and recommend assessment that considers physical, psychological, and social contributors rather than attributing symptoms to a single structural abnormality (1, 2).

Within physical therapy practice, assessment of muscle length, muscle strength, and pelvic alignment may therefore provide clinically useful information for identifying impairments that coexist with LBP. The assessment of the iliopsoas, rectus femoris, thoracolumbar musculature, abdominal muscles, gluteus maximus, and gluteus medius can help characterize the lumbopelvic muscular profile of individuals presenting with LBP. The present study was designed within this clinical context to examine the relationship

between LCS-related muscular characteristics and diagnosed LBP. Specifically, it evaluates pelvic tilt, selected muscle length impairments, and the strength of abdominal and gluteal muscles among patients presenting with LBP.

Although LCS is frequently discussed in physical therapy and musculoskeletal rehabilitation, empirical evidence regarding the coexistence of its individual components among patients with LBP remains variable. Furthermore, the available evidence does not justify if every patient with LBP demonstrates the complete classical lower-crossed pattern. Therefore, examining the individual components of LCS rather than treating the syndrome as an all-or-none diagnosis may provide a more clinically meaningful understanding of the lumbopelvic impairments associated with LBP. The present investigation consequently aimed to determine the relationship of lower-crossed muscular characteristics with LBP and to describe the pattern of pelvic alignment, muscle shortening, and muscle weakness observed among patients with diagnosed LBP.

OBJECTIVE

To determine the relationship between Lower Cross Syndrome (LCS) and low back pain among patients diagnosed with low back pain.

MATERIALS AND METHODS

Study Design and Setting

A cross-sectional analytical study was conducted to determine the relationship between Lower Cross Syndrome (LCS) and diagnosed low back pain (LBP). The study was conducted in the Physiotherapy Department of Pakistan Railway Hospital, Rawalpindi, Pakistan, from November 2024 to May 2025.

Sample Size and Sampling Technique

The sample size was calculated using the OpenEpi tool, considering a 95% confidence interval, a 5% margin of error, and a 50% response distribution. A total of 180 patients were initially approached for participation. Of these, 130 patients fulfilled the specified eligibility criteria, while 27 individuals refused to participate. The study

assessment was subsequently conducted among the eligible participants who consented to participate. Participants were recruited using a purposive sampling technique based on the predefined inclusion and exclusion criteria.

Participants

Patients with a clinical diagnosis of low back pain were initially assessed and subsequently referred to the physiotherapy department. Participants of either sex aged between 15, and 55 years were eligible for inclusion. Patients younger than 15 years or older than 55 years and those with diagnosed disc protrusion resulting from trauma were excluded from the study.

Ethical Considerations

The study was initiated following approval from the Research Ethical Committee (REC) of Riphah Institute of Rehabilitation Sciences (RIRS). The research was conducted in accordance with the ethical guidelines of the Pakistan Medical Research Council (PMRC) and the Declaration of Helsinki. Participant anonymity and confidentiality were maintained throughout the study. Blinding was reported to have been ensured. Written informed consent was obtained from all participants in their preferred language, either English or Urdu, before recruitment.

Data Collection Procedure

Data was collected using a self-structured questionnaire. The questionnaire consisted of demographic characteristics and three principal assessment domains: pain intensity, pelvic tilt, and muscle tightness and strength. Demographic information included age, sex, height, weight, and occupation. Pain intensity was assessed using the Numeric Pain Rating Scale (NPRS), with scores ranging from 1 to 10, where 1 represented minimum or no pain and 10 represented maximum pain.

Assessment of Pelvic Tilt

Sagittal-plane pelvic tilt was assessed in the standing position by comparing the relative height of the posterior superior iliac spine (PSIS) and

anterior superior iliac spine (ASIS). A higher position of the PSIS relative to the ASIS was interpreted as indicating a greater degree of anterior pelvic tilt.

Assessment of Muscle Length and Tightness

Before assessment of muscle length and strength, participants performed a warm-up under the supervision of a physiotherapist. The warm-up consisted of a 5-minute walk followed by back stretching inside flexion and rotation for 10 repetitions. Muscle tightness was assessed for the iliopsoas, rectus femoris, and thoracolumbar musculature.

Iliopsoas Muscle

Iliopsoas length was assessed with the participant positioned supine and the buttocks placed at the end of the examination table. The participant was instructed to flex one knee and hold it close to the chest with both arms while allowing the opposite leg to hang freely toward the floor. The lumbar spine was maintained flat against the table. Tightness of the hip flexors was indicated when the free thigh remained in flexion or when lumbar extension occurred to allow the leg to rest on the table.

Rectus Femoris Muscle

Rectus femoris tightness was assessed by observing hip position and knee extension. If the hip remained above neutral, hip-flexor or rectus femoris tightness was suspected. The participant was then instructed to extend the knee. Movement into greater hip extension with knee extension was interpreted as indicating rectus femoris tightness, whereas lack of full hip extension with knee flexion of less than 45° was considered indicative of iliopsoas tightness.

Thoracolumbar Muscle

Thoracolumbar muscle length was assessed as part of the muscle-length examination. The study classified participants according to the recorded thoracolumbar muscle length, with the results subsequently categorized for statistical analysis.

Assessment of Muscle Strength

The strength of the abdominal, gluteus maximus, and gluteus medius muscles were assessed using manual muscle testing according to Medical Research Council (MRC) grading. The methodology used grades II through V.

Abdominal Muscle Strength

Abdominal muscle strength was assessed with the participant in the supine position. Grade V was assessed with the hands clasped behind the head, Grade IV with the arms crossed over the chest, Grade III with the arms outstretched above the plane of the body, and Grade II with the arms positioned alongside the body and the knees flexed.

Gluteus Maximus Strength

For assessment of the gluteus maximus, the participant was positioned prone with the knee flexed to 90°. The examiner stood beside the participant at pelvic level, applying resistance over the posterior thigh just above the knee while the opposite hand stabilized the pelvis. The participant was instructed to extend the hip through the available range while maintaining knee flexion. Resistance was applied downward toward the floor. Grade V represented completion of the available range and maintenance of the end position against maximal resistance; Grade IV represented holding against moderate-to-heavy resistance; Grade III represented completion and maintenance of the available range without resistance; and Grade II was classified as poor strength.

Gluteus Medius Strength

Gluteus medius strength was assessed with the participant positioned in side-lying with the test limb uppermost. The test limb was positioned slightly beyond the midline in extension, with the pelvis slightly rotated forward, while the lower limb was flexed for stability. The examiner stood behind the participant and applied resistance across the lateral aspect of the knee. The participant was instructed to abduct the hip through the available range without hip flexion or rotation. Resistance was applied downward, and

the participant was asked to maintain the elevated position against resistance. Muscle strength was graded from II to V according to the described manual muscle-testing procedure.

Data Management and Statistical Analysis

Data was collected using a paper-and-pen questionnaire and subsequently entered and analyzed using SPSS version 25. The normality of the data was assessed using the Shapiro-Wilk test. Categorical variables were presented as frequencies and percentages, whereas continuous variables were summarized using mean $\pm$ standard

deviation. Associations between the study variables were assessed using the Chi-square test. Statistical significance was set at $p < 0.05$.

RESULTS

Participant Characteristics

A total of 130 patients were approached for participation in the study, of whom 27 refused to participate. The reported mean age of the participants was 38.2 ± 6.22 years, with a male-to-female ratio of 2:1. Among the participants, 82% were married, while 41.3% were housewives.

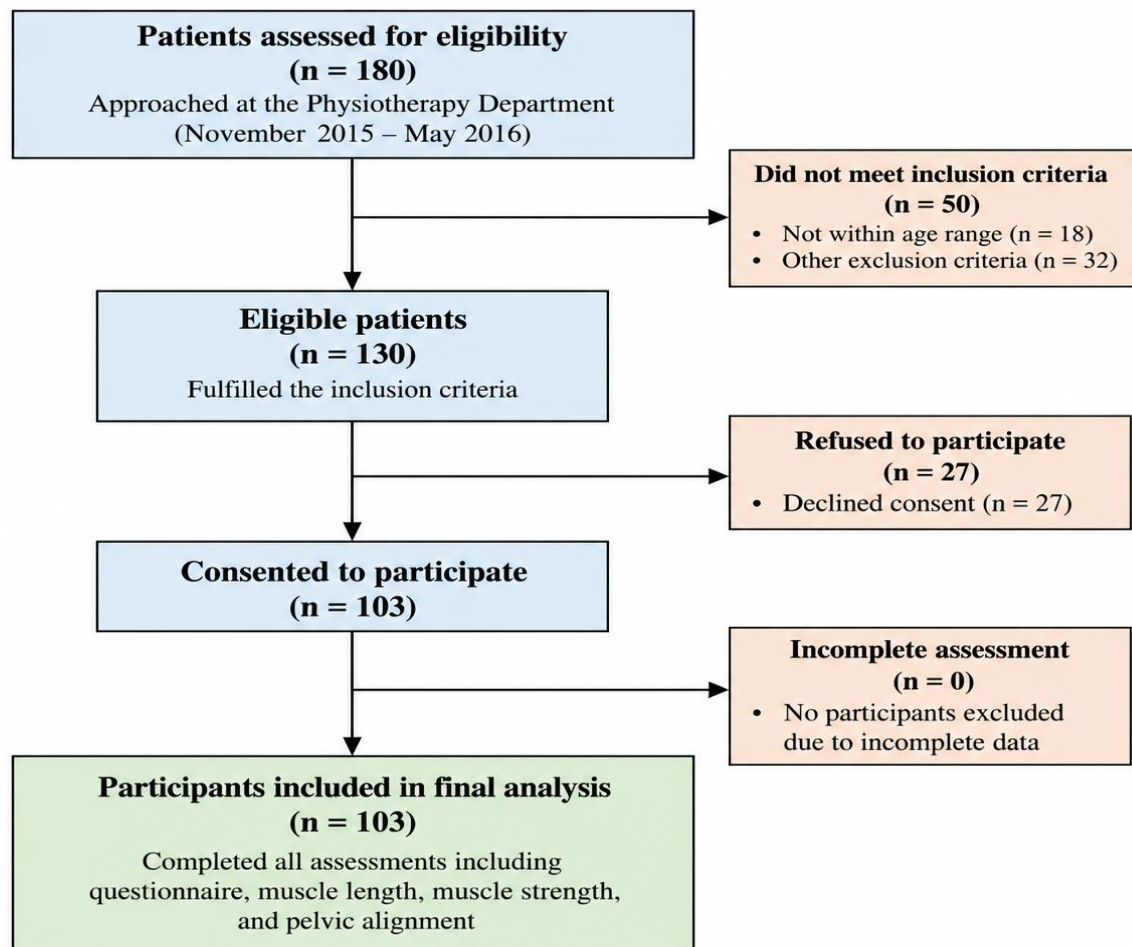


Figure 1. Participant flow diagram showing patient recruitment, exclusions, and final sample included in the analysis

The demographic and selected clinical characteristics of the study participants are presented in Table 1.

Table 1. Demographic and Clinical Characteristics of the Study Participants

Variable	Result
Total patients approached	130
Refused to participate	27
Mean age (years)	38.2 ± 6.22
Male-to-female ratio	2:1
Married participants	82%
Housewives	41.3%
NPRS score of 5	60%
Recent episode of LBP within 4–6 months	38.1%
Intermittent aching pain	Approximately 50%
Bending reported as aggravating position	Most participants
Lying down reported as relieving position	Most participants
Lordotic lumbar curve	>65%
Anterior pelvic tilt	50%

Pain Characteristics and Lumbopelvic Alignment

Regarding pain intensity, 60% of participants had an NPRS score of 5. Approximately 38.1% reported a recent episode of LBP within the preceding 4–6 months. Approximately half of the participants reported intermittent aching pain. Bending was identified as the most common aggravating position, whereas lying down was reported as the most relieving position. More than 65% of participants demonstrated a lordotic lumbar curve, while 50% demonstrated anterior pelvic tilt. These findings indicate that altered lumbar and pelvic alignment was frequently observed within the assessed LBP population.

Muscle Length and Tightness

The assessment demonstrated shortening of the iliopsoas muscle in all participants. Among them, 76.2% had more than 20 iliopsoas shortenings, 19% had more than 10° shortening, and 4.8% had 5° shortening. Rectus femoris shortening was also documented. The reported distribution included 30° shortening in 20.6%, 25° shortening in 15.9%, and 20° shortening in 14.3% of participants. The source additionally reported 40°, 35°, 45°, 60°, and 15° categories, but because the original document's formatting of the degree values is corrupted in places, these values should be verified against the original data sheet before publication. For thoracolumbar muscle length, 38.1% of participants were reported to have normal muscle length (10 inches), whereas 61.9% demonstrated thoracolumbar muscle tightness, defined in the study as less than 10 inches.

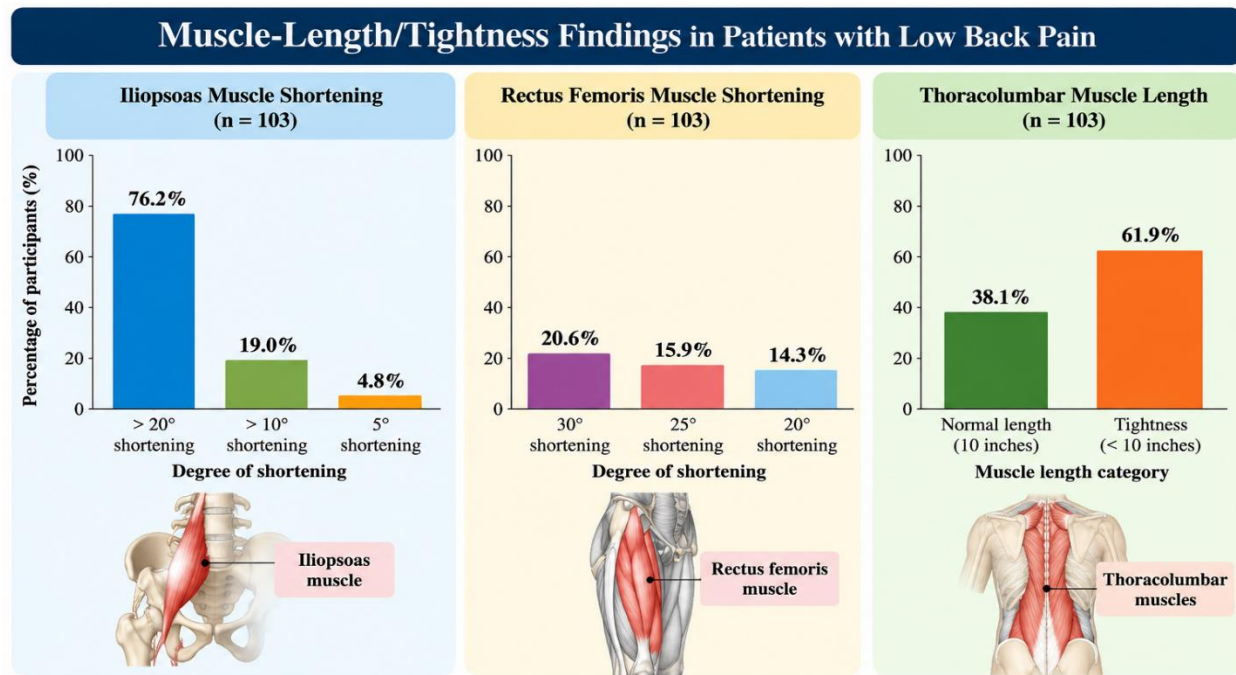


Figure 2. Distribution of selected muscle-length impairments among patients with low back pain – iliopsoas, rectus femoris, and thoracolumbar tightness

The muscle-length findings are summarized in Table 2.

Table 2. Distribution of Muscle Length and Tightness

Muscle	Assessment category	Participants (%)
Iliopsoas	Shortening >20°	76.2
Iliopsoas	Shortening >10°	19.0
Iliopsoas	Shortening 5°	4.8
Rectus femoris	30° shortening	20.6
Rectus femoris	25° shortening	15.9
Rectus femoris	20° shortening	14.3
Thoracolumbar	Normal length (10 inches)	38.1
Thoracolumbar	Tightness (<10 inches)	61.9

Muscle Strength

Reduced abdominal muscle strength was common among the participants. 28.6% demonstrated Grade 4 abdominal strength, 27.0% demonstrated Grade 4+, 20.6% demonstrated Grade 3+, and 11.1% demonstrated Grade 3. Only approximately 12% were reported to have normal abdominal muscle strength. For the gluteus maximus, 31.7% demonstrated Grade 4 strength,

28.6% Grade 4+, 17.5% Grade 3+, and 9.5% Grade 3, while 12.7% were reported to have normal strength. Regarding the gluteus medius, more than 30.2% of participants demonstrated Grade 4 or 4+ strength, 17.5% demonstrated Grade 3+, and 11.1% demonstrated Grade 3. Approximately 11.1% were reported to have normal gluteus medius strength.

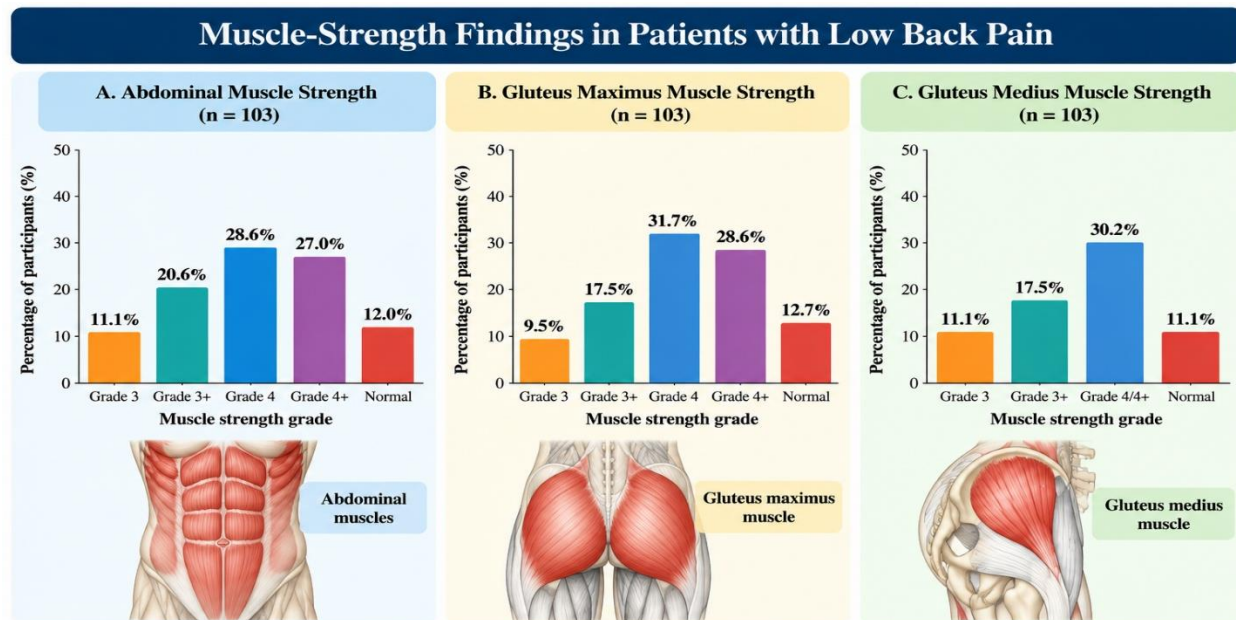


Figure 3. Distribution of abdominal, gluteus maximus, and gluteus medius muscle strength grades

These findings are presented in Table 3.

Table 3. Distribution of Muscle Strength Grades

Muscle	Strength grade/category	Participants (%)
Abdominal	Grade 4	28.6
Abdominal	Grade 4+	27.0
Abdominal	Grade 3+	20.6
Abdominal	Grade 3	11.1
Abdominal	Normal	~ 12.0
Gluteus maximus	Grade 4	31.7
Gluteus maximus	Grade 4+	28.6
Gluteus maximus	Grade 3+	17.5
Gluteus maximus	Grade 3	9.5
Gluteus maximus	Normal	12.7
Gluteus medius	Grade 4/4+	>30.2
Gluteus medius	Grade 3+	17.5
Gluteus medius	Grade 3	11.1
Gluteus medius	Normal	~ 11.1

Associations Between Muscle Characteristics and Demographic Variables

Significant associations were observed between thoracolumbar muscle length and marital status ($p < 0.003$) and occupation ($p < 0.005$). Rectus femoris muscle length was significantly associated with marital status ($p < 0.044$). Iliopsoas muscle

length was significantly associated with marital status ($p < 0.002$), whereas its reported association with occupation was $p < 0.051$. Abdominal muscle strength was significantly associated with age, marital status, and occupation, with all reported p -values < 0.001 . Gluteus maximus strength was significantly associated with age ($p < 0.002$), marital

status ($p < 0.000$), and occupation ($p < 0.001$). Gluteus medius strength was significantly associated with age ($p < 0.001$), marital status ($p < 0.000$), and occupation ($p < 0.000$). No, statistically significant association was reported between gender and muscle length or muscle strength. In addition, age was not significantly

associated with thoracolumbar, iliopsoas, or rectus femoris muscle length, while occupation was not significantly associated with rectus femoris muscle length. The reported associations are summarized in Table 4.

Table 4. Associations Between Muscle Characteristics and Demographic Variables

Muscle	Strength grade/category	Participants (%)	Muscle
Abdominal	Grade 4	28.6	Abdominal
Abdominal	Grade 4+	27.0	Abdominal
Abdominal	Grade 3+	20.6	Abdominal
Abdominal	Grade 3	11.1	Abdominal
Abdominal	Normal	~12.0	Abdominal
Gluteus maximus	Grade 4	31.7	Gluteus maximus
Gluteus maximus	Grade 4+	28.6	Gluteus maximus
Gluteus maximus	Grade 3+	17.5	Gluteus maximus
Gluteus maximus	Grade 3	9.5	Gluteus maximus
Gluteus maximus	Normal	12.7	Gluteus maximus
Gluteus medius	Grade 4/4+	>30.2	Gluteus medius
Gluteus medius	Grade 3+	17.5	Gluteus medius
Gluteus medius	Grade 3	11.1	Gluteus medius
Gluteus medius	Normal	~11.1	Gluteus medius

Summary of Principal Findings

Overall, the results demonstrated a high frequency of LCS-related musculoskeletal findings among the assessed patients with LBP. Anterior pelvic tilt and increased lumbar lordotic posture were commonly observed, while iliopsoas shortening and thoracolumbar tightness were frequent findings. Reduced abdominal, gluteus maximus, and gluteus medius muscle strength was also commonly reported. Several muscle characteristics demonstrated significant associations with age, marital status, or occupation, whereas gender was not significantly associated with the assessed muscle characteristics.

DISCUSSION

The present study investigated the relationship between Lower Cross Syndrome (LCS)-related muscular characteristics and low back pain (LBP), with particular emphasis on pelvic alignment, muscle length, and muscle strength. The findings

demonstrated a high frequency of lumbopelvic musculoskeletal impairments among patients diagnosed with LBP. More than 65% of participants demonstrated a lordotic lumbar curve, 50% presented with anterior pelvic tilt, all participants demonstrated some degree of iliopsoas shortening, and 61.9% demonstrated thoracolumbar muscle tightness. In addition, reduced abdominal, gluteus maximus, and gluteus medius muscle strength were frequently observed. These findings are broadly compatible with the concept that LBP may be accompanied by alterations in trunk and hip muscle function; however, because the present study was cross-sectional, the observed impairments cannot be interpreted as direct causes of LBP.

Muscle Imbalance and Low Back Pain

One of the most prominent findings of the present study was the high frequency of reduced trunk and hip muscle strength. Only approximately 12% of

participants demonstrated normal abdominal muscle strength, while the majority presented with strength grades ranging from 3 to 4+. Similarly, only 12.7% of participants demonstrated normal gluteus maximus strength, and approximately 11.1% demonstrated normal gluteus medius strength. This pattern suggests that muscular impairment involving the trunk and hip musculature is common among the patients assessed in this study. The present findings are consistent with the work of Nourbakhsh and Arab, who investigated 17 mechanical factors in 600 participants and found that back-extensor endurance had the strongest association with LBP among the factors examined. Their study also identified significant associations between LBP and selected measures of muscle strength, including abdominal and hip muscle strength (8, 11). These findings support the relevance of assessing muscle performance in patients with LBP, although they also indicate that muscular factors should be considered within a broader multifactorial framework. The findings are further supported by Lee et al. who conducted a five-year prospective study and reported that participants who developed LBP had a significantly lower trunk extension-to-flexion strength ratio than those who remained free of LBP (9). Their findings suggest that an imbalance between trunk extensor and flexor strength may be associated with future LBP. In contrast, the present study assessed patients who already had diagnosed LBP; therefore, the current findings demonstrate the coexistence of muscle weakness with LBP rather than establishing muscle weakness as a prospective risk factor. An important consideration is that muscle weakness observed in individuals with LBP may have a bidirectional relationship with pain. Reduced activity altered movement strategies, and pain-related inhibition may contribute to reduced muscle performance after the onset of symptoms. Conversely, pre-existing deficits in muscle capacity may influence movement and load distribution. Thus, the high prevalence of abdominal and gluteal weakness observed in the present study should not be interpreted as evidence that these impairments independently caused LBP.

Iliopsoas and Rectus Femoris Muscle Shortening

The present study demonstrated iliopsoas shortening in all assessed participants, with 76.2% demonstrating more than 20° of shortening. Rectus femoris shortening was also frequently observed. These findings are compatible with the traditional LCS model, which proposes that shortening or increased activity of hip-flexor musculature may coexist with weakness of the abdominal and gluteal muscles and contribute to altered lumbopelvic alignment (5, 6). However, the findings should be interpreted cautiously. Nourbakhsh and Arab reported that structural characteristics, including iliopsoas length and pelvic tilt, were not associated with the occurrence of LBP in their multifactorial analysis (8, 11). This apparent difference between the present study and previous research may be explained by the different research questions. The current investigation describes the prevalence of iliopsoas shortening within a population already diagnosed with LBP, whereas Nourbakhsh and Arab examined whether specific mechanical characteristics were associated with the occurrence of LBP (8, 11). Therefore, the finding that all participants in the present study demonstrated iliopsoas shortening does not establish that iliopsoas shortening is a primary cause of LBP. It indicates that hip-flexor shortening was a common clinical finding in this LBP population. Prospective studies including asymptomatic controls would be required to determine whether iliopsoas shortening precedes the development of LBP or develops secondary to pain, altered activity, or changes in movement behavior.

Thoracolumbar Muscle Tightness

Thoracolumbar muscle tightness was identified in 61.9% of participants, while 38.1% demonstrated normal thoracolumbar muscle length according to the criteria used in the study. This finding is consistent with the broader concept that alterations in the length and performance of lumbar musculature may coexist with LBP. Arab et al. specifically investigated the relationship between hip-extensor strength and back-extensor length in 266 patients with LBP and 215 matched

controls. They reported differences in hip-extensor strength between the groups and identified a significant relationship between back-extensor length and hip-extensor strength in men with LBP (11). Their findings support the concept that weakness of the hip extensors and altered back-extensor length may occur together in patients with LBP. The current study extends this observation by demonstrating a high frequency of thoracolumbar tightness together with reduced gluteal and abdominal strength. However, the cross-sectional nature of both studies means that the temporal relationship between these impairments and LBP remains uncertain. Muscle tightness may contribute to altered movement and mechanical loading, but it may also develop as part of the patient's response to pain and reduced physical activity.

Gluteus Maximus and Gluteus Medius Weakness

Reduced gluteal muscle strength was another important finding of the present study. Only 12.7% of participants demonstrated normal gluteus maximus strength, while the remaining participants demonstrated varying degrees of weakness. Similarly, only approximately 11.1% of participants demonstrated normal gluteus medius strength. These findings are clinically relevant because the gluteal musculature plays an important role in controlling hip and pelvic movement. Gluteus maximus contributes to hip extension and assists with control of the pelvis, while gluteus medius contributes to pelvic stability during weight-bearing activities. Consequently, impaired gluteal strength may alter lumbopelvic movement and load distribution. The findings concerning gluteal muscle function are consistent with previous literature. De Sousa et al. reported evidence of lower-limb muscle-strength impairments in people with LBP and emphasized the importance of hip and lower-limb muscle function in the clinical presentation of LBP (7). Similarly, the study by Arab et al. found significantly lower hip-extensor strength among patients with LBP compared with matched controls and identified a relationship between hip-extensor weakness and back-extensor length in

men with LBP (11). The present findings should nevertheless be interpreted as evidence of an impairment pattern rather than proof of causation. Reduced gluteal strength could contribute to altered lumbopelvic mechanics, but it may also result from pain-related activity restriction. Therefore, rehabilitation assessment should identify whether the observed weakness represents a modifiable contributor, a consequence of symptoms, or a combination of both.

Pelvic Tilt and Lumbar Lordosis

Anterior pelvic tilt was observed in 50% of participants, while more than 65% demonstrated a lordotic lumbar curve. These findings are compatible with the traditional description of LCS, in which muscular imbalance around the pelvis is proposed to influence pelvic orientation and lumbar curvature (6). According to the classical LCS model, shortening of the hip flexors and lumbar extensor musculature combined with reduced function of the abdominal and gluteal muscles may promote anterior pelvic rotation and an increase in lumbar lordosis (5, 6). The present study demonstrated several of these characteristics concurrently, including iliopsoas shortening, thoracolumbar tightness, reduced abdominal strength, and reduced gluteal strength. However, the relationship between static pelvic alignment and LBP remains controversial. Nourbakhsh and Arab found that lumbar lordosis and pelvic tilt were not associated with the occurrence of LBP in their multifactorial analysis (8, 11). Similarly, Laird et al. in a systematic review and meta-analysis of lumbo-pelvic kinematics, reported substantial heterogeneity among studies examining movement and posture in people with and without LBP (12). These findings are important when interpreting the present results. The presence of anterior pelvic tilt in half of the participants does not demonstrate that anterior pelvic tilt caused their LBP. Rather, it indicates that altered pelvic alignment was a common finding within this clinical population. Static posture should therefore be considered alongside dynamic movement, muscle capacity, functional

limitations, pain characteristics, and other individual factors.

Relationship Between Muscle Imbalance and the Lower Cross Syndrome Model

Taken together, the findings of the present study demonstrate several characteristics traditionally associated with LCS. These include iliopsoas shortening, rectus femoris shortening, thoracolumbar tightness, anterior pelvic tilt, and weakness of the abdominal and gluteal musculature. The coexistence of these characteristics supports the clinical usefulness of evaluating multiple components of the lumbopelvic system rather than focusing on a single muscle. Nevertheless, the findings also highlight the importance of distinguishing between a pattern of impairments and a causal diagnosis. The LCS model provides a framework for describing relationships between muscle length, muscle strength, pelvic alignment, and lumbar posture (5, 6), but the current evidence does not establish that this pattern independently causes LBP. In fact, the study by Nourbakhsh and Arab found that several structural characteristics traditionally associated with LCS were not associated with the occurrence of LBP (8, 11). Therefore, the findings of the present study are best interpreted as demonstrating that LCS-related muscular characteristics frequently coexist with diagnosed LBP. This interpretation is more appropriate than concluding that LCS is the direct cause of LBP.

Demographic Associations

The present study identified significant associations between muscle characteristics and demographic variables. Thoracolumbar muscle length was significantly associated with marital status and occupation, while rectus femoris muscle length was significantly associated with marital status. Iliopsoas muscle length was significantly associated with marital status, whereas the reported association with occupation did not reach the predefined significance threshold of $p < 0.05$. Muscle strength demonstrated several significant associations. Abdominal muscle

strength was significantly associated with age, marital status, and occupation. Gluteus maximus and gluteus medius strength were also significantly associated with age, marital status, and occupation. In contrast, gender was not significantly associated with muscle length or muscle strength, and age was not significantly associated with thoracolumbar, iliopsoas, or rectus femoris muscle length. These associations suggest that muscle characteristics may vary according to demographic and occupational circumstances. Occupational activities may influence habitual posture, physical activity, repetitive loading, or prolonged sitting and standing. However, the present study did not investigate these mechanisms directly. Therefore, the observed associations should be interpreted as statistical relationships rather than evidence that occupation or marital status directly causes muscular impairment.

Clinical Implications

The findings have important implications for physical therapy assessment. The high frequency of abdominal and gluteal weakness suggests that assessment of trunk and hip muscle performance may be clinically relevant in patients presenting with LBP. Similarly, the high prevalence of iliopsoas and thoracolumbar tightness supports assessment of muscle flexibility and length as part of a comprehensive physical examination. The results also suggest that clinicians should consider the lumbopelvic region as an integrated functional system. Rather than assessing lumbar pain in isolation, examination may include abdominal muscle performance, hip-extensor and hip-abductor strength, hip-flexor length, thoracolumbar muscle characteristics, and pelvic alignment. This approach is consistent with evidence showing associations between muscle function and LBP (8, 11). At the same time, treatment should not be based solely on correcting a static posture. Evidence from systematic reviews indicates substantial variability in lumbo-pelvic movement and posture among individuals with and without LBP (12). Consequently, rehabilitation should be individualized and should

incorporate pain management, progressive strengthening, flexibility where clinically indicated, functional movement, physical activity, and patient-specific contributing factors rather than assuming that anterior pelvic tilt or lumbar lordosis is inherently pathological.

Strengths and Limitations

A strength of the present study is that several components of the lumbopelvic system were assessed within the same population. The study evaluated pelvic alignment, muscle length, and muscle strength, allowing a broader description of LCS-related impairments in patients with diagnosed LBP. The use of standardized clinical assessments and manual muscle testing also provided a practical clinical profile of the participants.

Several limitations should nevertheless be acknowledged. First, the cross-sectional design prevents determination of temporal or causal relationships between LCS-related impairments and LBP. Second, the absence of an asymptomatic control group prevents direct comparison of the prevalence of these impairments between individuals with and without LBP. Third, purposive sampling from a single hospital may limit the generalizability of the findings to other populations and healthcare settings. Fourth, several measurements relied on clinical assessment and manual muscle testing, which may be influenced by examiner-related variability. Finally, the study focused primarily on physical characteristics and did not comprehensively assess psychosocial or behavioral factors that may influence LBP.

Overall Interpretation

Overall, the present study demonstrates a high frequency of LCS-related muscular characteristics among patients diagnosed with LBP. Iliopsoas shortening, thoracolumbar tightness, abdominal weakness, gluteal weakness, anterior pelvic tilt, and lordotic lumbar posture were commonly observed. These findings are broadly consistent with previous research demonstrating associations between LBP and impaired trunk or hip muscle

function (7, 8). However, the findings should not be interpreted as demonstrating that LCS directly causes LBP. Previous research has shown inconsistent relationships between LBP and static pelvic posture or individual muscle-length characteristics (8, 12). The most appropriate interpretation is therefore that LCS-related muscular impairments may represent one component of the multifactorial clinical presentation of patients with LBP. Future prospective studies involving larger samples, healthy control groups, objective measures of muscle performance, and longitudinal follow-up are needed to determine whether the identified muscular impairments precede LBP, develop secondary to pain and reduced activity, or interact bidirectionally over time.

CONCLUSION

The present study demonstrated that Lower Cross Syndrome (LCS)-related musculoskeletal impairments were frequently observed among patients with diagnosed low back pain (LBP). Anterior pelvic tilt and a lordotic lumbar posture were commonly identified, while iliopsoas shortening and thoracolumbar muscle tightness were also frequently observed. Reduced strength of the abdominal, gluteus maximus, and gluteus medius muscles were similarly common among the assessed participants. Several muscle characteristics were significantly associated with demographic factors, particularly age, marital status, and occupation, whereas gender was not significantly associated with muscle length or muscle strength. These findings indicate that muscular imbalance involving the trunk, hip, and lumbopelvic region is a frequent clinical feature among patients with LBP. Overall, the findings support the importance of assessing muscle length, muscle strength, and pelvic alignment as components of the physical therapy examination of patients with LBP. However, because this was a cross-sectional study without a comparison group, the findings do not establish that Lower Cross Syndrome or any individual muscular impairment directly causes low back pain. Further longitudinal and controlled studies are recommended to clarify

the temporal and causal relationship between LCS-related muscular impairments and LBP.

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