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Diagnosis of Lower Cross Syndrome: A Review

Aman Hussain[1]; Dr. Jaganjyoti Das[2*]; Dr. SajjanPal[3]

[1]MPT, Faculty of Physiotherapy, SGT University, Gurugram (Haryana)-122505, India
[2]Assistant Professor, Faculty of Physiotherapy, SGT University, Gurugram (Haryana)-122505, India
[3]Associate Professor, Faculty of Physiotherapy, SGT University, Gurugram (Haryana)-122505, India

Corresponding Author: Dr. Jaganjyoti Das[2*]

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Abstract:

- ***Background:***
Lower Crossed Syndrome (LCS) is a condition marked by muscle imbalances, particularly involving tightness in the hip flexors and lumbar extensors, alongside weakness in the abdominal and gluteal muscles. This imbalance often leads to postural abnormalities such as anterior pelvic tilt and lumbar lordosis.

- ***Methodology:***
This review encompasses 13 studies conducted between 2006 and 2024, utilizing databases like PubMed and Scopus to investigate the prevalence and diagnostic methods associated with LCS. The studies were selected based on specific diagnostic criteria pertinent to LCS.

- ***Results:***
The analysis indicates a lack of consistency in diagnostic practices across the studies; however, prevalent indicators include tight hip flexors and lumbar extensors, coupled with weakness in the abdominal and gluteal regions. Notable diagnostic tools identified include the Thomas Test for assessing hip flexor tightness, manual muscle testing for evaluating core strength, and the use of non-elastic tape to measure paraspinal extensibility.

- ***Discussion:***
To enhance diagnostic precision, a standardized criterion is recommended, emphasizing the evaluation of posture, muscle flexibility, and strength. This methodology aims to assist clinicians in the early identification of LCS and the implementation of targeted interventions.

- ***Conclusion:***
Implementing a standardized diagnostic framework for LCS has the potential to improve diagnostic accuracy and treatment efficacy, thereby mitigating the prevalence and effects of chronic lower back pain in at-risk populations.

Keywords: *Lower Crossed Syndrome; Low Back Pain; Pelvic Tilt; Lumbar Lordosis; Flexibility; Strength.*

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I. INTRODUCTION

Lower Crossed Syndrome (LCS) is a condition involving imbalances in the muscles around the lower back and pelvis. First introduced by Dr. Vladimir Janda in the 1980s, LCS describes a pattern of muscle tightness and weakness that disrupts normal movement and posture (Janda,1983) (17). Specifically, tight hip flexors and lower back muscles are coupled with weak abdominal and gluteal muscles, leading to an anterior pelvic tilt, increased lumbar lordosis, and compensatory movement patterns. These imbalances often contribute to lower back pain and reduced mobility (Page et al., 2010; Dieèné et al., 2022) (18)(19).

Modern lifestyles, particularly those involving prolonged sitting and poor posture, have amplified the

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prevalence of LCS. Sedentary behavior can lead to shortened hip flexors and weakened gluteal muscles, exacerbating postural issues. This is commonly observed in office workers, drivers, and even athletes whose activities reinforce these imbalances, such as cycling or running (Sahrmann, 2022(20); Ebara et al., 2021)(21). Among athletes, the prevalence can be as high as 58%, especially in those involved in sports that require repetitive flexion and extension movements, such as cycling or weightlifting (Boyle et al., 2010). Additionally, aging populations are more susceptible to LCS, with studies indicating that muscle imbalances are prevalent in nearly 90% of individuals over the age of 60, contributing to an increased risk of falls and lower back pain. (4)

Beyond biomechanical factors, LCS is influenced by neuromuscular and lifestyle factors, underscoring the need for a multidimensional diagnostic approach. Diagnosing LCS is challenging because its symptoms overlap with other lumbopelvic disorders. Clinicians typically rely on assessments like postural analysis, muscle palpation, and functional movement tests such as the overhead squat or prone hip extension tests. These methods, while useful, can be subjective and vary in reliability (Cook et al., 2018). For instance, anterior pelvic tilt and hyper lordosis—key indicators of LCS—can also be seen in other conditions like spondylolisthesis, complicating diagnosis (Tayade et al., 2021) (22).

Advancements in diagnostic technology are helping overcome these limitations. Tools like surface electromyography (sEMG), ultrasound imaging, and motion analysis systems provide objective data on muscle activity and movement patterns. For example, sEMG identifies activation imbalances, while ultrasound imaging assesses the size and function of stabilizing muscles like the transverse abdominis (Cram et al., 2020; Hides et al., 2020) (24)(25). Motion analysis systems further enhance understanding by capturing dynamic movement patterns and compensatory strategies (Gupta et al., 2021) (23). However, these tools are often expensive and require specialized training, limiting their widespread use.

A major challenge in LCS diagnosis is the lack of standardized criteria. Variability in definitions and assessment techniques can result in inconsistent diagnoses and treatment plans. Some practitioners focus on muscle tightness and weakness, while others emphasize movement dysfunction and joint mechanics, creating disparities in clinical practice (Page et al., 2010; Sahrmann, 2022) (18)(20).

The interconnected nature of the musculoskeletal system highlights the need for a comprehensive diagnostic approach. Dysfunction in the lumbopelvic region often affects nearby areas like the thoracic spine and lower limbs, causing compensatory changes that perpetuate pain and functional issues. For example, weak gluteal muscles may lead to overactive hamstrings, altering gait mechanics and increasing lumbar spine strain (Tayade et al., 2021) (22). Similarly, tight hip flexors can restrict hip extension, forcing compensatory movements that increase injury risk.

Given its widespread impact, accurately diagnosing LCS is crucial for developing effective treatment strategies. Such strategies aim to restore muscle balance, improve movement efficiency, and prevent recurrence. This review explores current diagnostic approaches for LCS, evaluating traditional methods, functional assessments, and advanced technologies. By identifying their strengths and limitations, the goal is to enhance diagnostic accuracy and inform evidence-based clinical practice.

II. MATERIALS AND METHODS

- *Search Strategy:-*

Using search terms like "lower crossed syndrome," "pelvic crossed syndrome," "inferior crossed syndrome," and "nonspecific low back pain," a search of well-known major databases like PubMed, Scopus, Cochrane and by Google Scholar was carried out. Studies published from 2024 to 2006 that specifically followed the LCS diagnostic criteria in subjects with or without LBP were included in this review.

- *Inclusion Criteria:-*

TABLE 1 provides a summary of the included studies. As the review was inclusive, both randomized and non-randomised designs were allowed. The majority of studies are non-experimental. Due to a lack of available literature, studies that met the following criteria were included: they had to involve articles about lower crossed syndrome, be written in English only, and follow LCS diagnostic methods. Newsletters, case reports, dissertations, and thesis were excluded. Studies using animal models and LCS and LBP on diseased or injured subjects were not included in this study.

As a result, data on LCS diagnostic parameters, both quantitative and qualitative, were retrieved between 2024 and 2006. Only the studies that provided appropriate diagnostic criteria and data were incorporated into this review. In the end, 13 papers were found to be suitable after incomplete articles and studies in other languages were excluded.

Table 1 The Studies taken into Review

S. NO.	Author	Sample	Title	Source	Diagnostic Criteria Used
1.	Enas Ahmed Kandil **(2024) (8)**	Fifty participants (25 to 40 years old) suffer from low back pain with lower cross syndrome	**Effect of global postural reeducation on chronic low pain patients with lower cross syndrome**	Google scholar, Bulletin of Faculty of Physical Therapy (2024) 29:8	Modified Thomas test for testing length of B/L Iliopsoas muscle Tightness of erector spinae by visual assessment of shortness in lumbar erector spinae muscles Weakness of gluteus maximus by prone hip extension coordination\strength test

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					Weakness of abdominals by the trunk flexion coordination and strength test. Measurement of lumbar lordosis angle.
2.	Ghanishtha Burile **(2024) (6)**	A total of 75 housemaids between the ages of 35 and 50 years complaining of pain in the lower back were included in the study	**Prevalence of Lower Cross Syndrome in Housemaids**	PubMed, Cureus v.16(4); 2024 Apr	Length of the spinal extensor muscles measuring tape was employed. Abdominals and gluteus MMT in active B/L SLR. Bilateral iliopsoas Length measured by hip extension angle utilizing a goniometer.
3.	Mahishale Arati **(2023) (9)**	A total of 355 females were included in the study by convenience sampling.	**Prevalence of Pelvic Crossed Syndrome in Females with Primary Dysmenorrhea and its Impact on Physical Activity: An Observational Study**	Google scholar, Indian Journal of Physical Therapy and Research, 5(1), 60-65.	Thomas test for tightness of iliopsoas bilaterally using a universal goniometer. Modified Schober's test for thoracolumbar extensors flexibility Abdominals and gluteus MMT with MRC grading. Simple physical activity questionnaire (simPAQ) to determine the hours involved in physical activity.
4.	P. Puagprakong **(2022) (2)**	48 office workers (healthy:18, LCS type A:18, LCS type B:18) who work in computer use for at least 4 hours/day	**The Effects of Lower Crossed Syndrome on Upper Body Posture during Sitting in Female Office Workers**	Google scholar, Muscles, Ligaments and Tendons Journal 2022;12 (4)	Standing posture assessment in frontal and lateral view. Muscle length testing of iliopsoas length by Thomas test and Rectus femoris Length by modified Thomas test Hamstrings length was assessed by straight leg raise (SLR) Thoracolumbar and lumbar extensors muscle using an inclinometer. Gluteus maximus, gluteus medius, abdominal muscle, hip flexors muscle and back extensors muscle strength by Wireless muscle tester
5.	Nouman Khan **(2022) (14)**	The sample size of 58 patients age from 20-50 years.	**Comparing the Effect of Stretching and Muscle Energy Technique in the Management of Lower Cross Syndrome**	Google scholar, Vol. 16 No. 07 (2022): Pakistan Journal of Medical & Health Sciences	Presence of LCS pattern in standing position, patients having chronic low back pain. Positive prone hip extension movement pattern test.
6.	Sushmitha T **(2022) (10)**	33 Girls subjects in age group of 18-23yr were selected by using convenient sampling Technique.	**Prevalence of Lower Crossed Syndrome among Collegiate Young Females in Kochi**	Google search, International Journal of Science and Research (IJSR) Volume 11 Issue 1, January 2022	Modified Thomas test for tightness of iliopsoas bilaterally using a universal goniometer. Abdominal muscular strength and bilateral Gluteus maximus Manual muscle testing was graded by MRC grading system. Length of the spinal extensor muscles measuring tape was employed.
7.	Mohammad Rahimi **(2022) (13)**	Women with LCS in the age range of 35 to 50 years.	**Effect of Six Weeks of Pilates Exercises on the Function of Upper and Lower Extremities of Middle-aged**	Physical Treatments, October 2022. Volume 12. Number 4	Thomas test to rule out hip flexors tightness. Weakness of gluteus maximus by prone hip extension coordination\strength test Weakness of abdominals by the trunk flexion coordination and strength test

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			Women With Lower Crossed Syndrome		Shortness of erector spinal muscles straighteners
8.	Priyanka Sahu **(2021) (1)**	300 persons of 21-27 years of age	**Screening for lower cross syndrome in asymptomatic individuals**	Google scholar, Journal of medical pharmaceutical and allied sciences, Volume 10 - Issue 4, 1266, July - August 2021, Page - 3089-3093	REEDCO posture scale for initial postural examination. Universal Goniometer and the Modified Thomas test for B/L Illio psoas muscle Non-elastic measuring tape for length of the spinal extensor muscle Abdominal muscular strength and bilateral Gluteus maximus Manual muscle testing was graded by MRC grading system.
9.	Shrikrushna S. Kale **(2020) (5)**	41 Students between the ages 11 to 15 years were screened for lower crossed syndrome.	**Effect of Stretching and Strengthening Exercises (Janda's Approach) in School Going Children with Lower Crossed Syndrome**	Google scholar, Research gate, Indian Journal of Public Health Research & Development, May 2020, Vol. 11, No. 05	Manual Muscle Testing of abdominals and gluteal muscles was assessed. Thomas test to rule out flexor tightness causing the anterior pelvic tilt
10.	Sneha Pradeep **(2020) (12)**	Individuals of both genders between the age groups of 18 and 30 years who had low back pain with diagnosis of PCS were eligible for the study.	**Effect of Sciatic Nerve Neurodynamic Sustained Natural Apophyseal Glides on Individuals with Pelvic Crossed Syndrome: A Randomized Controlled Trial**	Indian Journal of Physical Therapy and Research | Volume 2 | Issue 1 | January-June 2020	Length of bilateral Iliopsoas muscle by Modified Thomas test. Erector spinae and hamstring flexibility by finger-to-floor test. Degree of lumbar lordosis by flexicurve tool. Modified Oswestry Disability Questionnaire Pain sensitivity of the erector spinae and quadratus lumborum muscles by pressure algometer.
11.	Shriya Das **(2017) (11)**	A stratified purposive sampling was done to include 200 healthy male and female volunteers within 21yrs to 31yrs of age.	**Prevalence Of Lower Crossed Syndrome In Young Adults: A Cross Sectional Study**	Google search, International Journal of Advanced Research (IJAR) Int. J. Adv. Res. 5(6), 2217-2228	Length of bilateral Iliopsoas muscle by Modified Thomas test using Universal Goniometer. Length of spinal extensor muscle by non elastic measuring tape. Strength of abdominal muscle and bilateral Gluteus maximus Muscle by MRC grading of manual muscle testing.
12.	Sneha Dhanani **(2014) (7)**	Girls in age group of 16-22yrs	**A SURVEY ON PREVALENCE OF LOWER CROSSED SYNDROME IN YOUNG FEMALES**	International Journal of Pharmaceutical Science and Health Care Issue 4, Vol 1. February 2014	Thomas test to rule out hip flexors tightness. Length of spinal extensor muscle by Sit and reach test. Strength of abdominal muscle and bilateral Gluteus maximus Muscle by MRC grading of manual muscle testing.
13.	Mohammad Reza Nourbakhsh **(2006) (4)**	A total of 600 subjects between the ages of 20 and 65 were selected.	**The relationship between pelvic cross syndrome and chronic low back pain**	Google scholar, Journal of Back and Musculoskeletal Rehabilitation 19 (2006) 119–128	Flexible ruler for measuring lumbar lordosis Extensibility of back extensor muscles indirectly by measuring the degree of maximum lumbar flexion Thomas test for B/L Illio psoas muscle

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					Active knee extension (AKE) method was used for hamstring muscle length Abdominal muscular strength and bilateral Gluteus maximus by Pressure meter.

III. RESULTS

The above-mentioned studies have followed a specific assessment criterion for screening of LCS but has a variability in the screening criteria and their values in the different population. This section summarizes the criteria and variability of the followed screening criteria of taken studies in this review.

A. Summary and Results of Diagnostic Methods used: -

➢ *Postural Assessment: -*

Only one study (Sahu et al., 2022)(1) used the REEDCO posture scale to screen for posture; out of 300 people, only 29.7% of the population met the criteria for normal posture. Another study (Puagprakong et al., 2022)(2) used a 2D motion analysis system to assess sitting posture in front and lateral view in sitting office workers with LCS and concluded how it affects upper body posture in sitting.

➢ *Assessment of Hip Flexors Flexibility: -*

The primary assessments utilized in research to measure the flexibility of hip flexors are the Thomas test and the Modified Thomas test. The Modified Thomas test is an adaptation of the original Thomas test, in which the subject lies supine at the edge of a couch, with the non-testing leg flexed and drawn towards the chest, while the tested leg remains extended.(3) The angle created between the couch and the extended leg is measured to assess the tightness of the hip flexors and the rectus femoris muscle: -

- *Thomas Test:*

This review includes studies that used the Thomas test to measure hip flexor tightness in different populations. Nourbakhsh et al. (2006)(4)found a significant difference in hip flexor length between men and women. Kale et al. (2020)(5)reported a mean difference of 10.37° between pre- and post-intervention measurements in school-aged children with lower back pain following stretching and strengthening activities. Burile et al. (2024)(6)found that housemaids with lower back pain had greater tightness in the left iliopsoas compared to the right. Dhanani et al. (2014)(7) conducted a survey on young girls with lower back pain, finding that 47% had iliopsoas tightness as measured by the Thomas test.

- *Modified Thomas Test:*

Many studies have used a modified version of the Thomas test to measure hip flexor tension, with varying results. Sahu et al. (2021)(1) found that the left iliopsoas muscle was weaker than the right in most participants. Ahmed et al. (2024)(8) reported a significant improvement in hip flexibility, with an average increase of 8° in two experimental groups after an intervention. Mahishale et al. (2023)(9) observed that 68.2% of female participants with primary dysmenorrhea had tightness in the right iliopsoas, while 60.3% had tightness in the left. Sushmitha et al. (2022)(10) found that 55% of young females had iliopsoas tightness. Das et al. (2017)(11) reported that 87.95% of females and 80.34% of males had right-sided iliopsoas tightness, while 86.75% of females and 74.36% of males showed left-sided tightness. Finally, Pradeep et al. (2020)(12) found a significant improvement of 9.71° in hip flexibility following stretching exercises.

➢ *Assessment of Paraspinal Muscles Extensibility: -*

Five studies(1,6,9–11) in this review assessed paraspinal muscle extensibility using a non-elastic measuring tape. Participants were instructed to maintain an upright posture, with the cervical, thoracic, and lumbar regions of the spine at 0° of lateral flexion and rotation. The spinous processes of the C7 and S1 vertebrae were marked, and the distance between these points was measured as the participant flexed their trunk. The movement stopped when further flexion was resisted, and the therapist noted any anterior pelvic tilting. A second measurement was taken, and the difference between the initial and final measurements reflected the degree of thoracic and lumbar flexion. A muscle length was considered normal when the distance measured 10 cm. The results shows a range of tightness from 100% to 48.7%, with a common range between 83% and 49%. One study also used this method while participants were seated (Lumbar Flexion Test), with results ranging from 2° to 45° in both males and females(4).

In addition, Mahishale et al. (2023)(9) used the modified Schober test, where participants stood with the lumbar, thoracic, and pelvis in neutral, and the therapist marked the L5 vertebra. Measurements were taken 5 cm below and 10 cm above the initial mark, and the distance was measured during trunk flexion. A difference of less than 20 cm indicated tight muscles. Dhanani et al. (2014)(7) employed the Sit and Reach test and found that 85% of girls exhibited tight thoracolumbar muscles. Pradeep et al. (2020)(12) used the Finger to Floor test, where participants stood on a raised platform, performed trunk flexion, and the distance between the floor and the tip of their third digit was measured. The results ranged from 20.21±3.43 to 10.82±3.25 cm. Ahmed et al. (2024)(8) assessed erector spinae tightness through visual inspection in a long sitting position. Noubakhsh et al. (2006)(4) also used Active Knee Extension (AKE) to measure hamstring length, hypothesizing that low back pain patients may have shortened hamstrings as a compensatory mechanism for weak gluteal muscles and pelvic instability.

➢ *Assessment of Lumbar Lordosis: -*

Three studies taken in this review have measured size of lumbar lordosis with the help of a flexicurve tool(4,8,12). The participant was instructed to stand upright without footwear. The T12 and S2 spinous processes were palpated and indicated on the participant's back. A flexicurve was then

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shaped to conform to the curvature of the spine at the marked locations. After removing the flexicurve, the inner boundary was traced onto graph paper, with T12, L4, and S2 being identified, and the degree of lumbar lordosis was assessed. The angle theta, representing the magnitude of the lordotic curve, was determined using the formula θ=4×arctan(2H/L)\theta = 4 \times \arctan(2H/L)θ=4× arctan(2H/L). The mean±S.D. results varies from 56.9±7.9 to 34.4±4.3. A lumbar lordosis angle of more than 50° was considered into inclusion criteria of LCS.

➢ *Assessment of Abdominal Muscles Strength: -*

In most studies, abdominal muscle strength was assessed using a standard manual muscle testing method. Participants lay on their backs with knees bent and hands positioned differently according to strength grade: behind the head for Grade V, crossed over the chest for Grade IV, and along the body for Grade III. The therapist stood beside the participant to observe scapular elevation, which indicated trunk flexion strength as participants performed a movement similar to a sit-up.(1,2,4–6,8–11,13)

Results varied across grades, with Grade 2 muscle strength ranging from 3.4% to 39%, Grade 3 from 8.6% to 48%, Grade 4 from 23% to 42.9%, and Grade 5 from 0% to 58.7%. Nourbakhsh et al. (2006)(4) recorded abdominal muscle strength using a pressure meter. Kale et al. (2020)(5) investigated children with lower cross syndrome (LCS), finding a post-intervention improvement suggesting positive effects of targeted exercises. In a more recent study, Burile et al. (2024)(6) found that out of 100 participants, 64.5% demonstrated fair abdominal strength, while 35.5% showed good strength.

Additionally, two studies(8,12) used the Trunk Flexion Coordination and Strength Test to assess not only abdominal strength but also the coordination of trunk muscles. This test involved repeated trunk flexion movements while lifting the scapula off the table, providing insight into participants' muscular coordination and endurance.

These findings underscore the variability in abdominal strength across populations and highlight the importance of reliable methods for evaluating core stability and strength, particularly in populations susceptible to lower cross syndrome or other musculoskeletal issues.

➢ *Assessment of Gluteal Muscles Strength: -*

Most of the reviewed studies have(1,2,4–7,9–11) measured gluteal muscle strength through manual muscle testing. Participants lay face down with knees bent at 90°, while the therapist stabilized their pelvis and applied resistance as they lifted one thigh. Muscle strength was then graded using the MRC scale. In her study, Burile et al. (2024)(6) assessed gluteus maximus strength using the Kendall grading system, which includes specific strength milestones, such as holding the lower back flat while lifting legs to various angles.

Sahu et al. (2021)(1) found that women tend to have weaker hip extensors than men, making them more susceptible to gluteal weakness. Similarly, Nourbakhsh et al. (2006)(4) examined gluteal strength and lower cross syndrome, concluding that while lower cross syndrome did not correlate with chronic low back pain, imbalances may impact lumbar spine forces and lead to microtrauma.

Strengthening exercises appear beneficial, as shown by Kale et al. (2020)(5), who reported significant improvements in school children with weak glutes. Further studies by Mahishale et al. (2023)(9) and Sushmitha et al. (2023)(10) found that most female participants had moderate strength (Grade 4) in both glutes, while Das et al. (2017)(11) and Dhanani et al. (2014)(7) found that women, particularly younger ones, were more prone to right-sided gluteal weakness.

Additionally, some studies (8,12,14)used the prone hip extension test to assess coordination and muscle activation patterns.

IV. DISCUSSION

This review highlights the common diagnostic practices, muscular imbalances, and prevalence of Lower Crossed Syndrome (LCS) across varied populations. LCS is characterized by a specific pattern of muscle tightness and weakness, resulting in postural abnormalities such as anterior pelvic tilt and increased lumbar lordosis. The reviewed studies reveal variability in diagnostic tools and criteria, indicating a lack of standardization that may contribute to inconsistent diagnoses and treatment approaches. However, common patterns in hip flexor and lumbar extensor tightness, along with abdominal and gluteal weakness, consistently emerge as primary indicators of LCS.

A. Proposed Diagnostic Criteria for LCS

To address the observed inconsistencies, this review synthesizes a standardized diagnostic criterion for LCS based on the most reliable and frequently used assessments. This criterion aims to improve diagnostic accuracy and provide clinicians with a reproducible method to identify LCS, especially in individuals with low back pain or prolonged sedentary behaviour.

➢ *Postural Assessment*

- **Anterior Pelvic Tilt:** Visual inspection of pelvic positioning is essential for LCS diagnosis and for an initial screening by visual postural examination in lateral view for LCS in patients with or without LBP. Using an inclinometer or a reliable digital postural examination tool to measure the pelvic tilt angle can add precision, with an anterior tilt greater than 10 degrees indicating potential LCS.
- **Lumbar Lordosis Measurement:** A flexicurve tool or inclinometer can quantify the degree of lumbar lordosis. A lumbar curvature angle exceeding 50 degrees calculated using formula θ=4×arctan(2H/L) may indicate the characteristic lumbar extension associated with LCS. It is a cost effective and less time-consuming procedure than X ray which has a risk of radiation and less feasible

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for every patient. However, measuring lumbar lordosis angle with a X ray film (if present) is considered more feasible and reliable.

➢ *Hip Flexors Tightness*

- *Hip Flexors Length Testing:*

The Thomas or Modified Thomas Test is extensively used to measure hip flexor and rectus femoris tightness. Hip flexor stiffness causes hip extension limitations with hip flexion angles beyond 10 degrees. Goniometers improve measuring accuracy. Iliopsoas length tests such the Modified Thomas Test show tightness in LCS patients. A hip extension angle below -10 degrees indicates shortened hip flexors. Thomas test has low inter- and intra-reliability, and its execution affects findings. A belt that secures the hips to the table and inhibits horizontal and longitudinal movement could standardize hip flexion during Thomas testing(3). The modified Thomas test reduces these inaccuracies, but it has low sensitivity and specificity and high false positive and false negative rates without pelvic tilt correction. During testing, controlling lumbopelvic motions greatly improves sensitivity and specificity. (15) It is suggested to apply Modified Thomas test for testing hip flexors flexibility i.e. Iliopsoas and Rectus femoris muscle and Thomas test should be applied for testing Iliopsoas alone with precautions for minimal errors in geriatric and overweight population and patients who are unable to execute MTT and patients with specific particular concerns.

➢ *Paraspinal Muscle Extensibility*

The most generally used approach by studies under review for testing spinal muscles extensibility is by measurement of the space between the C7 and S1 vertebrae during complete trunk flexion with the use of a non-elastic measuring tape also insight into paraspinal tightness. Differences under 10 cm between standing and full flexion indicate tight lumbar extensors. However, this procedure is affordable, practicable and less time consuming than others, it lacks specificity of flexibility of certain spinal group muscles and joint mobility. It delivers a greater insight of flexibility of spinal extensor muscles and joint motion. Due to its, practicality and low effort of patient and examiner it is generally acknowledged approach to test thoracolumbar flexibility and extensibility.

Other tests like Sit and Reach and finger to floor test also detects restricted lumbar flexibility, can be also utilized an alternative to technique indicated above while sitting. The Modified Schober test is used by some studies to determine paraspinal extensibility, based on the results of Schober test and its most commonly utilized adaptations it lacks accurate results for evaluating Lumbar ROM. Consequently, it is advisable to avoid the use of this test.(16) Using Active knee extension (AKE) is effective to test hamstring length and establish gluteus weakness as a compensatory mechanism is appreciated.

➢ *Abdominal Muscle Strength*

Since there is currently no gold standard for measuring abdominal muscle weakness, MMT is a crucial tool for evaluating abdominal strength. It is utilized in practically all of the reviewed studies and has good clinical reliability, indicating that grades below IV indicate abdominal weakness, a common feature of LCS. Applying it to any population is simple and doesn't require any particular expertise. Given its high clinical reliability and specificity, it appears to be a useful tool for LCS diagnostic testing, which examines the weakness of the abdominal muscles**.**

Additionally, The Trunk Flexion Coordination Test also assesses coordination, which is crucial for functional core strength which can be applied in young patients and athletes for better and precise outcome of abdominal strength. It is suggested to combine TFC test with MMT in young population and athletes.

➢ *Gluteal Muscle Strength*

The quantification of gluteus muscle strength lacks a reliable tool and method. Instead, it is assessed using manual muscle testing (MMT), which is recognized for its clinical reliability. In the context of MMT for gluteal strength, grades below IV are indicative of weakness.

Kendall grading and other standardized scales are utilized to evaluate the resistance capacity or strength of the gluteal muscles during hip extension with the knees flexed at 90 degrees. Furthermore, MMT for the gluteus does not necessitate specialized skills, is time-efficient, and can be applied across various populations. It also demonstrates good specificity and is widely favored in numerous studies for the diagnosis of low back pain (LCS). These attributes render MMT a suitable instrument for measuring gluteal strength in the context of LCS diagnosis.

Among the tests favoured by certain studies is the Prone Hip Extension Coordination Test, which evaluates coordination and muscle activation patterns. A positive result indicates that the gluteus maximus activates prior to the lumbar erector spinae, signifying an optimal activation sequence.

This test can confirm gluteal weakness and activation patterns, as patients exhibiting delayed gluteal activation are at a higher risk of developing and maintaining low back pain due to an over-reliance on the lumbar extensors and hamstrings.

➢ *Clinical Implications of a Standardized Diagnostic Criteria*

Implementing a standardized diagnostic criterion for LCS in clinical practice can enhance early identification and intervention, particularly in individuals prone to low back pain due to muscular imbalances. Reliable identification of LCS can enable clinicians to design targeted interventions, such as core strengthening and hip flexor stretching, that address specific muscle weaknesses and imbalances associated with LCS. A standardized approach may also reduce misdiagnoses and enable more effective management strategies across diverse patient populations.

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V. LIMITATIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

While the proposed criteria are rooted in commonly used assessments, several limitations warrant further investigation. The diagnostic tools included, such as MMT and inclinometer measurements, may still be subject to examiner variability, which could affect diagnostic accuracy. Future research should aim to validate these criteria in larger, more diverse populations and consider incorporating objective digital tools and wearable sensors to further refine diagnostic precision.

VI. CONCLUSION

Although visual signs like excessive anterior pelvic tilt and lumbar lordosis may suggest LCS, but after reviewing literature available for LCS and reviewing guidelines and protocol thoroughly. We finally conclude a definite following criterion which should be considered for a correct diagnosis of LCS following are:

- The lumbar lordosis angle more than 50°.
- The Thomas Test (TT) or the Modified Thomas Test (MTT) with a hip extension angle less than -s10° is used to measure hip flexor tightness.
- Tight lumbar extensors are indicated by paraspinal tightness with a flexion range of less than 10 cm.
- Along with this, two more factors which may or may not have significant role in subjects with LCS are: -
- Abdominal muscles strength evaluated using Kendall's Manual Muscle Testing (MMT) method with a grade below IV.
- Gluteal muscles strength evaluated using Kendall's Manual Muscle Testing (MMT) method with a grade below IV.

These tests may suggest weakness, but differences among examiners and subjects can affect their accuracy. For athletes with LCS, functional tests such as planks or timed crunches are more suitable for assessing abdominal weakness than MMT.

Establishing a standardized diagnostic protocol will enhance reliability, support personalized treatments, and help reduce chronic lower back pain associated with LCS.

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- *Conflict of Interest*

There is no conflict of interest.

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