Motor control on gait performance among individuals with lower crossed syndrome: A scoping review

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ABSTRACT

Introduction: Lower Cross Syndrome (LCS) is a prevalent condition that manifests as muscular tension due to the asymmetry in the strength of the lower extremity muscles. This imbalance could be due to the tautness of the iliopsoas, rectus femoris, tensor fascia latae, adductor group, gastrocnemius, and soleus muscles. LCS causes a postural imbalance in the individual, which triggers low back pain (LBP). When LCS is present alongside LBP, may cause the upper body to sway more in the transverse plane and at the lumbar level, making walking and termination of gait (GT) more difficult. However, the evidence of motor control and gait performance is scarce with inconclusive findings. Thus, this study aimed to review motor control on gait performance among individuals with lower crossed syndrome. This review is conducted to determine the motor control on gait performance in patients with LCS and how the conditions affect gait.

Materials and Methods: The databases Google Scholar, Science Direct, ResearchGate, PubMed, and Scopus were searched to identify potentially relevant documents. The keywords used for the search included “motor control” OR “motor learning” OR” core stability” AND “lower crossed syndrome” AND “gait”. The search includes articles published between 1970 and 2022 and written in English. It is excluded when the paper is not a full-text article. After finding the articles, the information was extracted, including author, year of publication, country, objective, type of study, and motor control analysis summary.

Results: There were 107 articles retrieved from the search. but only seventeen articles were included for analysis. The finding demonstrates that LCS may associate with LBP and reduces the motor control of the core muscle stability which indirectly influences gait performance.

Conclusions: This study suggests that individuals with LCS will have an alteration in their gait. However, there is still insufficient information on motor control in gait performance among lower crossed syndrome. Further research is needed to find what factors that may contribute to the adaptation of motor control in gait among LCS population

KEYWORDS:
Lower crossed syndrome, low back pain, motor control, gait

INTRODUCTION

Lower Cross Syndrome (LCS) is a common disorder characterised by muscle tension caused by an imbalance in the strength of the muscles in the lower extremities[1] and further clarified that LCS is a musculoskeletal imbalance characterised by specific muscle weakness patterns[2], which is also known as pelvic cross syndrome.[3] LCS results from the imbalance of muscle strength in the lower extremities, which is affected by muscle tightness on the iliopsoas, rectus femoris, tensor fascia latae, adductor group, gastrocnemius, and soleus.[1] Due to the muscle imbalance, a person with LCS may develop lower back pain later in life.[2]

Lower Back Pain (LBP) is a prevalent condition affecting people worldwide, among the poor and wealthy people. Also, it affects people in both age groups, from children to the elderly. Individuals experiencing chronic LBP may exhibit variations in muscle size, composition, and coordination that deviate from those who do not report pain.[4] Individuals experiencing chronic LBP may also exhibit diminished control over gait smoothness and stability at higher levels. This may be attributed to a decrease in muscle excitability, which can result in reduced control over trunk movements.[5] On the other hand, gait considers a fully autonomic task that interacts extensively with motor control.[6] Gait is also classified as an act and way of walking that involves the complex motor skill that facilitates locomotion. Lesions or dysfunctions in the central, peripheral, and musculoskeletal systems can cause gait disorders.[7]

Gait performance is influenced by motor control of the involved muscles in the trunk and extremities. It is said that, to initiate movement, the individual requires good motor control which associated with motor learning. Motor control is the ability to regulate or direct the mechanisms necessary for movement, while motor learning is the investigation of movement acquisition and modification. While motor control is concerned with understanding the control of previously acquired movement, motor learning is concerned with understanding the acquisition and modification of movement.[8] Therefore, having good motor control and learning is essential to enhance better gait performance and training in individuals with LCS.

However, it is imperative for an individual to possess proficient motor control and aptitude for learning. The question of whether individuals with a lower cross syndrome condition are more likely to experience low back pain has

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been raised. The purpose of this study was to investigate the potential relationship between lower extremity muscle strength in LCS and gait. The occurrence of gait pattern disorders can be ascribed to a decrease in the musculature of the lower extremities. Therefore, it can be inferred that the decline in muscle quality and strength is potentially responsible for the motor control and balance deficiencies that ultimately result in falls and unfavourable outcomes.[9]

Thus, the motor control of the trunk and lower extremities of an individual with LCS might influence the gait performance, which could also be associated with low back pain in reference to structures involve due to the LCS.

Lower Cross Syndrome and Low Back Pain

Individuals with LCS may present with a postural imbalance, which leads to LBP at any point of time in their life. In the presence of inhibited and weakened gluteal muscles, overactivity and tightness of the erector spinae muscle may alter the hip extension pattern by changing the order in which the muscles are more activated.[2]

In this case, the lower back erector spinae may fire first, followed by the gluteus. As a result, the lower spine becomes overloaded, compressed, and hypermobile, particularly in the L4-5 and L5-S1 joints. Excessive loading of the lumbar spines and hip joints can cause stiffness, irritation, and inflammation of the joints and the surrounding soft tissues, including the discs. Then, the pain eventually sets in, usually in the L5-S1 and L4-5 regions thus, develop LBP.[10]

Lower Cross Syndrome Affecting Gait

LCS may affect the gait due to the various patterns of back muscle activation, such as heightened co-contraction of flexor and extensor muscles during trunk movements, the heightened activity of the obliquus externus abdominis during standardised shoulder movements, and the heightened activity of the erector spinae during the swing phase of the gait cycle.[11]

When LCS is present together with LBP, the upper body can sway more in the transverse plane and at the lumbar level, making walking and termination of gait (GT) more difficult. Changes in the neuromuscular control of the upper body appeared to be task-dependent, and these changes are exacerbated by the necessity of a rapid cessation of gait in response to an environmental visual stimulus.[12] The potential correlation between the decline of the muscles in the lower extremities and the manifestation of irregularities in an individual's gait pattern is a subject of interest. It suggests that the loss of muscle quality and power may be the underlying cause of the motor control and balance impairments that result in falls and adverse consequences.[9]

MATERIALS AND METHODS

This scoping review used Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA).[13]

Eligibility Criteria

In searching for articles to be included in the review, the papers need to explain lower extremities pain, posture, and core stability. The papers should also emphasise the conceptual framework (e.g., lower crossed syndrome, gait, low back pain, lower extremities pain, and posture). This study also included peer-reviewed and systematic review papers published between 1970 and 2022 and written in English.

Exclusion Criteria

The paper was excluded when it did not align with the conceptual framework and involved neurological conditions.

Information Sources

The researchers searched the following databases to identify potentially relevant documents: Google Scholar, Science Direct, ResearchGate, PubMed, and Scopus.

Search Strategy

In the process of searching the papers, the keywords used were:

1. “Motor Control and Motor Learning” AND “gait” AND “lower crossed syndrome”
2. “Motor Control” AND “gait” AND “lower crossed syndrome”
3. “Motor Control” AND “gait” AND “low back pain”
4. “Gait” AND “low back pain”
5. “Gait” AND “lower crossed syndrome”
6. “Lower crossed syndrome” AND “lower back pain”
7. “Low back pain”
8. “Motor control and motor learning”

Data Extraction

During data extraction, a few article characteristics (e.g., motor control and motor learning, lower crossed syndrome, gait) and engagement characteristics and contextual factors need to be highlighted (e.g., structure affected, muscle involvement, how that affects gait).

The studies were organised and summarised based on the type of behaviour analysed: Authors (Year), Study design, Sample, Duration, Intervention, and Main Result. The studies for review were chosen after a thorough search and screening.

Ethics Approval and Infprmed Consent

This review does not require ethical approval.

RESULTS

There were 107 articles retrieved from the search. After removing duplicates, 90 articles were eliminated through the eligibility based on title, abstract, and full text. This selection process finally resulted in seventeen articles being included for further review. The details of the selected articles are illustrated in Figure 1.

The design of the study found in the eight reviewed articles included cross-sectional (n=1), Randomized Control Trial

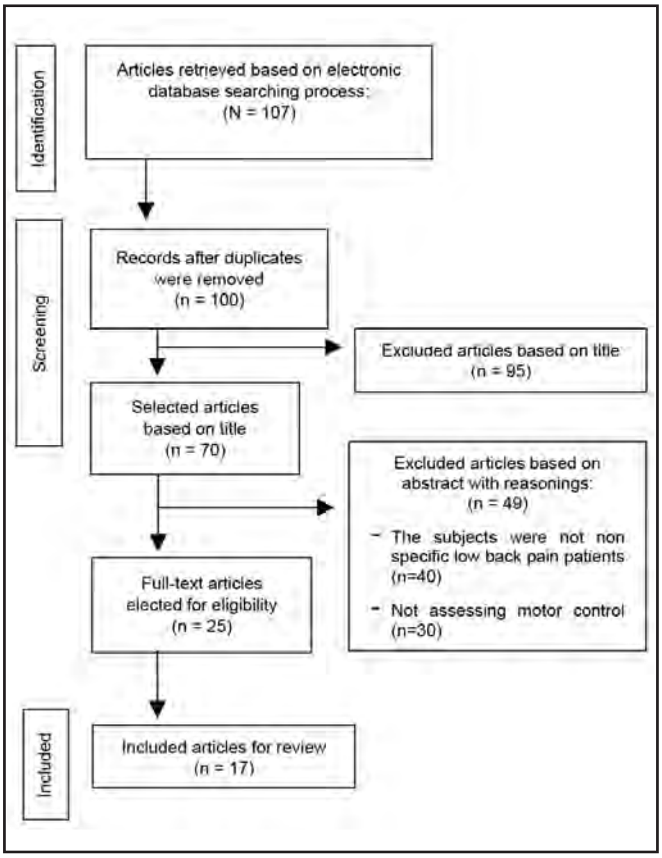

Fig. 1: Articles Selection Process Flowchart

(n=6), systematic review (n=3), Experimental study (n=6), and Stepped Wedge Intervention (n=1). Their study objectives vary but included one or more of the following: (1) identifying lower crossed syndrome, (2) gait, (3) motor control changes, (4) motor learning, and (5) low back pain.

DISCUSSION

The aim of this review was to conduct a thorough analysis of research related to individuals who suffer from LCS or LBP that affects their gait. The current investigation comprised a collective of seventeen articles that met the predetermined standards for analysis. The present study shows the enduring effects of motor control alterations following training, alongside the acquisition of automatic postural control strategies through motor learning.[27]

The therapeutic impact of core stability on individuals with non-specific CLBP is noteworthy, as it leads to a reduction in pain intensity, functional disability, and an improvement in quality of life, core muscle activation, and thickness.[24] The implementation of stabilisation exercises in individuals with LBP has the potential to mitigate pain and reduce disability. It may not be deemed imperative to prescribe exercises that are purported to reinstate motor control of specific muscles.[31]

This intervention is appropriate for individuals experiencing LBP. Nevertheless, there is a lack of evidence to suggest that stabilisation exercises are superior to other forms of active exercise in the long term.[32] Most studies included subgroups of people with LBP that associated with gait problems, however, display little studies that aimed specifically at people with the LCS who demonstrated with gait problem. The lack of amount of lower cross-syndrome-related research proves this.

A limited number of related studies were retrieved, with the majority being focused on the topic of lumbar pain. This scoping review criteria excluded gait-related studies pertaining to neurological conditions, which were the focus of most of the studies. The available evidence is inadequate to establish a conclusive differentiation between LCS and gait. A study conducted on musculoskeletal disorders revealed that there was no discernible distinction in pain, low back disability, lower body flexibility, kinesiophobia, gait characteristics, and quality of life.[17] Nonetheless, a comparable investigation contrasting the effects of core stability exercise (CSE) and myofascial relaxation technique (MRT) with those of core stability exercise alone revealed that the former combination of interventions yielded advantageous outcomes. The combination of CSE and MRT may provide greater benefits for individuals suffering from chronic LBP or LCS conditions over an extended period. Nevertheless, no scholarly investigation has explicitly contrasted this phenomenon with individuals who exhibit LCS. While these studies provide additional context regarding core stability interventions for this specific population, further clarification is required regarding the influence of lower crossed syndrome on gait performance. This limitation restricts the scope of conclusions that can be drawn from the available evidence.

There is a lack of literature that establishes the motor control and motor learning aspects related to LCS and gait in physiotherapeutic intervention in a manner that is replicable. The studies under consideration indicated the inclusion of motor control and motor learning in the intervention; however, many of them did not provide detailed description of the said component. The authors use the term "exercises" to denote the intervention, implying that it is a standalone treatment rather than a comprehensive label for diverse potential treatment methodologies.

This implies that there is insufficient evidence to guide physiotherapists in deciding what intervention to prescribe, supported by the systematic reviews in this study. One study found that people with LBP and pronated feet may benefit from corrective exercise programmes, but it did not include motor control components. Nonetheless, the two randomized control trials (RCT)[15,17] concluded that the core stability intervention improved people with low back pain and gait.

Comprehending the encounters of individuals afflicted with the LCS, a condition that impacts both gait and motor function, is deemed an essential component in the administration of any intricate intervention. The study's strengths lie in its comprehensive search approach and rigorous screening and data extraction methods. It is important to acknowledge that our focus was solely on musculoskeletal disorders within the scope of physiotherapy practice, thereby limiting our exploration of broader techniques that may be employed by physiotherapists in the context of neurological disorders.

Table I: Table of Evidence

Authors (Year)[Ref no]	Study Design	Sample	Duration	Intervention	Main Result
Steele, Bruce-Low, Smith, Jessop, & Osborne, (2016)[14]	Randomized Controlled Trial	24 people with non-specific CLBP	12 Weeks	Isolated lumbar extension exercise intervention (1x/week, performing a single set to momentary muscular failure with a load equal to 80% of maximum tested torque) or non-training control period.	Implementing a resistance exercise intervention that focuses on isolated lumbar extension can decrease gait variability. The results indicate that performing lumbar extension exercises in isolation may have a targeted effect on reducing variability in the sagittal plane. This suggests that the exercise may enhance the ability to replicate motor patterns in this particular plane of movement, potentially due to the exercise's use of this specific movement plane.
Kim, Park, & Kwon, (2020)[15]	Randomized Controlled Trial	39 patients who displayed the lumbar Ext Rot pattern were subjected to randomisation, with 19 patients assigned to the experimental group and 20 patients assigned to the control group.	6 weeks	Experimental group: classification-specific treatment (included an exercise to control or prevent lumbopelvic motion during lower-extremity movement) Control group: encouraged to perform general exercises and were educated about LBP.	Pain intensity, disability, fear-avoidance beliefs-physical activity score, and Erector Spinae muscle activity during walking all had significant time-by-group interaction effects. After the intervention, the group had significant effects on pain, disability, and fear-avoidance beliefs-physical activity score. Erector Spinae muscle activity decreased significantly during walking in the experimental group, but this was not an all-events decrease.
Madadi-Shad, Jafarnezhadgero, Sheikhalizade, & Dionisio, (2020)[16]	A double-blind, randomized controlled trial	30 older adults with both back pain and pronated feet	-	-	Higher walking speed, lower pain, lower LBP disability, comparable vertical loading rate and free moments, and lower muscle activities in the experimental group after CEP demonstrate improved gait efficiency.
Ozsoy et al., (2019)17	A randomized, controlled, single-blind study	45 participants	6 Weeks	Core stabilisation exercises (CSE) group: A core stabilisation exercise program CSE+MRT group: Core stabilisation exercises, myofascial relaxation technique with a roller massager	The results indicate that the CSE+MRT group exhibited more significant improvements in core stability endurance ($p=0.031$) and spinal mobility in the sagittal plane ($p=0.022$) compared to the CSE group. The study found no statistically significant difference between the two groups concerning pain about ability, lower body flexibility, kinesiophobia, gait characteristics, and quality of life ($p>0.05$).
Cai, Yang, & Kong, (2017)18	A randomized, controlled, single-blind study	84 recreational runners	8 Weeks	1)Lower limb (LL) exercises, 2) Lumbar extensor (LE) exercises 3)Lumbar stabilisation (LS) exercises.	Lower limb exercise therapy has shown promise in the clinical management of non-specific LBP in recreational runners. Lower limb exercise therapy was more effective than traditional back exercises in improving key rehabilitation outcomes such as self-rated running capability, knee extension strength, and running step length. All exercise therapies reduced running-induced pain and improved back muscle function equally well.
Koch & Hänsel, (2018)[19]	Systematic Review	-	-	The researchers compared neuromuscular and biomechanical parameters during walking or running in healthy adults and adults with chronic non-specific LBP.	Although there is limited scientific proof for any individual parameter, a comprehensive elucidation can be achieved by integrating biomechanical and neuromuscular parameters. The manifestation of compromised motor control while walking is evident in escalated erector spinae activity, leading to rigidity in the lumbar-pelvic area.

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Table I: Table of Evidence

Authors (Year)Ref no	Study Design	Sample	Duration	Intervention	Main Result
Martinikorena et al., (2016)[20]	Experimental Design	22 institutionalised frail elderly	-	Walked 7 meters in a straight line with no obstacles at a self-controlled pace.	An increase in the quantity of high-density fibres, particularly in the quadriceps femoris muscle, has been associated with enhanced gait performance in terms of step time variability, regularity, and symmetry. Moreover, there was a correlation between gait variability and muscle power.
Brach et al., (2015)[21]	Randomized Controlled Trial	40 Adults	12 Weeks	Both interventions included task-oriented motor learning, a standard exercise programme, and strength training.	There is preliminary evidence that task-oriented motor learning exercise improves motor control of walking, whereas standard exercise does not.
Lin, Halaki, & Leaver, (2023)[8]	Cross-sectional study	16 participants	-	The study employed an instrumented treadmill (FDMT Lido, Noraxon, USA) equipped with a deck comprising 2560 capacitive sensors (MyoPressure-T, Noraxon, USA) to measure gait parameters.	The absence of noteworthy inter-group disparities in gait parameters may suggest that individuals with low levels of LBP exhibited unmodified gait patterns after adjusting for gender, age, and height.
Rum et al., (2021)[12]	Experimental Design	22 participants	-	Walk straight at their own pace while keeping their gaze fixed on a black visual target displayed on a screen at the end of the 10-meter walkway.	Compared to individuals without chronic low back pain, those with CLBP exhibited an increased transverse range of motion in the lumbar region while engaging in walking and GT activities. The individuals with chronic low back pain (CLBP) showed a higher degree of sagittal range of motion (ROM) compared to their healthy counterparts during the termination phase of gait (GT). During ambulation, the group diagnosed with chronic low back pain exhibited greater variability in the transverse plane, while the group diagnosed with gluteal tendinopathy showed greater variability in lumbar frontal motion.
Nakisa, Ghasemzadeh Rahbardar, Sokhangouei, & Afsharmand, (2021)[22]	Quasi-experimental and applied research	15 male elite soccer players	8 Weeks	For eight weeks, core stability-based corrective exercises were performed thrice weekly, and changes in gait parameters (pre- and post-intervention) were measured.	By performing core stability-based corrective exercises during the study period, gait parameters in the post-intervention outperformed the results in the pre-intervention in most parameters. As a result, it is proposed that core stability-based corrective exercises are a safe and effective method for improving function in those with the middle-crossed syndrome. They could be used as therapy to assist players with this finding.
Leung, Mendis, Stanton, & Hides, (2015)[23]	Stepped-wedge intervention	46 AFL players participated	7 or 8 Weeks	The motor control training consisted of two 30-minute sessions per week overseen by qualified physiotherapists with experience in the motor control training programme.	The present study reveals that the size of the piriformis muscle in elite Australian Football League (AFL) players increases during the season and is impacted by lower back pain (LBP) and injuries to the lower limb. The size of the piriformis muscle in individuals with lower back pain (LBP) can be improved through motor control training.
Frizziero et al., (2021)[24]	Systematic Review	-	-	-	In patients with non-specific chronic low back pain, core stabilit has a significant therapeutic effect, reducing pain intensity and functional disability and improving quality of life, core muscle activation, and thickness.
Shih, Van Dillen, Kutch, & Kulig, (2021)[25]	Experimental Design	20 young adults	-	Participants were then given 3 minutes to become acquainted with the treadmill before completing a 30-second treadmill walking trial at 1.25 m/s to determine the preferred step width (PSW).	The exacerbation of unusual motion during the reduction of symptoms may suggest that modified trunk regulation in patients with recurrent low back pain is attributable to movement patterns or anatomical factors that predated the evaluated painful occurrence.

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Table I: Table of Evidence

Authors (Year)Ref no	Study Design	Sample	Duration	Intervention	Main Result
Xiao et al., (2022)[26]	Systematic Review	30 participants	-	For the actual testing, the participants completed 40 trials.	Older people with LBP had lower ankle proprioception than healthy peers, indicating impaired central proprioceptive processing.
Tsao & Hodges, (2008)[27]	Experimental Design	Nine people	4 Weeks, the follow-up was done after six months	During the initial and subsequent two-week sessions, the participants underwent training involving repeated isolated voluntary contractions of the transversus abdominis (TrA) muscle with the aid of real-time ultrasound imaging feedback. Over a month, the home regimen consisted of two daily training sessions.	The persistence of motor control changes after training is demonstrated, as is the motor learning of automatic postural control strategies.
Hall, Tsao, MacDonald, Coppieters, & Hodges, (2009)[28]	Experimental Design	Ten people	Single session	A single training session that included three tasks: "abdominal curl up," "side bridge," and "birdog."	After a single session of training, co-contraction training of the trunk muscles does not restore
Waters, (2014)[29]	Randomised controlled trial	Thirty people	4-week period	6-sessions of Bruegger's exercise and/or SM were administered to each group over the course of 3-week.	Bruegger's exercise, SM, and the combination of Bruegger's exercise+SM are all effective treatment protocols for improving hip and lumbar ROM, reducing the degree of lumbar lordosis, and relieving pain and disability. However, no treatment strategy is superior to others. Overall improvements in pain, disability, hip and lumbar ROM, and lumbar lordosis were greatest with SM alone, suggesting that SM alone is the most effective treatment for CLBP associated with LCS. After the full effects of the SM have set in and the muscles are in their optimal state for exercise, Bruegger's exercise may be added to the treatment plan to further assisting in some cases.
Niemier et al., (2019)[30]	prospective, rater-blinded, cross-sectional controlled multicenter study	31 Participants	-	The study's doctors or PT were given training in advance, and they all stay to the same exam schedule. They observed signs of secondary muscle strain in the postural muscles (TRPs), examined spontaneous and directed movements, postural patterns, movements, or postures thought to provoke special postural reactions. Janda classified muscles as predominantly tonic (tensing/ shortening) or phasic (weakening/ stabilizing), and thus the examined postural patterns were derived from the crossed syndromes.	A higher proportion of patients with CLBP exhibited LCS. However, there was no statistical significance difference observed. This could be due to the limited sample size of participants in this study.

CLBP=chronic low back pain; LBP=low back pain; CSE=Core stabilization Exercises; ROM=Range Of Motion; GT=Termination of Gait

CONCLUSION

This scoping review has demonstrated that individuals with LCS and concurrent LBP exhibit gait alterations. The reason for this phenomenon is that there exists a correlation between motor control among patients with LCS. Therefore, it is imperative to implement a thorough evaluation of motor control and a rehabilitation regimen focused on functional goals for individuals with LCS. Further investigation is required to determine the variables that potentially influence the adjustment of motor regulation in locomotion among individuals with LCS.

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CONFLICT OF INTEREST

No conflict of interest.

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