OPEN ACCESS Freely available online

International Journal of Physical Medicine and Rehabilitation

Review Article

Adaptations Associated with Non-Specific Chronic Low Back Pain: A Narrative Review

Joshua Brodie Farragher[1*], Gavin Paul Williams[2,3], Adrian Pranata[4], Doa El-Ansary[4,5,6], Selina Parry[3], Adam Leigh Bryant[1]

[1]Centre for Health Exercise and Sports Medicine, The University of Melbourne, Melbourne, Australia; [2]Department of Physiotherapy, Epworth Hospital, Richmond, Australia; [3]Department of Physiotherapy, The University of Melbourne, Melbourne, Australia; [4]Department of Nursing and Allied Health, Swinburne University of Technology, Hawthorn, Australia; [5]Department of Surgery, The University of Melbourne, Melbourne, Australia; [6]Clinical Research Institute, Westmead Private Hospital, Westmead, New South Wales, Australia

ABSTRACT

Background: Non-specific chronic low back pain (NSCLBP) represents a growing global burden. Individuals with LBP inherently adapt in a variety of ways, across psychological, behavioural and physical domains. However, adaptive changes (e.g., altered lifting behaviour) may persist, becoming maladaptive, resulting in negative functional consequences (i.e., persistence of pain, increased disability). Clinical practice guidelines lack specificity to direct the type of interventions, dosage and treatment duration. A better understanding of how the maladaptive changes seen in people with NSCLBP relate to meaningful outcomes (i.e., disability, function, quality of life) and defined sub-groups of people with NSCLBP may inform effective interventions. The aim of this review is to investigate the inter-relationship of psychological, behavioural and neuromuscular NSCLBP-related adaptations, and their clinical significance with respect to disability, function, quality of life and pain.

Methods and findings: Three MEDLINE searches were conducted to investigate the psychological, behavioural and neuromuscular adaptations in people with NSCLBP. The initial search returned 12972 articles and 238 were identified for full-text review. A total of 93 articles were included in this review. Psychological and behavioural maladaptations (i.e., fear-avoidance beliefs) are associated with poorer patient outcomes, whereas there is uncertainty regarding the impact of maladaptations in the neuromuscular system on important clinical outcomes. Moreover, the evidence is more supportive of the interrelationship between psychological and behavioural maladaptations than any interrelation with neuromuscular maladaptations. To date, methodologies designed to assess NSCLBP-related functional deficits lack ecological validity. Assessment of patients with NSCLBP should focus on psychological and behavioural domains that relate to an individual's disability and functional impairments. Individuals with NSCLBP present with a variety of diverse adaptions that should focus intervention that aligns patient goals and functional deficits.

Keywords: Non-specific chronic low back pain; Adaptations; Neuromuscular; Behaviour; Psychological factors

INTRODUCTION

Non-specific Chronic Low Back Pain (NSCLBP) is the leading cause of disability worldwide [1]. At least 80% of the population will experience Low Back Pain (LBP) in their lifetime [2] and approximately 5%-10% of those will go on to develop chronic symptoms [3]. The incidence of NSCLBP has increased by 19.6% since 2006 [4] and the enormity of this burden is

Correspondence to: Joshua Brodie Farragher, Centre for Health Exercise and Sports Medicine, The University of Melbourne, Melbourne, Australia, E-mail: jfarragher@student.unimelb.edu.au

Received date: April 06, 2021; **Accepted date:** April 20, 2021; **Published date:** April 27, 2021

Citation: Farragher JB, Williams G, Pranata A, El-Ansary D, Parry S, Bryant AL (2021) Adaptations Associated with Non-Specific Chronic Low Back Pain: A Narrative Review. Int J Phys Med Rehabil. 9:602.

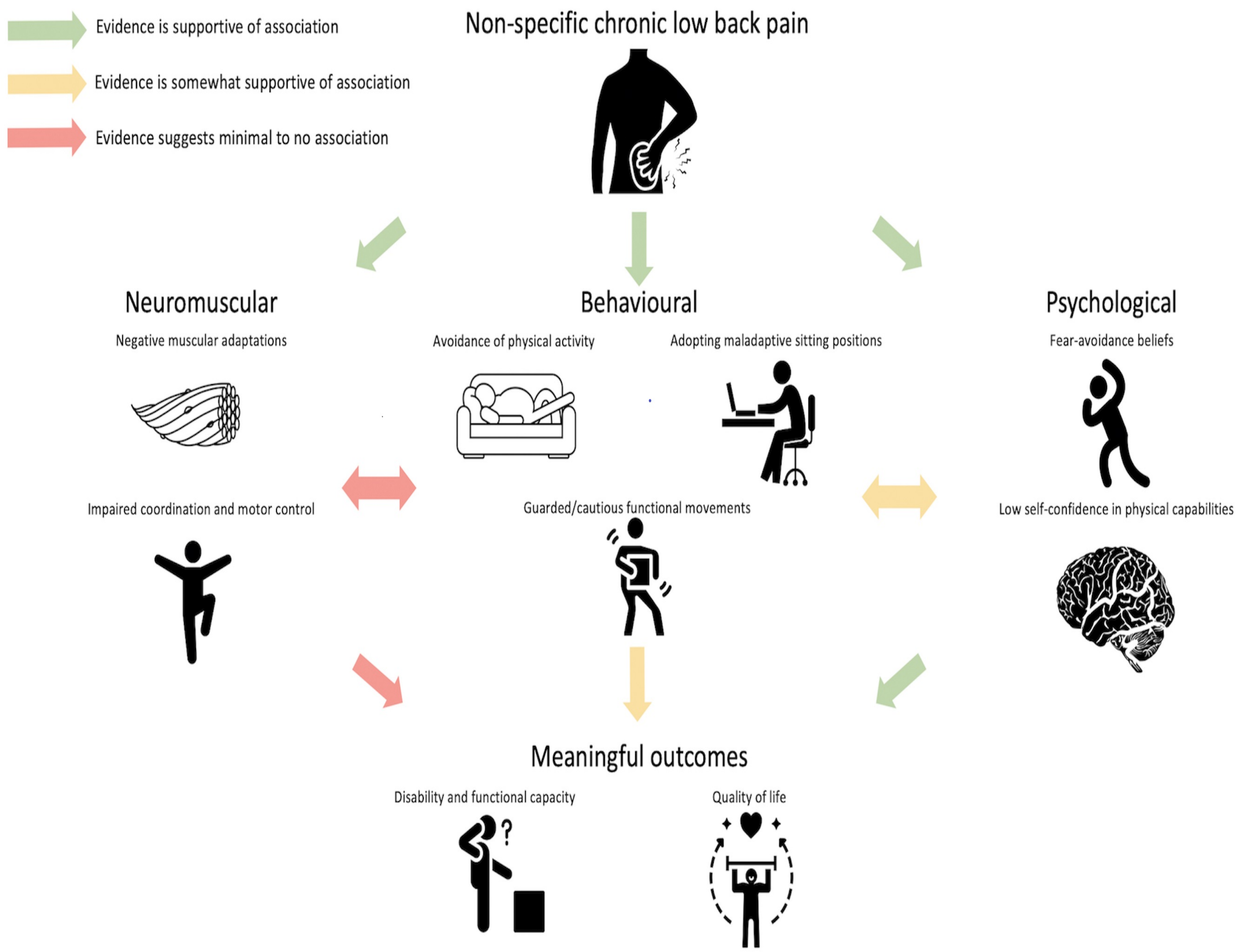

Figure 1: Placement holder. Model for inter-related multi-domain maladaptations associated with meaningful outcomes for individuals with non-specific chronic low back pain.

expected to continue to grow with the global increase in the ageing population number [5]. The growth in NSCLBP is also in line with a more general rise in chronic disease such as diabetes [6] and dementia [7], but any association with these conditions remains unclear. Sequelae observed in people with NSCLBP occur across multiple domains, including psychological, behavioural and neuromuscular [8]. These changes may be adaptative (i.e., compensatory changes that decrease one's symptoms, allowing better coping in their environment) or maladaptive (i.e., compensatory changes that increase one's symptoms, inhibiting their ability to cope in their environment) [9]. Importantly, maladaptive changes commonly observed in people with NSCLBP usually result from negative beliefs and a poor understanding of the relationship between pain and harm (e.g., sitting upright despite an increase in one's symptoms by doing so) [9]. Initial responses to LBP can be adaptive, but persistent adaptive behaviours can become maladaptive and contribute to the transition from acute to persistent pain [10].

Interventions for NSCLBP are primarily focused on reducing disability and improving function [11]. This has been a mainstay focus for almost a century [12]; however, the treatment approach has changed dramatically over the past three decades, with the introduction of the bio psychosocial model [12,13]. Clinical practice guidelines throughout the world support the use of exercise therapy and psychological interventions for the management of NSCLBP [14]. However, guidelines lack detail regarding delivery mode and specific exercises. This likely stems from the fact that numerous published interventional studies have reported minimal between-group effect sizes [15-19], ultimately leading to conclusions that each modality is equally effective. The clinical guidelines assert that the NSCLBP population is heterogenous, however, they provide no current recommendations as to how to distinguish or manage sub-groups within the broader NSCLBP population [14]. As a result of these issues, it is difficult for clinicians to apply these guidelines to people with NSCLBP [20]. Furthermore, there is an absence of recommendations pertaining to behavioural and neuromuscular assessments for people with NSCLBP, despite a large portion of NSCLBP-related literature devoted to these domains. Finally, the methods used to quantify NSCLBP-related adaptations are diverse and, in many instances, the clinical relevance of these adaptations has not been investigated.

Therefore, it is timely to consider the adaptive and maladaptive changes that occur in people with NSCLBP, with the anticipation that a better understanding of the clinical significance of these changes will lead to the development of better treatment strategies. As such, the aims of this paper are to i) evaluate the appropriateness and ecological validity of methods used to identify neuromuscular NSCLBP-related maladaptations; ii) discuss the nature and inter-relationships of psychological, behavioural and neuromuscular NSCLBP-related maladaptations; iii) evaluate the clinical significance of these maladaptations in relation to meaningful NSCLBP-related outcomes (i.e., disability, function and quality of life); and iv) propose a new model for multi-domain adaptations associated with NSCLBP (Figure 1). In addressing this knowledge gap, this review provides a narrative overview of the research investigating NSCLBP-related adaptations.

METHODS AND FINDINGS

A series of literature searches were conducted on MEDLINE (PubMed) between August 2020 and March 2021. Studies were included that evaluated the outcomes of fear-avoidance beliefs, pain self-efficacy, physical activity, lifting and sitting behaviour, motor weakness, lumbar muscle morphology and motor control in people with NSCLBP. Peer-review studies involving humans and available in English were included in the review. Randomised controlled trials, observational studies, systematic reviews and meta-analyses were also included as they denote higher levels of evidence [21]. All other study designs were excluded from this review. Three separate searches were conducted. Medical subject heading (MeSH) terms used to perform the first search were: (CLBP OR Chronic Low Back Pain OR LBP or Low Back Pain OR Non-Specific Chronic Low Back Pain OR NSCLBP) AND (kinesiophobia OR fear-avoidance OR self-efficacy OR pain self-efficacy), yielding 1318 articles. MeSH terms used in the second search included: (CLBP OR chronic low back pain OR LBP or low back pain OR non-specific chronic low back pain OR NSCLBP) AND (lifting OR sitting OR physical activity), yielding 7640 articles. The third search used MeSH terms including: (CLBP OR chronic low back pain OR LBP or low back pain OR non-specific chronic low back pain OR NSCLBP) AND (weakness OR strength OR lumbar multifidus OR erector spinae OR motor control OR neuromuscular control), yielding 4014 articles.

In total, the searches returned 12972 articles. After removing duplicates, 10711 remained. Of the 10711 studies, 538 were not available in English and 8605 were excluded based on study design, leaving 2106 for title and abstract review. The first author reviewed the titles and abstracts for relevance, resulting in 238 studies remaining for full-text review. As a result of the full-text review, 93 articles were included in the final review.

PSYCHOLOGICAL ADAPTATIONS

Psychological maladaptations are widely reported in people with NSCLBP [22-24]. Importantly, maladaptive psychological changes are strongly associated with functional disability [25-27] and development of chronic LBP [23].

Fear-avoidance beliefs

Pain is one of the most aversive stimuli and, as such, has a close relationship with fear [28]. Therefore, it is not surprising that the tendency to avoid painful tasks is a common adaptive mechanism seen in people with LBP [29,30]. Fear-avoidance beliefs have been described as both adaptive and maladaptive in that behaviours adopted in the short-term may be protective but when sustained in the longer-term, may be deleterious [28]. Fear-avoidance beliefs are generally sustained as a result of 'catastrophising' beliefs and negative interpretations of painful stimuli and their association with harm [31]. In those with LBP, there is limited evidence to suggest the commonality of these negative beliefs; however, it is well understood that they are associated with the persistence of LBP [32-35]. This could explain why fear-avoidance beliefs are sustained into the chronic phase of NSCLBP.

The longevity of behavioural adaptations resulting from fear-avoidance beliefs may be responsible for changes in the neuromuscular system [36]. Whilst it has long been hypothesised that people with NSCLBP who demonstrate high levels of fear-avoidance beliefs would demonstrate more protective behaviours [37], the evidence pertaining to this is unclear. Specifically, the uncertainty regarding the relationship between fear-avoidance beliefs and behavioural changes is partly due to conflicting results [37-44]. Furthermore, a proportion of the uncertainty is due to varied assessment methods of fear-avoidance beliefs. For example, there is recent evidence suggesting that data derived from task-specific fear-avoidance questionnaires [45] are more strongly associated with behavioural changes than data from general fear-avoidance questionnaires [46].

Whilst a body of literature has investigated the relationship between fear-avoidance and behavioural changes [37,39-41], there is a paucity of evidence investigating the relationship with neuromuscular-related deficits in NSCLBP. Of the muscular properties investigated, high fear-avoidance beliefs are associated with reduced lumbar extension strength [47]. The evidence is conflicting with respect to the relationship between fear-avoidance beliefs and lower limb muscle strength [48,49]. Importantly, studies investigating relationships between fear-avoidance beliefs and NSCLBP-related muscle deficits are in short supply with considerable measurement variability [48,49] and small sample sizes [50]. Thus, there is uncertainty about the relationship between fear-avoidance beliefs and neuromuscular maladaptations. Furthermore, there is evidence to suggest neuromuscular maladaptations and fear-avoidance beliefs contribute to disability independently [51].

Pain self-efficacy

Pain self-efficacy is defined as the belief in one's ability to perform painful or perceived painful tasks or movements in order to achieve a desirable outcome [52]. Self-efficacy beliefs are modifiable through an individual's experiences [53]. Indeed, longstanding improvements in pain self-efficacy have been identified in people with NSCLBP as a result of education and exercise [54]. By contrast, it is also possible that experiencing pain can negatively impact one's perception of their ability to perform painful tasks, thereby resulting in lower pain self-efficacy. Low pain self-efficacy during the acute phase of LBP could also lead to avoidance of provocative tasks, not because of fear-avoidance itself, but due to the lack of confidence in their ability to cope with pain. The continued avoidance of painful tasks may perpetuate the existence of low pain self-efficacy and lead to the persistence of LBP. In those with NSCLBP, higher levels of pain self-efficacy are associated with decreased pain intensity, reduced disability scores [55, 56] and greater functional capacity [57-59]. Moreover, low pain self-efficacy and high fear-avoidance beliefs typically coexist in people with NSCLBP [60]. Despite greater research emphasis on fear-avoidance beliefs, there is evidence to suggest that pain self-efficacy is a more important psychological mediator in the relationship between pain and disability in the NSCLBP population [61]. Furthermore, pain self-efficacy appears to be a critical mediator in the relationship between fear-avoidance and NSCLBP-related outcomes, such as pain and disability [62]. However, to date, the impact of pain-self efficacy on physical measures such as muscle weakness, muscle morphology and neuromuscular control is currently unknown.

BEHAVIOURAL ADAPTATIONS

Functional behaviours are impacted by pain or the threat of pain in people with NSCLBP. Physical activity, lifting and sitting are examples of behaviours that are commonly reported as problematic in this population [63-65]. Importantly, changes in these behaviours in response to pain or fear of pain vary amongst individuals with NSCLBP [66].

Physical activity

It is a commonly held belief by clinicians that people with NSCLBP are less physically active than healthy individuals. Arguably, this belief is attributed to the theoretical fear-avoidance model which indicates that decreases in physical activity are the result of fear of pain or harm [23]. Indeed, theoretical models have identified physical inactivity following the onset of LBP as a perpetuating factor for chronicity [65]. However, these theoretical models are only partially supported as there is conflicting evidence to suggest that physical activity deficits are commonplace in those with NSCLBP [67,68]. One limitation to our understanding of physical activity behaviours in people with NSCLBP stems from the outcome measures used to quantify physical activity that are unable to differentiate between different types of activities (e.g., walking or lifting). Therefore, whilst some people with NSCLBP demonstrate levels of physical activity similar to healthy individuals, they may actually modify or avoid certain provocative tasks (e.g., lifting). Indeed, no previous studies have performed time and motion analyses of people with NSCLBP. Importantly, time and motion analyses has led to a paradigm shift in the early rehabilitation phase following stroke [69,70]. The nature and extent of adaptations to physical activity in NSCLBP need to be established before appropriate interventions and education can be developed.

The heterogenic nature of the NSCLBP population has likely contributed to findings presented in previous studies that indicate negligible to no differences in physical activity-related behaviours compared with healthy control participants. The avoidance-endurance theoretical model suggests that a proportion of people with NSCLBP will decrease their physical activity-related behaviours whilst others will persevere despite their LBP [71]. Recent evidence supports this model by demonstrating that people with NSCLBP exhibit avoidance, persistence or a combination of both behaviours, towards tasks that reproduce pain [72]. Thus, people with NSCLBP display considerable diversity in their behaviours relating to physical activity, thereby supporting the notion that this population is heterogenous.

Lifting

Lifting is a risk factor for the development of LBP [73]. A popular belief held by people with NSCLBP, and clinicians is that a safe lifting technique should be characterised by a 'straight' back with movement and force produced from the lower limbs [74,75]. This squat-lift technique is also commonly advocated for the prevention of LBP in the workplace [64]; however, from a biomechanical and scientific perspective, 'best' lifting technique is equivocal [76-78] with spinal load (i.e., compression and shear) comparisons between 'squat' (i.e., bent knee and straight back) and 'stoop' (i.e., minimal knee bend and bent back) lifting techniques demonstrating mixed results [79-82]. Moreover, biomechanical comparisons of lifting techniques between those with and without NSCLBP have shown i) considerable variability, and ii) conflicting results with increased [83], and reduced to no differences [84,85] in lumbar range of motion. These inconsistent findings also provide support to the notion that people with NSCLBP are not homogenous with respect to their lifting behaviour [86]. Sub-classification, based on observed motor control impairments (i.e., flexion pattern or active extension pattern), has demonstrated significant differences in spinal kinematics between healthy controls and people with NSCLBP, as well as significant differences between NSCLBP sub-groups [87]. Therefore, the commonly held community perceptions together with general clinical recommendations suggesting that there is a singular 'safe' way of lifting are not evidence-based.

Coordination deficits between the trunk and lower limbs during lifting has also been associated with NSCLBP [88,89]. Individuals with NSCLBP display differences in trunk and lower limb coordination and reduced movement variability compared with healthy controls [90]. Coordination deficits extend beyond the musculoskeletal system as dysfunction of the respiratory system during lifting has been identified in individuals with NSCLBP. Specifically, individuals with NSCLBP perform lifts with greater inhaled lung volume than those without LBP [91]. The increase in inspired lung volume is associated with increased spinal stability and requires further thoracic spine extension [92,93]. Furthermore, altered breathing patterns may be associated with psychological factors commonly seen in people with NSCLBP, such as fear and apprehension [94].

Sitting

People with NSCLBP often identify sitting as a task that exacerbates their symptoms [63]. There are two key components regarding sitting: i) time and ii) posture. Similar to lifting, clinicians and people with NSCLBP commonly share the misconception that an upright sitting posture is optimal [95-97]. However, like lifting, there is a lack of evidence to support the notion that there is a singular 'best' universal sitting posture. In reality, people with NSCLBP tend to adopt sitting positions at either extreme of range (i.e., lordotic or kyphotic positions) compared to healthy individuals [98,99]. Adopting end of range sitting postures is a NSCLBP-related maladaptive trait as evidence demonstrates that when patients are positioned at the opposing end of range position or in a more neutral sitting position, they report reductions in pain intensity during sitting [98]. When it comes to sitting posture, it is apparent that a 'one size fits all' approach fails to address the complex and highly specific needs of people with NSCLBP. The evidence relating to the impact of sitting time on NSCLBP, however, is unclear due to inconsistencies in the literature [100-104], which likely result from differences in outcome measures used (e.g., patient reported measures vs. accelerometry).

NEUROMUSCULAR ADAPTATIONS

Maladaptations within the neuromuscular system including muscle weakness, muscle atrophy and motor control impairments, have long been described in those with NSCLBP [105,106]. Exercise interventions aimed at reducing disability in people with NSCLBP have targeted these neuromuscular deficits [15,16].

Morphological adaptations

Adaptations in NSCLBP-related muscle morphology have been investigated for almost 30 years [107]. These studies have primarily focussed on the morphology of the lumbar extensors and trunk muscles given their involvement in lumbar spine stability [107,108]. Indeed, numerous imaging studies have reported altered morphology and decreased size of the lumbar multifidus in NSCLBP people compared to healthy controls [109-112]. People with unilateral NSCLBP display significantly reduced multifidus size on the symptomatic side with a moderate positive relationship with pain duration. However, no associations with weakness or self-reported disability have been identified [113,114]. Importantly, these studies have focused on people with minimal disability and may not be representative of a more disabled NSCLBP population.

In addition to muscle size, numerous studies have investigated NSCLBP-related changes in muscle composition. Specifically, magnetic resonance imaging studies have demonstrated that people with NSCLBP exhibit increased fat infiltration in their erector spinae and lumbar multifidus muscles [115-120]. Surprisingly, the severity of fat infiltration in the lumbar muscles is only weakly associated with the severity of NSCLBP-related disability [117,118]. Whilst similar to the abovementioned evidence pertaining to lumbar muscle size, no studies have investigated relationships between lumbar muscle morphology, weakness and performance of functional tasks. Considering the weak associations between lumbar muscle morphology and disability, it is unlikely that interventions aimed at augmenting muscle size and composition would yield clinically relevant improvements in people with NSCLBP.

Motor weakness

The impact of motor weakness on function in people with NSCLBP is contentious [121]. Even the existence of NSCLBP-related motor weakness is debated in the literature. In this respect, there are inconsistent findings regarding the presence of motor weakness in the lumbar extensors of those with NSCLBP when compared with healthy controls [122-130].

The disparity of findings between studies may be partly due to the testing methods employed as some protocols limit pelvic rotation in a seated position [129,130] in order to isolate lumbar extension [131], whilst others permit posterior pelvic rotation [122-128]. Studies that restricted pelvic rotation reported no difference in lumbar extensor force-output between people with and without NSCLBP [129,130]. In contrast, six of the seven trials that did not restrict pelvic rotation found significant evidence of motor weakness during lumbar extension between participants with NSCLBP and healthy controls [122-127]. Restriction of pelvic rotation may lack ecological validity. Some studies have attempted to address this issue by testing lumbar extensor muscle strength in standing [122,123,126]. However, this test is 'static' in nature and, as such, does not test the types of isotonic muscle contractions utilised during functional tasks, such as lifting.

Despite the known involvement of the posterior pelvic rotators (i.e., gluteal and hamstring muscles) in functional tasks [132], there is a paucity of evidence evaluating them in people with NSCLBP. Of the single study identified, no difference between a NSCLBP group and healthy controls was identified [133]. However, obvious methodological flaws create uncertainty, as muscle strength testing has been performed i) using manual muscle testing, which is inherently inaccurate [134,135]; ii) using maximal effort contractions which are rarely required in day-to-day activities, iii) are conducted in non-functional positions (i.e., side-lying), or iv) are quantified using isometric contractions that are not representative of the types of isotonic (i.e., concentric and eccentric) muscle contractions involved in functional, closed kinetic chain movements. Therefore, it is not surprising that neuromuscular impairments including motor weakness exhibit limited associations with clinical and functional outcome measures (i.e., disability and functional performance) given that the testing methods lack ecological validity. Assessment protocols designed to quantify muscle force output though coordinated functionally relevant movements are likely to be more relatable to functional deficits in this population.

Motor control deficits

Motor control is defined as the ability of the central nervous systems to produce purposeful and coordinated movements [136]. In people with LBP, motor control deficits have been described in the literature for decades. A landmark study by Hodges and Richardson [105] indicated that spinal stability and control are altered with LBP. Early studies focussed on the deep trunk muscles (i.e., transversus abdominus and multifidus muscles) [137-139]. However, there are conflicting results regarding differences in recruitment patterns of the transversus abdominus between those with and without NSCLBP [105, 140-143]. Potential reasons for the disparity between studies may be due to low participant numbers and differing assessment methods (e.g., lower-limb tasks in supine [143], bilateral upper limb tasks whilst standing [105] or performing abdominal drawing-in in a hook-lying position and in supine [140-142]). Only one study has reported an association, albeit weak, between improvements in the ability to contract the transversus abdominus muscle and LBP-related disability [144].

Motor control deficits have also been explored via other methods. One prospective cohort study assessed LBP-related motor control impairments via three different methods. Firstly, visual observation of thoracolumbar dissociation was used to assess motor control, but visual observation is inherently inaccurate. Secondly, passive extension of the lumbar spine was assessed, but this measures range of movement rather than motor control. Thirdly, deep muscle contraction, which is similar to the abovementioned methods, lacks ecological validity [145]. Overall, none of these clinical tests were able to predict changes in NSCLBP-related disability or pain over an 8-week period [145]. In an attempt to implement a more ecologically valid assessment of motor control, Pranata, Perraton [129] found isometric assessment of force control of the lumbar extensor muscles was predictive of disability level. Whilst this protocol has some functional relevance in that it examined i) a provocative task (sitting) and ii) a sub-maximal force output of a muscle group associated with lumbar spine stability and movement, data collected in sitting may not translate to other functional tasks such and walking and lifting. It is apparent that testing muscle strength and motor control in static, isometric or non-functional tasks limits the strength of associations with NSCLBP-related disability.

CONCLUSION

Maladaptations in multiple domains can lead to disability, impaired function and health related quality of life for people with NSCLBP. However, current evidence suggests that maladaptations in the psychological and behavioural domains have a greater impact than those in the neuromuscular domain. Furthermore, the interrelationship between behavioural and psychological factors is stronger than any interrelationships with neuromuscular factors. Based on the available evidence, it is clear that the neuromuscular system is impacted by NSCLBP; however, studies evaluating the measures of these impairments have failed to identify meaningful relationships with clinically important outcomes. This lack of association is arguably attributed to variability in methods. Future investigation could consider: i) developing novel ecologically valid tests for neuromuscular impairments in relation to functional deficits commonly experienced in NSCLBP; ii) identifying and/or validating already proposed heterogenous sub-groups within the NSCLBP population; and iii) if NSCLBP sub-groups exist, identify discriminating features between them in order to tailor specific interventions towards these sub-groups. This will more importantly inform targeted and specific interventions for NSCLBP.

FUNDING

There was no funding source for this review.

COMPETING INTERESTS

The authors declare they have no competing interests.

REFERENCES

1. Hoy D, March L, Brooks P, Blyth F, Woolf A, Bain C, et al. The global burden of low back pain: Estimates from the Global Burden of Disease 2010 study. Ann Rheum Dis. 2014;73(6): 968-674.
2. Rubin DI. Epidemiology and risk factors for spine pain. Neurol Clin. 2007;25(2): 353-71.
3. Meucci RD, Fassa AG, Faria NM. Prevalence of chronic low back pain: Systematic review. Rev Saude Publica.2015;49.
4. Global burden of disease, injury incidence, prevalence collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990–2016: A systematic analysis for the Global Burden of Disease Study. 2016. 2017.
5. Gatchel RJ. The continuing and growing epidemic of chronic low back pain. Healthcare (Basel). 2015;3(3): 838-45.
6. Pozzobon D, Ferreira PH, Dario AB, Almeida L, Vesentini G, Harmer AR, et al. Is there an association between diabetes and neck and back pain? A systematic review with meta-analyses. PLoS One, 2019;14(2): e0212030.
7. Whitlock EL, Diaz-Ramirez LG, Glymour MM, Boscardin WJ, Covinsky K E, Smith AK. Association between persistent pain and memory decline and dementia in a longitudinal cohort of elders. JAMA Intern Med. 2017;177(8): 1146-1153.
8. Alhowimel A, AlOtaibi M, Radford K, Coulson N. Psychosocial factors associated with change in pain and disability outcomes in chronic low back pain patients treated by physiotherapist: A systematic review. Sage Open Medicine. 2018;6(1): 1-8.
9. DiNapoli EA, Craine M, Dougherty P, Gentili A, Kochersberger G, Morone NE, et al. Deconstructing chronic low back pain in the older adult--step by step evidence and expert-based recommendations for evaluation and treatment. Part V: Maladaptive Coping. Pain Med. 2016;17(1): 64-73.
10. Nees F, Becker S. Psychological processes in chronic pain: influences of reward and fear learning as key mechanisms-Behavioral evidence, neural circuits, and maladaptive changes. Neuroscience. 2018;387: 72-84.
11. Gatchel RJ, Mayer TG. Evidence-informed management of chronic low back pain with functional restoration. Spine J. 2008;8(1): 65-69.
12. Allan DB, Waddell G. An historical perspective on low back pain and disability. Acta Orthopaedica Scandinavica. 1989;60:1-23.
13. Harland N, D Lavallee. Biopsychosocial management of chronic low back pain patients with psychological assessment and management tools. Physiotherapy. 2001;89(5): 305-312.

14. Oliveira CB, Maher CG, Pinto RZ, Traeger AC, Lin CC, Chenot JF, et al. Clinical practice guidelines for the management of non-specific low back pain in primary care: An updated overview. Eur Spine J. 2018;27(11): 2791-2803.
15. Hayden JA, Van Tulder MW, Malmivaara A, Koes BW. Exercise therapy for treatment of non-specific low back pain. Cochrane Database Syst Rev. 2005;3: CD000335.
16. Saragiotto BT, CG Maher, Yamato TP, Costa LO, Menezes Costa LC, Ostelo RW, et al. Motor control exercise for chronic non-specific low-back pain. Cochrane Database Syst Rev. 2016(1): CD012004.
17. Hajihasani A, Rouhani M, Salavati M, Hedayati, Kahlaee AH. The influence of cognitive behavioral therapy on pain, quality of life, and depression in patients receiving physical therapy for chronic low back pain: A systematic review. PMR. 2019;11(2): 167-176.
18. Vitoula K, Venneri A, Varrassi G, Paladini A, Sykioti P, Adewusi J, et al. Behavioral therapy approaches for the management of low back pain: An up-to-date systematic review. Pain Ther. 2018;7(1): 1-12.
19. Wood L, Hendrick PA. A systematic review and meta-analysis of pain neuroscience education for chronic low back pain: Short-and long-term outcomes of pain and disability. Eur J Pain. 2019;23(2): 234-249.
20. Brouwers MC, Kho ME, Browman GP, Burgers JS, Cluzeau F, Feder G, et al. AGREE II: Advancing guideline development, reporting and evaluation in health care. CMAJ. 2010;182(18): E839-42.
21. Burns PB, Rohrich R J, Chung KC. The levels of evidence and their role in evidence-based medicine. Plast Reconstr Surg. 2011;128(1): 305-310.
22. Gatchel RJ, Neblett R, Kishino N, Ray CT. Fear-avoidance beliefs and chronic pain. J Orthop Sports Phys Ther. 2016;46(2): 38-43.
23. Vlaeyen JW, Linton SJ. Fear-avoidance and its consequences in chronic musculoskeletal pain: A state of the art. Pain. 2000;85(3): 317-332.
24. Crombez G, Vlaeyen JW, Heuts PH, Lysens R. Pain-related fear is more disabling than pain itself: Evidence on the role of pain-related fear in chronic back pain disability. Pain. 1999;80: 329-339.
25. Lundberg M, Frennered K, Hagg O, Styf O. The impact of fear-avoidance model variables on disability in patients with specific or nonspecific chronic low back pain. Spine (Phila Pa 1976). 2011;36(19): 1547-53.
26. Boersma K, Linton SJ. Psychological processes underlying the development of a chronic pain problem a prospective study of the relationship between profiles of psychological variables in the fear–avoidance model and disability. Clin J Pain. 2006;22(2): 160-166.
27. Boersma K, Linton SJ. How does persistent pain develop? An analysis of the relationship between psychological variables, pain and function across stages of chronicity. Behav Res The. 2005;43:1495-1507.
28. Leeuw M, Goossens ME, Linton SJ, Crombez G, Boersma K, JW Vlaeyen. The fear-avoidance model of musculoskeletal pain: current state of scientific evidence. J Behav Med. 2007;30(1): 77-94.
29. Grotle M, Vollestad NK, Veierod MB, JI Brox. Fear-avoidance beliefs and distress in relation to disability in acute and chronic low back pain. Pain, 2004;112(3): 343-52.
30. Picavet HS, Vlaeyen JWS, Schouten JS. Pain catastrophizing and kinesiophobia: Predictors of chronic low back pain. Am J Epidemol. 2002;156: 1028-1034.
31. Turk DC, Wilson HD. Fear of pain as a prognostic factor in chronic pain: Conceptual models, assessment, and treatment implications. Curr Pain Headache Rep. 2010;14(2): 88-95.
32. Barbosa FM, Vieira ÉB d M, Garcia JBS. Beliefs and attitudes in patients with chronic low back pain. Brazil J Pain. 2018;1(2).
33. Gron S, Jensen RK, Jensen TS, Kongsted A. Back beliefs in patients with low back pain: A primary care cohort study. BMC Musculoskelet Disord. 2019;20(1): 578.
34. Urquhart DM, Bell RJ, Cicuttini FM, Cui FM, Forbes A, Davis SR. Negative beliefs about low back pain are associated with high pain intensity and high level disability in community-based women. BMC Musculoskelet Disord. 2008;9:148.
35. Ng SK, Cicuttini FM, Wang Y, Wluka AE, Fitzgibbon B, Urquhart DM. Negative beliefs about low back pain are associated with persistent high intensity low back pain. Psychol Health Med. 2017;22(7): 790-799.
36. van Dieen JH, Flor H, Hodges PW. Low-back pain patients learn to adapt motor behavior with adverse secondary consequences. Exerc Sport Sci Rev. 2017;45(4): 223-229.
37. Geisser ME, Haig AJ, Wallbom AS, Wiggert EA. Pain-related fear, lumbar flexion, and dynamic emg among persons with chronic musculoskeletal low back pain. Clin J Pain. 2004;20(2): 61-69.
38. Verbunt JA, Seelen HA, Vlaeyen JW, van der Heijden GJ, Knottnerus JA. Fear of injury and physical deconditioning in patients with chronic low back pain. Arch Phy MedRehabil. 2003;84(8):1227-1232.
39. Yahia A, Yangui N, Mallek A, Ghroubi S, Elleuch MH. Kinesiophobia, functional disability and physical deconditioning evaluation in chronic low back pain. Ann Phy Rehabil Med. 2017;60.
40. Thomas JS, France CR, Sha D, Wiele NV. The influence of pain-related fear on peak muscle activity and force generation during maximal isometric trunk exertions. Spine. 2008;33: e342-e348.
41. Panhale VP, Gurav RS, Nahar SK. Association of physical performance and fear-avoidance beliefs in adults with chronic low back pain. Ann Med Health Sci Res. 2016;6(6): 375-379.
42. Karayannis NV, Jull GA, Nicholas GA, Hodges P W. Psychological features and their relationship to movement-based subgroups in people living with low back pain. Arch Phys Med Rehabil. 2018;99(1): 121-128.
43. Jette NG, Lim, Lim HL, Mokhtar SA, Gan SA, Singh DKA. Lumbar kinematics, functional disability and fear avoidance beliefs among adults with nonspecific chronic low back pain. Sultan Qaboos Univ Med J. 2016;16(4): e430–e436.
44. Demoulin C, Huijnen IP, Somville PR, Grosdent S, Salamun I, Crielaard JM, et al. Relationship between different measures of pain-related fear and physical capacity of the spine in patients with chronic low back pain. Spine J. 2013;13(9): 1039-1047.
45. Leeuw M, Goossens ME, van Breukelen GJ, Boersma K, Vlaeyen JW. Measuring perceived harmfulness of physical activities in patients with chronic low back pain: The Photograph Series of Daily Activities--short electronic version. J Pain. 2007;8(11): 840-849.
46. Matheve T, Baets LDe, Bogaerts K, Timmermans A. Lumbar range of motion in chronic low back pain is predicted by task-specific, but not by general measures of pain-related fear. Eur J Pain. 2019;23(6):1171-1184.
47. Al-Obaidi SM, Nelson RM, Al-Awadhi S, Al-Shuwaie N. The role of anticipation and fear of pain in the persistence of avoidance behavior in patients with chronic low back pain. Spine (Phila Pa 1976). 2000;25(9): 1126-1131.
48. Verbunt JA, Seelen HA, Vlaeyen JW, Bousema EJ, van der Heijden GJ, Heuts PH, et al. Pain-related factors contributing to muscle inhibition in patients with chronic low back pain: An experimental investigation based on superimposed electrical stimulation. Clin J Pain. 2005;21(3): 232-240.
49. Lee J, Park S. The relationship between physical capacity and fear avoidance beliefs in patients with chronic low back pain. J Phys Ther Sci. 2017;29(10): 1712-1714.

50. Wesselink E, Raaij E de, Pevenage P, van der Kaay N, J Pool. Fear-avoidance beliefs are associated with a high fat content in the erector spinae: A 1.5 tesla magnetic resonance imaging study. Chiropr Man Therap. 2019;27: 14.
51. Dubois JD, J Abboud, C St-Pierre, M Piche, M Descarreaux. Neuromuscular adaptations predict functional disability independently of clinical pain and psychological factors in patients with chronic non-specific low back pain. J Electromyogr Kinesiol. 2014;24(4): 550-557.
52. Ferrari S, Vanti C, Pellizzer M, Dozza L, Monticone M, Pillastrini P. Is there a relationship between self-efficacy, disability, pain and sociodemographic characteristics in chronic low back pain? A multicenter retrospective analysis. Arch Physiother. 2019;9: 9.
53. Bandura A. Self-efficacy: Toward a unifying theory of behavioral change. Psychol Rev. 1977;84(2): 191-215.
54. Nicholas MK, Wilson PH, Goyen J. Comparison of cognitive-behavioral group treatment and an alternative non-psychological treatment for chronic low back pain. Pain. 1992;48(3): 339-347.
55. Levin JB, Lofland KR, Cassisi JE, Poreh AM, Blonsky ER. The relationship between self-efficacy and disability in chronic low back pain. Inter J Rehabil Hea. 1996;2(2): 19-28.
56. Karasawa Y, Yamada K, Iseki M, Yamaguchi M, Murakami Y, Tamagawa T, et al. Association between change in self-efficacy and reduction in disability among patients with chronic pain. PLoS One. 2019;14(4): e0215404.
57. Asghari A, Nicholas MK. Pain self-efficacy beliefs and pain behaviour. A prospective study. Pain. 2001;94(1): 85-100.
58. La Touche R, Grande-Alonso M, Arnes-Prieto P, Paris-Alemany A. How does self-efficacy influence pain perception, postural stability and range of motion in individuals with chronic low back pain? Pain Physician. 2019;22: E1-E13.
59. Lackner JM, Carosella AM, Feuerstein M. Pain expectancies, pain, and functional self-efficacy expectancies as determinants of disability in patients with chronic low back disorders. J Consul Clin Psychol. 1996;64(1): 212-220.
60. de Moraes Vieira EB, de Goes Salvetti M, Damiani LP, de Mattos Pimenta CA. Self-efficacy and fear avoidance beliefs in chronic low back pain patients- coexistence and associated factors. Pain Manag Nurs. 2014;15(3): 593-602.
61. Costa LCM, Maher CG, McAuley JH, Hancock MJ, Smeets RJ. Self-efficacy is more important than fear of movement in mediating the relationship between pain and disability in chronic low back pain. Eur J Pain. 2011;15(2): 213-219.
62. Woby SR, Urmston M, Watson PJ. Self-efficacy mediates the relation between pain-related fear and outcome in chronic low back pain patients. Eur J Pain. 2007;11(7):711-718.
63. Williams MM, Hawley JA, McKenzie RA, van Wijmen PM. A comparison of the effects of two sitting postures on back and referred pain. Spine. 1991;16(10).
64. Garg A, Moore JS. Prevention strategies and the low back in industry. Occupa Med. 1992;7(4): 629-640.
65. Vlaeyen JWS, Kole-Snijders AMJ, Boeren RGB, van Eck H. Fear of movement/(re)injury in chronic low back pain and its relation to behavioral performance. Pain. 1995;62(3): 363-372.
66. O'Sullivan PB, Caneiro JP, O'Keefe M, Smith A, Dankaerts W, Fersum KV, et al. Cognitive functional therapy: An integrated behavioral approach for the targeted management of disabling low back pain. Phys Ther. 2018;98(5): 408-423.
67. van Weering M, Vollenbroek-Hutten MMR, Kotte EM, Hermens HJ. Daily physical activities of patients with chronic pain or fatigue versus asymptomatic controls. A systematic review. Clin Rehabil. 2007;21:1007-1023.
68. Griffin DW, Harmon DC, Kennedy NM. Do patients with chronic low back pain have an altered level and/or pattern of physical activity compared to healthy individuals? A systematic review of the literature. Physiotherapy. 2012;98(1): 13-23.
69. Bernhardt J, Dewey H, Thrift A, Donnan G. Inactive and alone: Physical activity within the first 14 days of acute stroke unit care. Stroke. 2004;35(4): 1005-1009.
70. Efficacy and safety of very early mobilisation within 24 h of stroke onset (AVERT): A randomised controlled trial. The Lancet. 2015;386(9988): 46-55.
71. Hasenbring M, Hallner D, Klasen B. Psychological mechanisms in the transition from acute to chronic pain-over-or underrated? Schmerz. 2001;15(6): 442-447.
72. Huijnen IP, Verbunt JA, Peters ML, Smeets RJ, Kindermans HP, Roelofs J, et al. Differences in activity-related behaviour among patients with chronic low back pain. Eur J Pain. 2011;15(7):748-755.
73. de Looze MP, Dolan P, Kingma I, Baten CTM. Does an asymmetric straddle-legged lifting movement reduce the low-back load? Hum Move Sci. 1998;17(2): 243-259.
74. Singh G, Newton C, K O'Sullivan, Soundy A, Heneghan NR. Exploring the lived experience and chronic low back pain beliefs of English-speaking Punjabi and white British people: A qualitative study within the NHS. BMJ Open. 2018;8(2): e020108.
75. Nolan D, O'Sullivan K, Stephenson J, O'Sullivan P, Lucock M. How do manual handling advisors and physiotherapists construct their back beliefs, and do safe lifting posture beliefs influence them? Musculoskelet Sci Pract. 2019;39: 101-106.
76. Hsiang SM, Brogmus GE, Courtney TK. Low back pain (LBP) and lifting technique- A review. Intern J Indus Ergonomics. 1997;19(1): 59-74.
77. van Dieen JH, Hoozemans MJ, Toussaint HM. Stoop or squat: A review of biomechanical studies on lifting technique. Clin Biomech (Bristol, Avon). 1999;14(10): 685-696.
78. Saraceni N, Kent P, Ng L, Campbell A, Straker L, O'Sullivan P. To flex or not to flex? is there a relationship between lumbar spine flexion during lifting and low back pain? a systematic review with meta-analysis. J Orthop Sports Phys Ther. 2020;50(3): 121-130.
79. Bazrgari B, Shirazi-Adl A, Arjmand N. Analysis of squat and stoop dynamic liftings: muscle forces and internal spinal loads. Eur Spine J. 2007;16(5): 687-699.
80. Dolan P, Earley M, Adams MA. Bending and compressive stresses acting on the lumbar spine during lifting activities. J Biomech. 1994;27(10): 1237-1248.
81. Kingma I, Faber GS, Bakker AJ, van Dieen JH. Can low back loading during lifting be reduced by placing one leg beside the object to be lifted? Phys Ther. 2006;86(8): 1091-1105.
82. Shin G, Mirka G. The effects of a sloped ground surface on trunk kinematics and L5/S1 moment during lifting. Ergonomics. 2004;47(6): 646-659.
83. McGregor AH, Mc Carthy ID, Hughes SP. Lumbar spine motion during freestyle lifting and changes in this motion with time. J Back Musculoskelet. Rehabil. 1997;9(1): 35-37.
84. Lariviere C, Gagnon D, Loisel P. A biomechanical comparison of lifting techniques between subjects with and without chronic low back pain during freestyle lifting and lowering tasks. Clin Biomech. (Bristol, Avon), 2002;17(2): 89-98.
85. Sanchez-Zuriaga D, Lopez-Pascual J, Garrido-Jaen D, de Moya M F, Prat-Pastor J. Reliability and validity of a new objective tool for low back pain functional assessment. Spine (Phila Pa 1976). 2011;36(16): 1279-1288.
86. Slaboda JC, Boston JR, Rudy TE, Lieber SJ. Classifying subgroups of chronic low back pain patients based on lifting patterns. Arch Phys Med Rehabil. 2008;89(8): 1542-1549.

87. Hemming R, Sheeran L, van Deursen R, Sparkes V. Non-specific chronic low back pain: differences in spinal kinematics in subgroups during functional tasks. Eur Spine J. 2018;27(1): 163-170.
88. Coenen P, Gouttebarge V, van der Burght AS, van Dieen JH, Frings-Dresen MH, van der Beek AJ, et al. The effect of lifting during work on low back pain: A health impact assessment based on a meta-analysis. Occup Environ Med. 2014;71(12): 871-877.
89. Kim MH, Yi CH, Kwon OY, Cho SH, Cynn HS, Kim YH, et al. Comparison of lumbopelvic rhythm and flexion-relaxation response between 2 different low back pain subtypes. Spine (Phila Pa 1976). 2013;38(15): 1260-1267.
90. Pranata A, Perraton L, El-Ansary D, Clark R, Mentiplay B, Fortin K, et al. Trunk and lower limb coordination during lifting in people with and without chronic low back pain. J Biomech, 2018.
91. Hagins M, Lamberg EM. Individuals with low back pain breathe differently than healthy individuals during a lifting task. J Orthop Sports Phys Ther. 2011;41(3): 141-148.
92. Shirley D, Hodges PW, Eriksson AEM, Gandevia SC. Spinal stiffness changes throughout the respiratory cycle. J App Physiol. 2003;95(4): 1467-1475.
93. McGill S, Seguin J, Bennett G. Passive stiffness of the lumbar torso in flexion, extension, lateral bending, and axial rotation. Effect of belt wearing and breath holding. Spine. 1994;19(6): 696-704.
94. Chaitow L. Breathing pattern disorders, motor control, and low back pain. J Osteo Med. 2004;7(1): 33-40.
95. O'Sullivan K, O'Keeffe M, O'Sullivan L, O'Sullivan P, Dankaerts W. Perceptions of sitting posture among members of the community, both with and without non-specific chronic low back pain. Man Ther. 2013;18(6): 551-556.
96. O'Sullivan K, O'Sullivan P, O'Sullivan L, Dankaerts W. What do physiotherapists consider to be the best sitting spinal posture? Man Ther. 2012;17(5): 432-437.
97. Korakakis V, O'Sullivan K, O'Sullivan PB, Evagelinou V, Sotiralis Y, Sideris A, et al. Physiotherapist perceptions of optimal sitting and standing posture. Musculoskelet Sci Pract. 2019;39: 24-31.
98. Dankaerts W, O'Sullivan P, Burnett AF, Straker LM. Differences in sitting postures are associated with non-specific chronic low back pain disorders when sub-classified. Spine. 2006;31(6): 698-704.
99. O'Sullivan K, O'Sullivan L, O'Sullivan P, Dankaerts W. Investigating the effect of real-time spinal postural biofeedback on seated discomfort in people with non-specific chronic low back pain. Ergonomics. 2013;56(8): 1315-1325.
100. Roffey DM, Wai EK, Bishop P, Kwon BK, Dagenais S. Causal assessment of occupational sitting and low back pain: Results of a systematic review. Spine J. 2010;10(3): 252-261.
101. Chen SM, Liu MF, Cook J, Bass S, Lo SK. Sedentary lifestyle as a risk factor for low back pain: A systematic review. Int Arch Occup Environ Health. 2009;82(7): 797-806.
102. Park SM, Kim HJ, Jeong H, Kim H, Chang BS, CK Lee, et al. Longer sitting time and low physical activity are closely associated with chronic low back pain in population over 50 years of age: A cross-sectional study using the sixth Korea National Health and Nutrition Examination Survey. Spine J. 2018;18(11): 2051-2058.
103. Gupta N, Christiansen CS, Hallman DM, Korshoj M, Carneiro IG, Holtermann A. Is objectively measured sitting time associated with low back pain? A cross-sectional investigation in the NOMAD study. PLoS One. 2015;10(3): e0121159.
104. Hanna F, Daas RN, El-Shareif TJ, Al-Marridi HH, Al-Rojoub ZM, Adegboye OA. The relationship between sedentary behavior, back pain, and psychosocial correlates among university employees. Front Public Health. 2019;7: 80.
105. Hodges PW, Richardson CA. Inefficient muscular stabilization of the lumbar spine associated with low back pain. A motor control evaluation of transversus abdominis. Spine (Phila Pa 1976). 1996;21(22): 2640-2650.
106. Nourbakhsh MR, Arab AM. Relationship between mechanical factors and incidence of low back pain. J Ortho Sports Phys Ther. 2002;32(9): 447-460.
107. Hides JA, Stokes MJ, Saide M, Jull GA, Cooper DH. Evidence of lumbar multifidus muscle wasting ipsilateral to symptoms in patients with acute/subacute low back pain. Spine (Phila Pa 1976). 1994;19(2): 165-172.
108. Cholewicki J, VanVliet JJ. Relative contribution of trunk muscles to the stability of the lumbar spine during isometric exertions. Clin Biomech (Bristol, Avon). 2002;17(2): 99-105.
109. Hides J, Gilmore C, Stanton W, Bohlscheid E. Multifidus size and symmetry among chronic LBP and healthy asymptomatic subjects. Man Ther. 2008;13: 43-49.
110. Danneels LA, Vanderstraeten GG, Cambier DC, Witvrouw E, De Cuyper HJ. CT imaging of trunk muscles in chronic low back pain patients and healthy control subjects. Euro Spine J 2000;9: 266-272.
111. Barker K L, Shamley DR, Jackson D. Changes in the cross-sectional area of multifidus and psoas in patients with unilateral back pain: The relationship to pain and disability. Spine. 2004;29: E515-519.
112. Kader DF, Wardlaw D, Smith FW. Correlation between the MRI changes in the lumbar multifidus muscles and leg pain. Clin Radiol. 2000;55:145-149.
113. Hides J, Stanton W, Mendis MD, Sexton M. The relationship of transversus abdominis and lumbar multifidus clinical muscle tests in patients with chronic low back pain. Manu Ther. 2011;16: 573-577.
114. Rezazadeh F, Taheri N, Okhravi SM, Hosseini SM. The relationship between cross-sectional area of multifidus muscle and disability index in patients with chronic non-specific low back pain. Musculosk Sci Pract. 2019;42: 1-5.
115. Wan Q, Lin C, Li X, Zeng W, Ma C. MRI assessment of paraspinal muscles in patients with acute and chronic unilateral low back pain. Br J Radiol. 2015;88(1053): 20140546.
116. Kjaer P, Bendix T, Sorensen JS, Leboeuf-Yde C. Are MRI-defined fat infiltrations in the multifidus muscles associated with low back pain? BMC Medicine, 2007;5: 2.
117. Hildebrandt M, Fankhauser G, Meichtry A, Luomajoki H. Correlation between lumbar dysfunction and fat infiltration in lumbar multifidus muscles in patients with low back pain. BMC Musculoskelet Disord. 2017;18(1): 12.
118. Teichtahl AJ, Urquhart DM, Wang Y, Wluka AE, Wijethilake P, O'Sullivan R, et al. Fat infiltration of paraspinal muscles is associated with low back pain, disability, and structural abnormalities in community-based adults. Spine J. 2015;15(7): 1593-1601.
119. Mengiardi B, Schmid MR, Boos N, Pfirrmann CWA, Brunner F, Elfering A, et al. Fat content of lumbar paraspinal muscles in patients with chronic low back pain and in asymptomatic volunteers: Quantification with MR spectroscopy. Radiol. 2006;240: 786-792.
120. Urquhart DM, Berry P, Wluka AE, Strauss BJ, Wang Y, Proietto J, et al. 2011 Young Investigator Award winner: Increased fat mass is associated with high levels of low back pain intensity and disability. Spine (Phila Pa 1976), 2011;36(16): 1320-1325.
121. Verbunt JA, Smeets RJ, Wittink HM. Cause or effect? Deconditioning and chronic low back pain. Pain. 2010;149: 428-430.

122. Bayramoglu M, Akman MN, Kilinc S, Cetin S, Yavuz N, Ozker R. Isokinetic measurement of trunk muscle strength in women with chronic low-back pain. Am J Phys Med Rehabil. 2001;80: 650-655.
123. Crossman K, Mahon M, Watson PJ, Oldham PJ, Cooper RG. Chronic low back pain-associated paraspinal muscle dysfunction is not the result of a constitutionally "adverse" fiber-type composition. Spine. 2004;29(6): 628-634.
124. Demoulin C, Grosdent S, Debois I, Mahieu G, Maquet D, Jidovsteff B, et al. Inter-session, inter-tester and inter-site reproducibility of isometric muscle strength measurements. Isokine Exer Sci. 2006;14: 317-325.
125. Hultman G, Nordin M, Saraste H, Ohlsèn H. Body composition, endurance, strength, cross-sectional area, and density of MM erector spinae in men with and without low back pain. J Spi Dis. 1993;6: 114-123.
126. Humphrey AR, Nargol AV, Jones AP, Ratcliffe AA, Greenough CG. The value of electromyography of the lumbar paraspinal muscles in discriminating between chronic-low-back-pain sufferers and normal subjects. Eur Spine J. 2005;14(2): 175-84.
127. Kankaanpaa M, Taimela S, Laaksonen D, Hanninen O, Airaksinen O. Back and hip extensor fatigability in chronic low back pain patients and controls. Arch Phys Med Rehabil. 1998;79(4): 412-417.
128. Renkawitz T, Boluki D, Grifka J. The association of low back pain, neuromuscular imbalance, and trunk extension strength in athletes. Spine J. 2006;6(6): 673-83.
129. Pranata A, Perraton L, El-Ansary D, Clark R, Fortin K, Dettmann T, et al. Lumbar extensor muscle force control is associated with disability in people with chronic low back pain. Clin Biomech (Bristol, Avon). 2017;46: 46-51.
130. Lariviere C, Bilodeau M, Forget R, Vadeboncoeur R, Mecheri H. Poor back muscle endurance is related to pain catastrophizing in patients with chronic low back pain. Spine (Phila Pa 1976). 2010;35(22): E1178-1186.
131. Graves JE, Webb DC, Pollock ML, Matkozich J, Leggett SH, Carpenter DM, et al. Pelvic stabilization during resistance training its effects on the development of lumbar extension strength. Arch Phys Med Rehabil. 1994;75(2): 210-215.
132. de Looze MP, Toussaint HM, van Dieën JH, Kemper HCG. Joint moments and muscle activity in the lower extremities and lower back in lifting and lowering tasks. J Biomech. 1993;26(9): 1067-1076.
133. Cooper NA, Scavo KM, Strickland KJ, Tipayamongkol N, Nicholson JD, Bewyer JD, et al. Prevalence of gluteus medius weakness in people with chronic low back pain compared to healthy controls. Eur Spine J. 2016;25(4): 1258-1265.
134. Anderson H, Jakobsen J. A comparative study of isokinetic dynamometry and manual muscle testing of ankle dorsal and plantar flexors and knee extensors and flexors. Europ Neurol. 1997;37(4): 239-242.
135. Bohannon RW. Manual muscle testing: Does it meet the standards of an adequate screening test? Clin Rehabil. 2005;19(6): 662-667.
136. Latash ML, Levin MF, Scholz JP, Schoner G. Motor control theories and their applications. Medicina (Kaunas). 2010;46(6): 382-392.
137. Hodges PW, Richardson CA. Delayed postural contraction of transversus abdominis in low back pain associated with movement of the lower limb. J Spin Dis. 1998;11: 46-56.
138. Hodges PW, Richardson CA. Relationship between limb movement speed and associated contraction of the trunk muscles. Ergonomics. 1997;40(11): 1220-1230.
139. Moseley GL, Hodges PW, Gandevia SC. Deep and superficial fibers of the lumbar multifidus muscle are differentially active during voluntary arm movements. Spine (Phila Pa 1976), 2002;27(2): E29-36.
140. Ferreira PH, Ferreira ML, Hodges PW. Changes in recruitment of the abdominal muscles in people with low back pain: Ultrasound measurement of muscle activity. Spine. 2004;29: 2560-2566.
141. Teyhen DS, Bluemle LN, Dolbeer JA, Baker SE, Molloy JM, Whittaker J, et al. Changes in lateral abdominal muscle thickness during the abdominal drawing-in maneuver in those with lumbopelvic pain. J Orthop Sports Phys Ther. 2009;39(11): 791-798.
142. Pulkovski N, Mannion AF, Caporaso F, Toma V, Gubler D, Helbling D, et al. Ultrasound assessment of transversus abdominis muscle contraction ratio during abdominal hollowing: a useful tool to distinguish between patients with chronic low back pain and healthy controls? Eur Spine J. 2012;21 Suppl 6: S750-9.
143. Pinto RZ, Ferreira PH, Franco MR, Ferreira MC, Ferreira ML, Teixeira-Salmela LF, et al. The effect of lumbar posture on abdominal muscle thickness during an isometric leg task in people with and without non-specific low back pain. Man Ther. 2011;16(6): 578-584.
144. Ferreira ML, Machado G, Latimer J, Maher C, Ferreira PH, Smeets RJ. Factors defining care-seeking in low back pain--A meta-analysis of population based surveys. Eur J Pain. 2010;14(7): 747.e1-7.
145. Oliveira CB, Pinto RZ, Schabrun SM, Franco MR, Morelhao PK, Silva FG, et al. Association between clinical tests related to motor control dysfunction and changes in pain and disability after lumbar stabilization exercises in individuals with chronic low back pain. Arch Phys Med Rehabil. 2019;100(7): 1226-1233.