

THE RELATIONSHIP BETWEEN DIAPHRAGMATIC BREATHING AND
LUMBOPELVIC CONTROL IN PHYSICALLY ACTIVE PATIENTS WITH AND
WITHOUT CHRONIC LOW BACK PAIN

by

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LIST OF ABBREVIATIONS

Abbreviation	Description
ASLR	Active Straight Leg Raise
BKFO	Bent Knee Fall Out
HLBA	Hi-Lo Breathing Assessment
KLAT	Knee Lift Abdominal Test
LANSS	Leeds Assessment for Neuropathic Symptoms and Signs
LBP	Low Back Pain
mODI	Modified Oswestry Disability Index
PBU	Pressure Biofeedback Unit
VAS	Visual Analogue Scale

ABSTRACT

Context: Lumbopelvic hip complex control is an essential component to function. The trunk stabilizers exhibit altered recruitment patterns and postural changes in patients with chronic low back pain (LBP). Limited research has been conducted to understand the role that the diaphragm plays on trunk stability in physically active patients with LBP.

Objective: This study had three objectives: to determine the effect of diaphragmatic breathing (DB) on lumbopelvic control, differences in DB patterns in participants with and without chronic LBP, and differences in lumbopelvic control in participants with and without chronic LBP.

Design: Case control design. **Setting:** Controlled laboratory setting. **Participants:** Twenty-one participants with LBP ($n=21$; $\text{age}=20.19 \pm 1.33$; $\text{height}=68.18 \pm 4.38$; $\text{weight}=167.33 \pm 34.32$) and 21 healthy participants ($n=21$; $\text{age}=19.71 \pm 1.10$; $\text{height}=68.48 \pm 4.25$; $\text{weight}=166.76 \pm 30.87$). Participants were between 18-30 years old and were involved in competitive sports. The LBP participants had LBP for at least 3 months, a score of 2 or greater on a VAS, and met nociceptive LBP criterion.

Interventions: The independent variables were group assignment (LBP versus healthy participants) and breathing styles (DB versus non-DB). At rest, breathing was examined with the Hi-Lo Breathing Assessment (HLBA), a clinical tool used to assess the relative movement of the ribcage and abdomen during respiration. Breathing pattern was characterized dichotomously as DB or non-DB based on the relative excursion of the abdominal and thoracic areas during breathing.

Main Outcomes Measures: The dependent variables were 2 lumbopelvic motor control test scores for each limb: the

active straight leg raise (ASLR) and knee lift abdominal test (KLAT). Reliability for the ASLR (ICC = 0.61-0.98) and KLAT (ICC >0.85) have been established. Participants repeated each test 3 times and a pressure biofeedback unit (PBU) inflated to 40 mmHg, was used to determine pressure variation. Independent samples t-tests and Chi Square analysis with ana-priori value of $p < 0.05$ were used to answer the research questions.

Results: Baseline VAS scores [$t(38) = 8.04, p < .001$] and mODI scores [$t(32.7) = 7.48, p < .001$] were significantly different with LBP participants demonstrating moderate levels of pain and disability when compared to the healthy controls. Breathing pattern and LBP history did not significantly affect motor control test performance. In addition, participants with LBP did not demonstrate significantly different breathing patterns compared to healthy controls. **Conclusions:** The results of the study revealed that physically active patients with chronic LBP display correct breathing patterns and have similar lumbopelvic stability when compared to healthy participants. Future research should consider more challenging lumbopelvic stability tests and investigate populations with greater levels of disability.

Keywords: low back pain, stability, diaphragmatic breathing

CHAPTER I

INTRODUCTION

The development of low back pain (LBP) has been a common problem for people across various age groups and activity levels.¹⁻⁴ Multiple studies have reported that up to 70-80% of individuals experience at least one episode of LBP within their lifetime.⁵⁻⁸ Low back pain has been a financial inconvenience for many years. In 1998, the amount of money spent in the United States on the treatment of LBP exceeded 90 billion dollars in direct costs⁹ and in 2004, the United States averaged 7.4 billion dollars in indirect costs.¹⁰ Given the prevalence and impact of LBP in the population, research has been performed to understand the risk factors, causes, and appropriate treatment for LBP.

Multiple studies have demonstrated that finding the pathological cause for LBP is difficult. In fact, many patients are diagnosed as having non-specific low back pain because of unremarkable physical examination and radiological findings.^{11,12} This difficulty in determining the cause of LBP may also account for the protracted recovery periods noted in LBP patients. In 2013, a systematic review of the clinical course of non-specific low back pain found that 65% of patients still experienced LBP one year after the initial pain onset.¹³ Because of the difficulty with LBP diagnosis, multiple clinical assessment algorithms and diagnostic classification systems have been proposed to assist clinicians in ascertaining the mechanical and/or pathoanatomical origin of many low back conditions.¹⁴⁻¹⁶ In particular, a combination of neurophysiological and biomechanical compensations that arise from LBP can result in movement dysfunctions in patients.¹¹

The movement dysfunctions seen in patients with LBP are sometimes attributed to problems with the activation of the trunk muscles.^{17,18} Research demonstrates that the

stabilizing back musculature including the transverse abdominis (TrA) and multifidus become prohibited as a result of pain inhibition from LBP.^{18,19} Low back pain has also been shown to alter posture and lead to an instability of the trunk muscles.²⁰ The changes in muscle activation manifest as movement dysfunction because the deep segmental stabilizers lack recruitment and motor control.²¹

Motor control is the key element in maintaining neutral posture.²² Motor control of the lumbopelvic hip complex works via the synergistic activation of the TrA, multifidus, pelvic floor muscles, and the diaphragm²³⁻²⁶ to stabilize the lumbar spine, hips, and lower extremities during movement. The supporting structures of the lumbopelvic hip complex work to maintain optimum positioning of the spine and pelvic girdle. The pelvic girdle and the lumbar segments must anticipate sudden changes in movement to stabilize the core musculature.²⁷ When improper activation of the trunk musculature occurs, changes in postural control and weakness of the abdominal cavity and trunk are noted.^{5,27} As previously mentioned, the TrA, multifidus, diaphragm, and muscles of the pelvic floor work synergistically via their contraction to provide trunk stability.²⁸ The diaphragm specifically helps in stabilizing the trunk and contributes to postural stability by increasing intra-abdominal pressure (IAP).²⁹ Hodges reported that the diaphragm causes an increase in IAP before initiation of movement, further indicating that there may be a direct link of the diaphragm providing postural control of the trunk.²⁰ In patients with chronic LBP, the IAP is compromised due to the altered stability and dysfunctions of the trunk and abdominal musculature.

The modulation of IAP, via the control of the diaphragm, is regulated by maintaining proper ventilation through a pattern of normal inspiration and expiration; thus making the

diaphragm a large factor in trunk stability.^{30,31} Some physical signs of dysfunctional breathing can include, but are not limited to, posterior rib cage tilt, elevated shoulders, and hyperextension of the cervical spine.³⁰ A normal breathing pattern should consist of movement of the ribcage in a cranial, lateral, and ventral direction with outward movement of the abdomen during inspiration.³¹

Overall, stability of the trunk and proper function of the diaphragm are important factors, as they play a large role in the etiology of LBP. However, there is limited research on the role of the diaphragm and its importance to lower extremity movement. Very few research has investigated the relationship between diaphragmatic breathing and lumbopelvic control. The majority of this research has been conducted on dancers or healthy populations;³² therefore, more research is necessary to determine their relationship in the physically active population. More specifically, research should investigate the relationship and differences between diaphragmatic breathing and lumbopelvic control in physically active patients with and without chronic low back pain to further understand the potential contribution of the diaphragm, as it plays a role in stability of the trunk.

Purpose

The purpose of this study is to use a case-control design to examine the relationship between diaphragmatic breathing and lumbopelvic control in physically active patients with and without chronic low back pain. The efficiency of diaphragmatic movement will be assessed as well as functional movement of the lumbopelvic hip complex.

Research Questions

1. Is there a relationship between diaphragmatic breathing and lumbopelvic control in physically active patients with and without chronic low back pain?
2. Is there a difference between participants with a history of chronic low back pain and those without low back pain in regards to diaphragmatic breathing?
3. Is there a difference between participants with a history of chronic low back pain and those without low back pain in regards to lumbopelvic control?

Significance

As previously mentioned, LBP can lead to a number of physical changes throughout the body.^{4,7} Allied health professionals typically assess their patients globally to evaluate compensatory movements that occur along the kinetic chain to understand the potential causes and results of LBP in a patient. This study aims to understand the role of the diaphragm and lumbopelvic hip complex instability while also understanding the potential differences that occur in physically active patients with and without LBP. Evaluating patients at the global level can allow the health care provider a better viewpoint in understanding why the patient displays patterns of dysfunction and how to retrain these dysfunctional patterns in order for the patient to return to activities of daily living.

Recognizing the dysfunctional patterns that result from LBP is important and incorporating specific protocols to retrain these patterns in a rehabilitation program is essential to return to physical activity. This can be the link necessary to perform functional tasks more efficiently during every day and athletic activities. The overall goal is to limit the compensations that inhibit functional movement patterns. Comerford

et al.²¹ states that retraining the muscles locally allows co-activation of the muscles globally so they can synergistically co-activate in normal function. This is of particular importance in physically active persons who continue to participate in activity despite LBP.

Limitations

1. This study will use a clinical test of diaphragmatic breathing (Hi-Lo Breathing Assessment) rather than lab tests such as Respiratory Inductance Plethysmography (RIP), diaphragmatic EMG, and piezoelectric belts to assess the movement and function of the diaphragm.
2. Assessment of core and trunk musculature function will be assessed via lumbopelvic motor control tests rather than by direct measures of muscle function using EMGs.
3. History of low back pain and demographic information will only be obtained through self-reports and Leeds Assessment of Neuropathic Symptoms and Signs (LANSS) due to inability to acquire exact diagnosis.

Delimitations

1. This study will only involve competitive athletes who participate in club sports or intercollegiate athletics of a college or university.
2. The subjects in the case group will consist of patients with specific types of LBP pain including but not limited to lumbar discogenic pain, sacroiliac joint pain, zygapophyseal joint pain, spondylolysis, and/or myofascial pain.¹⁶

3. This study will only include subjects in the range of 18-30 years old.
Recruitment of subjects will occur at a Division I and III university in the central Texas area.

Assumptions

1. It is assumed that the subjects will provide honest and accurate answers when completing the demographic self-report tool, Modified Oswestry Disability Index, Visual Analog Scale, and the Leeds Assessment for Neuropathic Symptoms and Signs.
2. It is assumed that the participants will perform to the best of their abilities during the lumbopelvic motor control tests.
3. It is assumed that patients will not alter breathing during assessment using Hi-Lo Breathing Assessment.
4. It is assumed that the questions on the demographic self-report tool will be clear and concise for the subjects upon the time of completion.

Operational Definitions

1. Competitive sports are defined as those that are sponsored by club sports and/or intercollegiate athletics at a college or university and who have regular practices and competitions during a competitive season.
2. Chronic low back pain is defined as pain that is persistent for 3 months or greater and that fits into the nociceptive pain category.
3. Nociceptive pain is defined as pain that is derived from noxious stimulation of peripheral tissue that includes but not limited to lumbar discogenic pain,

spondylolysis, sacroiliac joint pain, zygapophyseal joint pain, and/or myofascial pain.^{16,33,34}

4. Neuropathic pain is defined as pain that is derived from tissues of the peripheral or central nervous system that includes the following: compressive radiculopathy, non-compressive radiculopathy, neurogenic claudication, and/or central pain.¹⁶
5. Lumbopelvic movement control is defined as the ability to activate and control the muscles of the lumbopelvic hip complex and to hold a position isometrically while simultaneously producing active movement at another joint.^{32,35}
6. Diaphragmatic breathing is defined as an outward motion of the abdominal wall while reducing movement of the upper rib cage during inspiration.³⁶
7. The pressure biofeedback unit (PBU) is defined as a device used to detect positional changes of the lumbar spine from exertion against the device during performance of exercise tests while simultaneously determining maintenance of stabilization positions.³⁷
8. The Active Straight Leg Raise (ASLR) is defined as a functional test used to evaluate the transference of loads unilaterally between the lumbopelvic region and the lower extremities.³⁸
9. The Knee Lift Abdominal Test (KLAT) is defined as a functional test used to evaluate the ability to control movement of the lumbopelvic region.^{31,32}
10. The Hi-Lo Breathing Assessment (HLBA) is defined as a tool that is used to assess the motion of the upper and lower rib cage including the abdomen to determine specific aspects of breathing such as motion, rate, rhythm, and phase relation of the upper and lower breathing compartments.^{39,40}

11. The Modified Oswestry Disability Index (mODI) is defined as a tool that specifically measures function and disability in patients with low back pain.⁴¹⁻⁴³
12. The visual analog scale (VAS) is defined as a tool used to assess severity and intensity of pain.^{31,32,41,42,44}
13. Allied Health Professionals are defined as health care practitioners with formal education and clinical training who are credentialed through certification, registration and/or licensure. They collaborate with physicians and other members of the health care team to deliver high quality patient care services for the identification, prevention, and treatment of diseases, disabilities, and disorders.⁴⁵

CHAPTER II

LITERATURE REVIEW

There has been much research conducted to understand the causes and impacts of chronic low back pain (LBP). Many researchers have investigated the role and prevalence of different lower back pain injuries in a number of very different populations that include those in work/industrial settings, patients referred to rehabilitation clinics, athletic populations, and even adolescents. Often times, LBP can cause changes in lumbar stability, lumbopelvic motor control, and even diaphragmatic breathing. This study will be conducted to examine the relationship between diaphragmatic breathing and lumbopelvic control in physically active patients with and without chronic LBP, examine the difference in diaphragmatic breathing between participants with and without a history of chronic low back pain, and lastly, examine the difference in lumbopelvic motor control between participants with and without a history of chronic low back pain. To better appreciate these concepts, it's important to understand the role that LBP plays in each of these variables; but more specifically in athletes. This literature review will help to establish the epidemiology and diagnosis of LBP, describe its effects on low back stabilization, explain the role of diaphragmatic breathing in lumbopelvic control, and to summarize the research conducted in these areas.

Low Back Pain Epidemiology and Diagnosis

During the 20th century, simple back strains disabled more people than all of the serious spinal diseases combined.¹¹ Unfortunately, LBP still continues to be an issue for the new millennium.¹¹ Although modern medicine has done an excellent job in treating

the serious spinal diseases, this has not been true for the treatment and diagnosis for general LBP.¹¹ Not only is there a physical burden for LBP, but there is also a high financial burden that has been noted globally. The amount of money spent in the United States on the treatment of LBP exceeded 90 billion dollars in direct costs in 1998.⁹ In Sweden, total costs amounted to 2.3 billion dollars in 2001⁴⁶ and in the Netherlands, total cost amounted to over 8.5 billion dollars in 2002.⁴⁷ Direct costs are those in which there is a monetary exchange, mostly from third-party payers, that results in medical fees, hospital services, medications, emergency room visits, radiographic imaging, etc.⁴⁷⁻⁴⁹ In contrast, indirect costs are those in which there is no monetary exchange but includes time off from work, sick leave, decrease in productivity, etc.⁴⁸ In 2004, the United States averaged 7.4 billion dollars in indirect costs alone.¹⁰ The largest proportion of direct costs in the treatment of LBP was physical therapy (17%), inpatient services (17%) and pharmaceuticals (13%) respectively.⁴⁸

The causes for LBP are typically multifactorial as it ranges from a number of causative factors: overuse of muscles, compensatory movements, and uneven distribution of loads, to name a few.⁵⁰ Because research has demonstrated that finding the pathological cause for LBP is difficult,^{5,16,51,52} many patients are diagnosed as having non-specific low back pain because of unremarkable (unfamiliar) physical examinations,¹¹ pathoanatomic/radiological findings,^{12,52} and other unknown causes.¹³ In addition, many clinical examination techniques specific to LBP have been shown to be unreliable.⁵³ Often times, LBP is then termed as chronic when the pain persists for longer than three months.^{31,41,54,55} Of the multiple clinical assessment algorithms and diagnostic classification systems established, the Leeds Assessment of Neuropathic

Symptoms and Signs (LANSS) was the first screening tool developed.¹⁴⁻¹⁶ The LANSS consists of five symptomatic items and two clinical exam items to determine if a patient's LBP has neuropathic or nociceptive origin.¹⁵ Neuropathic pain is defined as pain that is derived from tissues of the peripheral or central nervous systems that includes compressive radiculopathy, non-compressive radiculopathy, neurogenic claudication, and/or central pain.¹⁶ Nociceptive pain is defined as pain that is derived from noxious stimulation of peripheral tissue that have been divided into 4 subcategories according to the possible pain generator: lumbar discogenic pain, sacroiliac joint pain, zygapophyseal joint pain, and/or myofascial pain.^{16,33,34} Other screening tools similar to the LANSS include the Neuropathic Pain Questionnaire (NPQ), Donleur Neuropathique en 4 questions (DN4), painDETECT, and ID-Pain.¹⁴ Of these screening tools, LANSS has been established as having a sensitivity of 85% and a specificity of 80% when compared to clinical diagnosis.¹⁴

Prevalence of Low Back Pain in Athletes

Research has been conducted to understand the role of LBP in sports. In 2011, Sato et al.⁵⁶ conducted a survey requesting physically active adolescents to report if they currently experienced LBP when compared to those who were not physically active. In his study of 26,766 students, 34.9% had LBP who participated in sports and 20.1% of these students had a history of LBP. Sato further suggests that physical activity plays a large role in the prevalence of LBP in athletes. Bahr et al.⁵⁷ conducted research investigating the prevalence of LBP in cross-country skiers, rowers, and orienteers when compared to nonathletic controls. The results of this study revealed that LBP was more common in cross-country skiers and rowers than orienteers and the controls; determining

that LBP may be common in endurance sports due to high loads during practices and competitions.⁵⁷ The prevalence of LBP has also been evaluated in adolescent gymnasts. These competitive gymnasts actually had lower incidence (26%-46.15%) of LBP when compared to aged-matched, non-athletic populations (36%-60%).² In other research, 29% of injuries were to the back or lower extremity after examining the relationship of core stability measures between male and female basketball and cross-country athletes.⁵⁸ Additionally, 16.1% of overuse injuries were located in the back in basketball players of different competitive levels.⁵⁹ Schmidt et al.⁶⁰ reported interesting findings of LBP in athletes in which he found that from a total of 272 athletes, 4.6% had one episode of LBP, 51.1% had 2-11 episodes, and 9.6% of the athletes had chronic reports of LBP. Overall, multiple studies have confirmed that LBP is a commonly reported injury among athletes of different activity levels and age groups.

Low Back Pain's Effect on Low Back Stabilization

Panjabi⁶¹ describes three subsystems that work simultaneously to maintain spinal stability: the passive (ligamentous) subsystem, the active (musculotendenous) subsystem, and the neural control (central nervous system) subsystem. Each system has a specific task to support and allow the body to function properly. The passive subsystem has the role of resisting movement at the end ranges of motion via neural control of the surrounding ligaments of the spinal column.⁶¹ The active subsystem is most important in achieving large load-carrying capacities as the muscles coordinate to support the spinal column; however, injury to this system causes altered activation modifying the structural integrity of the spine which can no longer react appropriately to sudden loads and can lead to chronic low back pain if not properly addressed.^{22,61} The large mobilizing

muscles that work as prime movers are associated with concentric acceleration of the back to produce large movements like flexion and extension of the spine, whereas the stabilizing muscles play a role in postural control and thus, are associated with eccentric deceleration or resisting momentum.⁶² The transverse abdominis (TrA), multifidus, diaphragm, and the muscles of the pelvic floor have been considered the main stabilizers of the low back.^{18,27} These stabilizers are called so because they contract prior to the prime movers and therefore, protect the spine from unwanted and additional movements.^{24,28} Lastly, the neural control subsystem receives signals to the appropriate structures to adjust excessive movements placed on the spine.⁶¹ The central nervous system (CNS) is the controlling center for motor control. Motor control is the key element in maintaining neutral posture, as the spine displays the least amount of stiffness.²¹ The coordination of the CNS is able to anticipate reactive forces of limb movement and contribute to spinal stability as the core musculature stabilizes to maintain a stable base for movement.^{27,28,61} When one of these systems are not functioning properly, the overall stability of the spine is compromised and can contribute to pain and dysfunctional patterns.^{61,63}

When LBP arises, various impairments, functional limitations, disabilities, and other changes are experienced by the patient. The causes of these changes can be connected to pathoanatomical, biomechanical, neurophysiological, and psychosocial changes.^{4,11} In particular, a combination of neurophysiological and biomechanical compensations that arise from LBP can result in movement dysfunctions such as poor movement habits, faulty postural alignment, and irregular neuro-dynamic sensitization.^{11,25} The dysfunctions seen in patients with LBP are sometimes attributed to problems with the

activation of trunk muscles.^{17,18} Research demonstrates that the stabilizing back musculature including the TrA and multifidus become prohibited as a result of pain inhibition.^{18,19} Low back pain has been shown to alter posture and lead to an instability of the trunk musculature.^{18,64,65}

The lumbopelvic region aids in movement and control of the spine and hip complex while interacting with forces placed on the trunk.⁶⁶ Motor control of the lumbopelvic hip complex works via the synergistic activity of the TrA, multifidus, pelvic floor muscles, and the diaphragm²³⁻²⁶ to stabilize the lumbar spine, hips, and lower extremities during movement. In the presence of LBP, the changes in muscle activation manifest as dysfunction due to the insufficiency in recruitment and motor control of the deep segmental stabilizers resulting in poor control of the neutral joint position especially in the lumbopelvic hip complex.²¹

Modifications in Trunk Musculature

Multiple studies have been conducted to observe the normal and altered functions of the trunk in patients with and without LBP. Early research shows that activation of the trunk muscles occur prior to limb movement which is observed by utilizing electromyographic electrodes.^{28,65,67} In healthy subjects, initiation of the TrA, internal oblique, and even the diaphragm, occur prior to upper and lower extremity movement. Hodges conducted a study to investigate if trunk motion is preceded by direction-oriented movement of the shoulder.⁶⁷ The results revealed that while the TrA does not react differently to changes in directions of shoulder movement, but it does contract prior to the superficial muscles of the trunk. This further indicates that the TrA and other stabilizers of the trunk, aid in preparation of sudden tasks placed on the body.^{24,28,65}

In contrast, there are different results noted in patients who have chronic low back pain. In a number of his studies, Hodges revealed that these specific patients cannot activate the trunk stabilizers like their healthy counterparts.^{24,65} For example, when performing rapid shoulder flexion, the TrA, internal, and external oblique did not activate prior to shoulder movement when compared to the healthy subjects.²⁴ While different directions have been observed for upper extremity movement, trunk activation at varying speeds has also been investigated in patients with and without LBP. There was a delayed onset of recruitment patterns of the trunk stabilizers in patients with a history of LBP.⁶⁵ Recent research, suggests that healthy subjects should be able to produce a proximal-to-distal sequencing relative to lumbopelvic movements, but in patients with LBP, they exhibit a distal-to-proximal activation sequence; thus implying poor lumbopelvic control.⁶⁸

Diaphragmatic Function

The diaphragm is the primary muscle that provides ventilatory work,³⁰ although it is not the sole provider for respiration. The diaphragm is shaped like a dome and divides the thorax from the abdomen that is composed of left and right hemidiaphragms.^{23,69} The diaphragm flattens during inspiration to increase intra-abdominal pressure (IAP), increase thoracic volume, and lower intra-thoracic pressure.⁶⁹ In a normal breathing pattern, the ribcage should move in a cranial, lateral, and ventral direction with outward movement of the abdomen during inspiration and reverse directions for expiration.³¹ Some physical signs of dysfunctional breathing can include but not are limited to posterior rib cage tilt, elevated shoulders, and hyperextension of the cervical spine.^{26,30} Changes in diaphragmatic function can lead to breathing patterns that utilize the upper chest and

accessory muscles including the scalenes, sternocleidomastoid and pectoralis major that further result in hyperactivity of those muscles. When this occurs, the diaphragm is not working effectively and efficiently via the downward movement of the diaphragm.^{23,69}

Proper breathing via diaphragmatic contraction modulates IAP³¹ while maintaining ventilation through a pattern of normal inspiration and expiration.³⁰ Intra-abdominal pressure is measured in mmHg as the amount of pressure exerted on the abdominal cavity and the trunk.⁷⁰ The CNS coordinates the motor activities of the trunk to stabilize posture and respiratory tasks.⁷¹ Because the TrA, multifidus, diaphragm, and muscles of the pelvic floor work synergistically via their contraction to provide trunk stability,²⁸ they also assist in stabilizing the trunk and contribute to postural stability by increasing IAP.^{28,29,71} In order for intra-abdominal pressure to be reached via contraction of the abdominal muscles, the diaphragm needs to contract prior to limb movement.²⁰ In patients with LBP, improper activation of the trunk and abdominal region can lead to weakness of the abdomen,⁵ diaphragm, and pelvic floor muscles thus, losing the role of postural control.²⁷ Hodges confirmed that increases in IAP has a direct link to increasing spinal stability via the coordination of the trunk stabilizers.⁷²⁻⁷⁴ From this, it can be concluded that IAP and the trunk musculature act to produce lumbopelvic stability. In patients with LBP, the diaphragm is limited in the ability to descend thus lacking ability to create IAP.^{28,71,75} In turn, the trunk musculature also lacks ability to properly maintain movement and the transference of loads at the lumbopelvic hip complex.⁷³

Although there is evidence to support that inhibition of the diaphragm and other core musculature could result in low back instability, there is little evidence on the assessment of diaphragmatic function in patients with LBP when compared to literature

investigating other core stabilizers. There are a variety of methods in which the function of the diaphragm is assessed in laboratory settings and include respiratory induction plethysmography (RIP), elastomeric plethysmography (aka piezoelectric sensors), impedance plethysmography, etc. These tools are aimed at assessing the movement of the diaphragm and to support other components of respiration. However, current research in rehabilitation is trying to discern the role and the function of the diaphragm in pelvic stability. To date, there are only two field-based methods used to assess the role of the diaphragm. The Manual Assessment of Respiratory Motion (MARM) and the Hi-Lo Breathing Assessment (HLBA) are inexpensive tests and do not require use of technological software. The MARM and the HLBA only involve specific hand placement of the clinician. More specifically, the MARM requires the hands to be placed comfortably at the lower rib cage while the patient is in a seated position and the examiner can decipher whether the motion is from the lateral expansion of the lower rib cage/abdomen or upper rib cage/chest motion.^{39,76} The HLBA requires the patient to be lying supine while the examiner places one hand on the sternum and the other hand on the upper abdomen, while determining if the patient is breathing with the upper chest, abdomen, or paradoxical pattern. Paradoxical breathing is noted when the patient's abdomen goes toward the spine and the chest expands outward during inspiration.³⁹ In 2009, Courtney³⁹ conducted a study to determine the relationship between MARM and HLBA and to assess sensitivity and consistency between the two. The results revealed that both MARM and HLBA are both valid and reliable tests to measure diaphragmatic breathing patterns.

Current Research

Motor control tests of the lumbopelvic region have been well established in the literature. Each of these tests has a specific functional purpose and an overall evaluation to assess ability of lumbopelvic motor control. However, there is lacking evidence on methods to assess diaphragmatic breathing. Even more so, there is limited evidence on the relationship of lumbopelvic motor control tests and diaphragmatic breathing in physically active patients with chronic LBP. Current research tells us that patients with LBP have altered breathing patterns and changes in motor control of the lumbopelvic region.^{31,51,55} However, this information was collected on healthy subjects.

In 2009, Roussel³¹ conducted a study investigating the breathing patterns in patients with LBP and to further examine its impact on motor control of the lumbopelvic hip complex. The participants of this study had chronic LBP but were otherwise healthy. Breathing patterns were assessed during the active straight leg raise (ASLR) and bent knee fall out (BKFO). Further investigations of motor control tests were noted during the knee lift abdominal test (KLAT) and BKFO via a pressure biofeedback unit. The author found that the patients with chronic LBP had altered breathing patterns during the motor control tests. This further indicates that trunk stability and breathing efficiency is challenged in these specific patients.³¹ Other research has identified that patients with LBP display a variety of lumbopelvic control patterns during performance of the ASLR and hip abduction when compared to a control group.⁶⁸ Although diaphragmatic function was not assessed in this study, the overall outcomes are the same. Patients with LBP are not able to control simple movement of the hip; thus displaying lack of trunk stability. But the bigger question still remains. Are these findings similar in the physically active

population who have LBP?

Conclusion

More research is needed to better understand the relationship between diaphragmatic breathing, control of lumbopelvic hip complex, and its role in physically active patients with LBP. From there, clinicians can better appreciate the role each of these variables play in everyday life and how to improve them in injured athletes. Therefore, this study will be done to determine the differences and examine the relationship of the aforementioned variables. By providing this information, it can be helpful for medical health care providers when implementing rehabilitation protocols for their patients.

CHAPTER III

METHODS

Research Design

The purpose of this study is threefold: 1) to understand the relationship between diaphragmatic breathing and lumbopelvic control in physically active patients with and without a history of chronic LBP, 2) to determine the differences between diaphragmatic breathing patterns in physically active patients with and without chronic LBP, 3) to determine the differences between lumbopelvic control in physically active patients with and without chronic LBP. The independent variables are group assignment (LBP participants versus non-LBP participants) and breathing styles (diaphragmatic breathing versus non-diaphragmatic breathing). The dependent variables are 2 lumbopelvic motor control test scores for each limb. The study analyzed the outcomes of these variable using a case-control design.

Participants

Participants were recruited from a Division I and III university in the central Texas area via a variety of recruitment methods. The following recruitment methods were used based on the availability of athletic groups: an information session with a sign-up sheet requesting general contact information (name, email address, and phone number), posting flyers that had general information regarding the study as well as the principal investigator's contact information, and sending emails to coaches and/or allied health care staff. Once potential participants were identified, the principal investigator met with each participant to determine whether they met the inclusion criteria for the

study. Inclusion criteria stated that the participants in the LBP group (n=15-20) were between 18-30 years old, had LBP for at least 3 months, and were involved in competitive sports. Competitive sports criteria states that they are sponsored by club sports and/or intercollegiate athletics at a college or university, and had regular practices and competitions during a competitive season. Additionally, the participants had a score of less than 12 points on the Leeds Assessment for Neuropathic Symptoms and Signs (LANSS); a score of 2 or greater on the Visual Analog Scale (VAS)⁴²; and back pain that met the criteria of nociceptive pain, which includes but is not limited to, lumbar discogenic pain, sacroiliac joint pain, zygapophyseal joint pain, spondylolysis, and/or myofascial pain.¹⁶ Participants were excluded if they had a history of systemic disease, spinal surgery, spinal or pelvic fracture, history of hypertension, coronary artery disease, neuromuscular disease, rib fracture, history of respiratory disease, referred leg pain, radicular symptoms, cancer/serious infections, lower extremity surgeries in the past 6 months, or neuropathic pain resulting from any injury.^{5,16,41} Neuropathic pain is described as pain that is derived from tissues of the peripheral or central nervous system that fit into the following four subcategories: compressive radiculopathy, non-compressive radiculopathy, neurogenic claudication, and/or central pain.¹⁶

Participants in the matched control group (n=15-20) were required to meet the same criteria with the exception of information regarding low back pain. These healthy participants were also involved in competitive sports. Participants in the healthy group were excluded if they have a history of systemic disease, spinal surgery, spinal or pelvic fracture, history of hypertension, coronary artery disease, neuromuscular disease, rib fracture, history of respiratory disease, cancer/serious infections or lower extremity

surgeries in the past 6 months.^{16,41} The healthy participants were matched to the LBP group based on 4 characteristics gathered through self-reported demographic information: height, weight, gender, and age.

All participants completed a self-report tool collecting demographic information (height, weight, age, gender, and general questions regarding history of LBP), VAS, and the Modified Oswestry Disability Index (4-week recall). Participants with low back pain additionally completed the LANSS. All participants were asked to wear comfortable athletic clothing on the same day of completing the testing trials. The men were asked to wear only shorts and the women were asked to wear a tank top/t-shirt with shorts (cropped yoga pants are also allowed).⁷⁷ Participants were not allowed to wear clothing that restricted movement or negatively affected any of the testing procedures.

Unacceptable clothing included but was not limited to shoes, jeans, belt, khakis, hoodies, etc. All participants had the opportunity to ask questions at any time regarding the study and they were properly notified of the procedures, minimal risks, and possible benefits of the study. Participants were allowed to withdraw from the study at any point without penalty. Once all potential participants were properly informed of the aforementioned conditions, a written informed consent was signed prior to participation in accordance with the Texas State University Institutional Review Board.

Instrumentation

The VAS is a tool used to measure severity and intensity of pain and had adequate test-retest reliability (ICC = 0.66-0.93).^{44,78-81} Prior to beginning the procedures, the participants with low back pain completed the VAS on a 10cm horizontal line ranging from no pain to worst pain imaginable. Low back pain participants had to score a 2/10 or

greater to be considered eligible for the study. Previous studies suggest that a score of 2 or less is slight to no pain⁸² and a score of 3 or less is moderate pain to no pain on the VAS.⁷⁹ For the purposes of this study, a VAS score of 2 or greater was required. Additionally, the participant was asked to mark on a diagram, the location of low back that had the highest level of pain. Each participant marked an “X” indicating the highest level of pain and marked an “O” for lower levels of pain in other areas.

The LANSS is a tool used to assess whether the origin of pain is nociceptive versus neuropathic based on five sensory dysfunction questions and two questions that required physical examination.¹⁵ The physical examination required two tests that are designed to determine abnormal sensations (i.e tingling, numbness, nausea, etc) when compared to the contralateral side. First, a cotton tip applicator was used to stroke on an area of the low back on the non-painful side and then stroke on the same area on the painful side. Second, the LANSS required use of a 23 gauge needle fixed inside a 2ml syringe barrel to pin-prick the skin¹⁵; however, for ease of use, reduced chance of puncturing the skin, and cross contamination, a pin prick with a Medipin tool was used. Medipin is a single use, neurological tool that was designed to stretch the skin with its faceted point instead of penetrating the skin upon contact⁸³ and is also used to elicit cutaneous sensation and perception of pain. Once the participant identified the area of pain, the examiner used the Medipin on the non-painful side and compared the sensation at the same location on the painful side. The examiner was consistent in applying the same amount of pressure for each identified site on the low back. The examiner first demonstrated the application of the Medipin tool on herself so the participant was aware of how this tool was applied. After each single use, the Medipin was properly disposed

into a sharps biohazard container. For each physical examination test, the subject answered “No” if the sensations were equal in both areas and “Yes” if there was altered sensation from the non-painful to the painful area. The LANSS scale demonstrated to good test–retest reliability ($r = 0.70$; $P < 0.001$) as well as internal consistency (Cronbach’s alpha = 0.78).⁸⁴ Please see Table 3.1 for a more detailed description of the sensory testing of the LANSS. Please see Figure 3.1 for an image of the Medipin tool.

Table 3.1: LANSS Sensory Testing			
Patient will identify the painful area of the low back. This painful area will be compared to a similar non-painful area on the contralateral side via the presence of: 1) allodynia* and 2) altered pin prick^.			
Sensory Testing	Altered Sensation Presents as:	<u>NO</u>: equal sensation in both areas	<u>YES</u>: altered sensation in painful area
1). Allodynia: Lightly stroke cotton tip applicator to non- painful area then compare to painful area	Allodynia: abnormal sensations of the skin (i.e. tingling, numbness, nausea, etc.)	0 points	5 points
2). Pin Prick: Applying minimum pressure, prick the non- painful area then compare to painful area	Pin Prick: If sharp prick is felt on non-painful area, but different sensation in the painful area (i.e. nothing, altered sensation, increase pain, etc.)	0 points	3 points

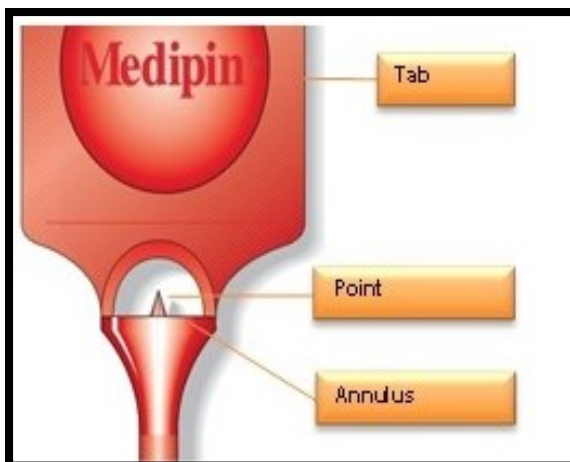


Figure 3.1. Medipin Tool

The Modified Oswestry Disability Index (mODI) is a tool that measured function and disability in patients with low back pain. High test-retest reliability (ICC=0.78) was established for the modified version at 4 weeks.⁸⁵ The validity of the tool has been assessed and has an effect size of 1.12.⁸⁶ The mODI is designed with 10 categories that are specific to everyday activities. Each category is scored from 0-5, with the higher value indicating more severe pain.⁸⁷ All participants completed this form prior to beginning of the procedures for this study.

The pressure biofeedback unit (PBU; [Stabilizer Pressure Biofeedback-Chattanooga Group, Australia]) is a 3-cell chamber pressure transducer that is connected to a sphygmomanometer that measures changes in pressure up to 200mmHg.⁷⁷ When weight is applied to the PBU, it reacts to changes in pressure. This device was used to detect positional changes of the lumbopelvic hip complex by recording changes in pressure during movement and exercise.³⁷ The PBU's intra-rater reliability is good to excellent (ICC = 0.60-0.95) and inter-rater reliability is fair to excellent (ICC = 0.40-0.86).^{37,77} It is also sensitive to detecting changes in pressure that are exerted on the lumbar spine (40 mmHg).^{37,88} For this study, the PBU was set to 40 mmHg at the start of each motor control test. Excessive changes in pressure indicate lack of stability of the lumbopelvic region.⁸⁹ More specifically, pressure increases indicate posterior pelvic tilts, while pressure decreases indicate anterior pelvic tilt during activity.³⁷

Procedures

To ensure that the participants met the criteria for inclusion, all participants interested in the study completed the following paperwork: demographics, VAS, LANSS, and mODI. The healthy participants did not complete the LANSS, as it was used in

determining a specific type/origins of LBP. All participants signed informed consent on the same day as completing other paperwork and testing procedures. The performance of three separate tests will include: Hi-Lo Breathing Assessment (HLBA), active straight leg raise (ASLR), and the knee lift abdominal test (KLAT) in a quiet room.

The HLBA is a clinical tool used to assess the relative movement of the ribcage and abdomen during respiration to establish breathing patterns as diaphragmatic or non-diaphragmatic.³⁹ This test has been compared to the Manual Assessment for Respiratory Motion (MARM), which also assesses movement of the ribcage, and was found to correctly identify simulated abdominal and thoracic breathing patterns in both expert and novice clinicians.³⁹

During the HLBA, the participants laid supine on a treatment table with their legs in a hook lying position and with their arms at their sides. The participants had up to 2 minutes to relax before the breathing assessment began. The examiner stood at the side of the participant while placing one hand on their sternum and one hand on their upper abdomen.³⁹ The participant was then told to breathe normally for approximately 1 minute, while the examiners hands were in the correct position. After about 1 minute, the examiner determined the dominant breathing pattern utilized. If the majority of the motion was coming from the abdomen, this was considered diaphragmatic breathing (DB). If thoracic or paradoxical breathing (abdomen moves toward the spine during inspiration while the thoracic cavity is moving in an opposite direction and vice versa during expiration) patterns were noted, this constituted as non-DB.^{39,41} Correct DB was noted using a “Yes”, and improper DB was noted using a “No”; therefore, the findings were measured dichotomously.

After completion of the HLBA, each participant performed the ASLR and KLAT. Testing order and leg order were counterbalanced by a coin toss method for randomization. The ASLR and KLAT were two motor control tests that were deemed valid and reliable measures of lumbopelvic control when used with a pressure biofeedback unit.^{31,32,37,41,90} Reliability for ASLR included an ICC of 0.61-0.98 in patients with a history of LBP.^{31,32} Mens³⁸ reported adequate test-retest reliability of the ASLR ($r=0.87$; ICC = 0.83) in females after pregnancy with pelvic girdle pain. The reliability for KLAT (ICC >0.85) in injured population has also been established.³² In addition, the ASLR and KLAT are internally consistent with Cronbach scores of 0.83.³²

The ASLR was used to evaluate the transference of loads unilaterally between the lumbopelvic region and the lower extremity.^{38,41} Before the start of the test, the participant was shown a before and after picture for visual representation of the movement. They also received verbal instructions, in which the participant was asked to lift one leg 20cm off the table. The testing table was placed perpendicular to the wall. A piece of tape was placed on the wall to the left and right sides of the testing table with a mark of 20cm measured at the base of the heel. A pre-testing trial, up to 5 times per leg,⁷⁷ was included to familiarize participants with the ASLR, use of PBU, and leg distance from table; after which the subject had the option to rest for up to 2 minutes prior to the start of the test. To determine leg randomization, a coin was flipped before the start of the test. At the beginning of the ASLR, the participants were in a supine position with their legs 20cm apart in full extension. The PBU was placed horizontally under the spine of subject with the lower edge at the level of posterior superior iliac spine (PSIS) and inflated to 40mmHg.³² As described by Mens,³⁸ each participant was instructed to

raise one leg at a time 20cm for 3 seconds above the table without bending the knee. The subject performed the test 3 times on each leg and the average pressure as well as average pressure difference from 40mmHg was documented for three trials.

The KLAT, based on a progression of abdominal exercise, is often indicated in patients with low back pain due to its ability to improve performance of the external oblique muscles.²⁵ The external oblique muscles and the contralateral internal oblique muscles control posterior pelvic tilt and pelvic rotation.²⁵ The nature of the test is also used to improve performance of the transverse abdominis, as it also stabilizes the lumbar spine.^{25,31,32} The participants were placed supine on a treatment table in a hook lying position. Before the start of the test, each participant was shown a before and after picture for visual representation of the movement. Each participant was given verbal instructions in which they were asked to bring one knee perpendicular to the ceiling with the knee in a relaxed flexed position. The PBU was placed horizontally under the spine with the lower edge at the level of PSIS set to 40mmHg.³² A pre-testing trial, up to 5 times per leg,⁷⁷ was included to familiarize participants to the KLAT; after which the participants had the option to rest for up to 2 minutes prior to the start of the test. The participants were asked to lift one leg (as determined by the coin flip) off the table bringing the hip to 90 degrees of flexion with the knee flexed and holding this position for 3 seconds. The subject performed the test 3 times on each leg and the average pressure as well as the average pressure difference was documented for each trial.

Data Analysis

IBM SPSS software version 22 was used to perform all statistical analyses. To determine the relationship between DB (categorical data) and lumbopelvic motor control

scores (continuous data), we used an independent samples t-test. A Chi Square analysis was used to determine differences between participants with and without low back pain (categorical) in regards to DB patterns (categorical). We also used an independent samples t-test to assess the differences between participants with and without low back pain (categorical) in regards to lumbopelvic motor control scores (continuous data). Cohens d (95% CI) was calculated to assess the magnitude of differences between groups. Lastly, we ran Pearson's correlation coefficients to understand the relationship between the lumbopelvic motor control tests as well as VAS and mODI.

CHAPTER IV

MANUSCRIPT

Introduction

The development of low back pain (LBP) has been a prevalent musculoskeletal concern experienced by persons of various age groups and activity levels.¹⁻⁴ Multiple studies have reported that up to 70-80% of individuals experience at least one episode of LBP within their lifetime.⁵⁻⁸ Additionally, 65% of patients still experience LBP one year after the initial onset of pain.¹³ Low back pain concerns are further complicated by the fact that establishing the pathological cause for LBP is difficult.^{5,16,51,52} Therefore, many patients are given a diagnosis of non-specific low back pain due to unremarkable physical examinations and radiological findings.^{11-13,52} Furthermore, many clinical examination techniques specific to LBP have been shown to be unreliable.⁵³ Often times, LBP is then classified as “chronic” when the pain persists for longer than three months.^{31,41,54,55}

One of the many concerns regarding chronic LBP, are the changes in recruitment patterns that can occur that are said to be attributed to poor activation of the trunk musculature.^{17,18} Insufficiency in the recruitment and motor control of the trunk stabilizers results in poor neutral joint position control especially in the lumbopelvic hip complex.²¹ The lumbopelvic region aids in movement to control the spine and hip complex while interacting with forces placed on the trunk.⁶⁶ Motor control of the lumbopelvic hip complex works via the synergistic activation of the transverse abdominis (TrA), multifidus, pelvic floor muscles, and the diaphragm to stabilize the lumbar spine, hips, and lower extremity during movement.²³⁻²⁶ In addition, the pelvic girdle and the

lumbar segments must anticipate sudden changes in movement to stabilize the core musculature.²⁷ Researchers have found that the diaphragm also helps in stabilizing the trunk and contributes to postural stability by increasing intra-abdominal pressure (IAP).^{29,72} Hodges reported that an increase in IAP comes from activation of the diaphragm prior to initiation of limb movement, further indicating that there is a direct link of the diaphragm providing postural control of the trunk.²⁰ However, IAP may be compromised in patients with LBP due to the altered stability and dysfunctions of the trunk and abdominal musculature.^{20,29,75}

Overall, stability of the trunk and proper function of the diaphragm are important factors, as they play a large role in the etiology of LBP. However, there is limited research on the role of the diaphragm and its importance to lower extremity movement. Few studies have investigated the relationship between diaphragmatic breathing (DB) and lumbopelvic control.^{31,41} The majority of this research has been conducted on healthy populations.³² However, there is limited research regarding these variables in athletes. It is interesting to see if physically active patients are able to maintain stability and display correct DB with chronic LBP in order to further understand the potential contribution of the diaphragm, as it too plays a role in stability of the trunk. Therefore, the purpose of this study is to examine the relationship between DB and lumbopelvic control in physically active patients with and without chronic low back pain. The efficiency of diaphragmatic movement was assessed as well as functional movement of the lumbopelvic hip complex via motor control tests.

Methods

Design

We used a case-control design to describe the relationship between DB and

lumbopelvic control. The independent variables were group (LBP participants versus non-LBP participants) and breathing patterns (DB versus non-DB). The dependent variables included 2 lumbopelvic motor control tests: the active straight leg raise and knee lift abdominal test.

Participants

The participants in LBP group ($n=21$; age= 20.19 ± 1.33 ; height= 68.18 ± 4.38 ; weight= 167.33 ± 34.32) were recruited from a Division I and III university. This sample of athletes participated in a number of sports that included: baseball, cheerleading, gymnastics, football, men's/women's track and field, men's/women's tennis, softball, ultimate frisbee, women's basketball, and women's soccer. To be included in the LBP group, participants were between 18-30 years old, had LBP for at least 3 months, and were involved in competitive sports. For the purposes of this study, competitive sports were defined as participation in athletic events sponsored by club sports and/or intercollegiate athletics at a college or university that had regular practices and competitions during a competitive season. Further inclusion criteria states that the participants must have a score less than 12 points on the Leeds Assessment for Neuropathic Symptoms and Signs (LANSS); a score of 2 or greater on the Visual Analog Scale (VAS)⁴²; and back pain that met the criteria of nociceptive pain, which includes but is not limited to, lumbar discogenic pain, sacroiliac joint pain, zygapophyseal joint pain, spondylolysis, and/or myofascial pain.¹⁶ Participants were excluded if they had a history of systemic disease, spinal surgery, spinal or pelvic fracture, history of hypertension, coronary artery disease, neuromuscular disease, rib fracture, history of respiratory disease, referred leg pain, radicular symptoms, cancer/serious infections, lower extremity

surgeries in the past 6 months, or neuropathic pain resulting from any injury.^{5,16,41}

Participants in the matched healthy group (n=21; age= 19.71 ± 1.10; height= 68.48 ± 4.25; weight= 166.76 ± 30.87) were also recruited from a Division I and III university and were required to meet the same inclusion and exclusion criteria with the exception of information regarding low back pain. The healthy participants were matched to the LBP group based on 4 characteristics gathered through self-reported demographic information: height, weight, gender, and age. We obtained a university IRB approved consent form from each participant prior to participation in the study.

Procedures

Testing procedures were completed in one session. During this session, all participants completed a demographic questionnaire, VAS for pain^{44,78-81} and the Modified Oswestry Disability Scale (mODI).⁸⁵⁻⁸⁷ In addition, the LBP participants completed the LANSS, in which they answered five sensory questions and the examiner used a cotton tip applicator and Medipin to elicit abnormal sensations in a painful area of the low back.¹⁵ Each participant then performed three separate tests in a quiet room: 1) Hi-Lo Breathing Assessment (HLBA), 2) active straight leg raise (ASLR), and 3) knee lift abdominal test (KLAT).

The HLBA is a clinical tool used to assess the relative movement of the ribcage and abdomen during respiration to establish breathing patterns as diaphragmatic or non-diaphragmatic.³⁹ During the HLBA, the participants laid supine on a treatment table with their legs in a hook lying position and with their arms at their sides. The participants were given a 2-minute relaxation window before the breathing assessment began. The examiner stood at the side of the participant and placed one hand on their sternum and

one hand on their upper abdomen.³⁹ The participants were instructed to breathe normally for approximately 1 minute to normalize breathing patterns. After 1 minute, the examiner determined the dominant breathing pattern utilized during this time. If the majority of the motion came from the abdomen and/or there was an even distribution of the upper chest and abdomen, this was considered to be DB. If thoracic or paradoxical breathing (abdomen moves toward the spine during inspiration while the thoracic cavity is moving in an opposite direction and vice versa during expiration) patterns were noted, this constituted non-DB.^{39,41} Correct DB was noted using a “Yes”, and improper DB was noted using a “No”; therefore, the findings were measured dichotomously. The primary investigator was trained by a respiratory therapist (Ph.D., RRT-NPS, RPSGT, RST) to determine proper breathing patterns utilized by the participants. The examiner computed intra-reliability of the HLBA on subjects (n=15) that were not a part of the sample. Substantial agreement (Kappa=0.75) was obtained.⁹¹

The order of the ASLR and KLAT were counterbalanced by using a coin toss method to establish the testing order and leg order for each participant. These motor control tests are two valid and reliable functional tests of lumbopelvic control when used with a pressure biofeedback unit (PBU).^{31,32,37,41,90} Reliability for the ASLR included an ICC of 0.61-0.98 in patients with a history of LBP.^{31,32,38} The reliability for KLAT (ICC >0.85) in an injured population has also been established.³² In addition, the ASLR and KLAT are internally consistent with Cronbach scores of 0.83.³²

The ASLR was used to evaluate the transference of loads unilaterally between the lumbopelvic region and the lower extremity.^{38,41} Similarly, the KLAT, was based on a progression of abdominal exercise and often indicated in patients with LBP due to its

ability to improve performance of the external oblique muscles.²⁵ The nature of this test is also used to improve performance of the transverse abdominis, as it also stabilizes the lumbar spine.^{25,31,32} Please see figure 4.1 and 4.2 for visual representation of the motor control tests.



Figure 4.1. Active Straight Leg Raise (ASLR) Figure 4.2. Knee Lift Abdominal Test (KLAT)

Before the start of each motor control test, the participant was shown a before and after picture for visual representation of the movement as well as given verbal instructions. A coin was tossed to determine test order and leg order to ensure randomization. During the ASLR, the participant was asked to lift one leg 20cm off the table with the knee in full extension.³⁸ During the KLAT, the participant was asked to bring one hip to 90 degrees of flexion with the knee fully relaxed starting from a hook lying position. A pre-testing trial, up to 5 times per leg,⁷⁷ was included to familiarize the participants with each test and placement of the PBU. The PBU was placed horizontally under the spine of subject with the lower edge at the level of posterior superior iliac spine (PSIS) and inflated to 40mmHg.³² Each participant was instructed to lift one leg at a time

for 3 seconds off the table. The participants performed each test 3 times on each leg and the average pressure for the three trials was documented including the average difference from 40mmHg.

The pressure biofeedback unit (Stabilizer Pressure Biofeedback-Chattanooga Group, Australia) is a 3-cell chamber pressure transducer that is connected to a sphygmomanometer that measures changes in pressure up to 200mmHg.⁷⁷ This device was used to detect positional changes of the lumbopelvic hip complex by recording changes in pressure during movement and exercise.³⁷ The PBU's intra-rater reliability is good to excellent (ICC = 0.60-0.95) and inter-rater reliability is fair to excellent (ICC = 0.40-0.86).^{37,77} The PBU was set to 40 mmHg at the start of each motor control test.⁸⁸ Excessive changes in pressure indicate lack of stability of the lumbopelvic region.⁸⁹ More specifically, pressure increases indicate posterior pelvic tilts, while pressure decreases indicate anterior pelvic tilt during activity.³⁷

Data Analysis

IBM SPSS software version 22 was used to perform all statistical analyses. To determine the relationship between DB (categorical data) and lumbopelvic motor control scores (continuous data), we used an independent samples t-test. A Chi Square analysis was used to determine differences between participants with and without LBP (categorical) in regards to DB patterns (categorical). We also used an independent samples t-test to assess the differences between participants with and without LBP (categorical) and lumbopelvic test scores (continuous data). Cohens *d* (95% CI) was calculated to assess the magnitude of differences between groups. Lastly, we ran Pearson's correlation coefficients to understand the relationship between the lumbopelvic

motor control tests as well as VAS and mODI using the guidelines as described by Hinkle.⁹²

Results

The purpose of this study was threefold, and therefore, each of the research questions were answered accordingly. To start, the baseline assessment between the LBP group and healthy group revealed significant differences for VAS scores [$t(38) = 8.04$, $p < .001$] and mODI scores [$t(32.7) = 7.48$, $p < .001$] with the LBP demonstrating moderate levels of pain and disability when compared to the healthy controls (see Table 4.1).

Table 4.1. Descriptive data on baseline questionnaire [mean and standard deviations (SD)] for LBP and healthy groups. Note. *signifies significant differences ($p \leq 0.05$).		
Questionnaire	Group	
	LBP (n=21)	Healthy (n=21)
VAS (cm)	4.8 ± 1.8*	0.90 ± 1.40
mODI (%)	13.0 ± 6.0*	2.00 ± 3.00
LANSS	4.10 ± 4.3	n/a
Participated in Rehabilitation (%)	9.5% (2/21)	n/a
Length of LBP (months)	35.4 ± 28.6	n/a

When examining the effect of DB on lumbopelvic control, there was no significant difference in lumbopelvic test performance (ASLR and KLAT) between the participants who displayed correct DB patterns and incorrect DB patterns. Included in table 4.2 is the effect size (ES) using Cohens d (95% CI) to assess the magnitude of the differences.⁹³ A medium ES was established between DB and non-DB for KLAT on the right leg. However, all other ES estimates were small or trace. This would indicate that participants who are incorrect DB perform similar to those who are correct DB in regards to the lumbopelvic motor control tests.

Table 4.2. Mean pressure, SD, and Cohen's <i>d</i> effect sizes for correct and incorrect DB.			
Lumbopelvic Test	Correct DB (n=36) (mean pressure ± SD)	Incorrect DB (n=6) (mean pressure ± SD)	Cohens <i>d</i> (95% CI)
ASLR-Right	3.6 ± 2.5	2.9 ± 3.2	<i>d</i> = 0.27 (-0.55 to 2.83)
ASLR-Left	2.0 ± 1.6	2.4 ± 1.5	<i>d</i> = -.025 (-0.77 to 0.95)
KLAT-Right	9.0 ± 7.3	5.0 ± 4.9	<i>d</i> = 0.57 (-1.81 to 4.49)
KLAT-Left	10.6 ± 9.7	6.4 ± 6.9	<i>d</i> = 0.45 (-2.72 to 5.97)

A Chi-square analysis determined that injury status (LBP versus healthy) did not significantly influence breathing patterns displayed by our participants [$\chi^2 (1) = .78$, $p=0.66$; Phi= -0.14; Cramer's V=0.14]. See table 4.3.

Table 4.3. LBP and healthy cross-tabulation					
			DB		Total
			Correct DB	Incorrect DB	
Injury Status	LBP	Count	17	4	21
		Expected Count	18.0	3.0	21.0
	Healthy	Count	19	2	21
		Expected Count	18.0	3.0	21.0
Total		Count	36	6	42
		Expected Count	36.0	6.0	42.0

An independent sample t-test also determined that there were no significant differences between the LBP and healthy groups in regards to the lumbopelvic motor control test performance (see table 4.4). All of the ES demonstrated to be small or trace and therefore had no effect. This would indicate that the participants in the LBP and healthy groups had similar test scores of motor control performance and therefore, both groups had similar levels of stability.

Table 4.4. Mean pressure, SD, and Cohens <i>d</i> between the LBP and healthy groups.			
Lumbopelvic Test	LBP (n=21) (mean pressure ± SD)	Healthy (n=21) (mean pressure ± SD)	Cohens <i>d</i> (95% CI)

Table 4.4 continued			
ASLR-Right	3.0 ± 2.3	3.9 ± 2.8	d= -0.35 (-1.34 to 0.84)
ASLR-Left	2.2 ± 1.4	1.8 ± 1.6	d= 0.19 (-0.41 to 1.39)
KLAT-Right	9.7 ± 8.2	7.2 ± 5.6	d= 0.36 (-3.14 to 2.76)
KLAT-Left	10.0 ± 10.6	10.0 ± 8.3	d= 0.00 (-4.53 to 3.55)

Lastly, we ran Pearson’s correlation coefficients between the lumbopelvic motor control tests, VAS, and mODI variables. We found that there is a positive, significant relationship between VAS and mODI as well as between the KLAT scores on the right and left legs.⁹² However, we found no other significant relationships between the other variables. See table 4.5 for more details.

Table 4.5. Pearson’s Correlations. Note *signifies significant differences between VAS and mODI; KLAT-Right and KLAT-Left.						
	VAS	mODI	ASLR-Right	ASLR-Left	KLAT-Right	KLAT-Left
VAS		r=.71 p=<0.001*	r=-0.16 p=.32	r=0.17 p=.27	r=.09 p=.56	r= -.02 p=.91
mODI	r=.71 p=<0.001*		r= -.27 p= .08	r= .11 p=.50	r= .26 p= .10	r=.06 p= .69
ASLR-Right	r= -.16 p= .32	r= -.27 p= .08		r= .15 p= .34	r= -.12 p= .47	r= .01 p= .96
ASLR-Left	r= .17 p= .27	r= .11 p= .15	r=.15 p= .34		r= -.01 p= .94	r= .05 p= .77
KLAT-Right	r= .09 p= .56	r= .26 p= .10	r= -.12 p= .47	r= -.01 p= .94		r=.88 p<0.001*
KLAT-Left	r= -.02 p= .91	r= .06 p= .69	r= .01 p= .96	r= -.05 p= .77	r=.88 p<0.001*	

Discussion

Given the prevalence and impact of LBP in a variety of populations, much research has been conducted to understand the risk factors, causes, and appropriate treatments for LBP. Research has found that movement dysfunctions, changes in posture, and trunk

instability are common in patients with chronic LBP which could be attributed to poor activation of the trunk musculature.¹⁷⁻¹⁹ The TrA, multifidus, pelvic floor muscles, and the diaphragm work synergistically to stabilize the lumbar spine, hips, and lower extremity during movement.²³⁻²⁶ Studies that investigate the recruitment patterns of these muscles have mostly been completed in the general population with chronic LBP (> 3 months).^{18,24,55,94} However, there is limited evidence on the direct relationship between the diaphragm and motor control of the lower extremity in an active population. Therefore, the purpose of this study was to examine the relationship between DB and lumbopelvic control in physically active patients with and without chronic low back pain. Additionally, this study aimed to understand the role of the diaphragm and instability of the lumbopelvic hip complex, while also understanding the potential differences that occur in an athletic population.

We recruited student athletes who were currently participating in competitive sports to further understand the role that lumbopelvic stability and breathing patterns play in patients with chronic LBP. To ensure that participants in the LBP group truly had low back pain, all participants were required to meet the requirements of LBP for at least 3 months, scored a 2 or greater on the VAS, and scored less than a 12 on the LANSS. In our sample, we found that only 2 out of 21 LBP patients were receiving rehabilitation. The remainder of these patients only received modalities when they felt that it was necessary. Some of these modalities were included but not limited to heat, ice, myofascial release, and stretching. We also used descriptive analysis to discover that the average length of time that these patients had LBP was almost 3 years (35.4 ± 28.6 months).

As expected, we found that there was a significant difference between the LBP group and healthy group in VAS and mODI scores. The average scores on the mODI, a tool that measures function and disability in patients with low back pain, was 13% for the LBP participants. The mODI guidelines states that a score of 0% to 20% is equivalent to having minimal disability and explains that the patient can “cope with most living activities without treatment”.⁸⁷ In addition, the LBP participants reported an average VAS pain score of 4.8cm on a horizontal line.

When we examined the relationship between DB and lumbopelvic control, our results showed that there was no significant difference between the correct breathers and the incorrect breathers, in regards to lumbopelvic control. In fact, we found that there were very few participants who had a non-DB breathing pattern (14%) and these non-diaphragmatic breathers were almost evenly distributed amongst the LBP (n=4) and healthy groups (n=2). The lack of significance was confirmed using a Cohen’s *d* to determine the magnitude of the difference between groups, revealing that the KLAT on the right leg had a moderate ES while the other motor control tests had small to trace effects when using the guidelines presented by Cohen.⁹³

Very few researchers have investigated the effects of breathing patterns on lumbopelvic control in active patients with low back pain. These researchers assessed subjects’ breathing at rest and during completion of the motor control tests in sedentary individuals and healthy subjects.^{31,73} Roussel³¹ and O’Sullivan⁷³ found that there was no significant difference of breathing patterns at rest between LBP patients and healthy patients. Unfortunately, the results of the current study revealed similar findings; thus explaining that the presence of LBP does not affect breathing patterns in physically active

patients. Interestingly, Roussel and O'Sullivan did find that there were significantly more abnormal breathing patterns detected during completion of the motor control tests for the LBP patients when compared to healthy subjects.^{31,41,73} Although these differences were not related to severity of pain, they further explained that motor control exercises that challenge trunk stability also challenges the diaphragm to function efficiently.³¹ This lack of diaphragmatic function during motor control tests may signify that the neuromuscular system is struggling to control the load of the lumbopelvic region.⁷³

We did not assess breathing patterns during the motor control tests, a limitation of the current study. However, future research may need to assess breathing patterns during the lumbopelvic control testing for more results. We would also like to point out that there are very limited breathing assessment tools established today. To our knowledge, only two have been identified: HLBA and the Manual Assessment of Respiratory Movement (MARM). The MARM also assesses movement of the ribcage and was found to correctly identify simulated abdominal and thoracic breathing patterns in both expert and novice clinicians.³⁹ The MARM was the most recommended by these clinicians for its ease of use³⁹; however, necessary information regarding proper procedures of the MARM were not provided in the research that established its use. In addition, the MARM has not been used in the majority of the literature that has investigated this question; thus we used HLBA. It is imperative that other breathing assessment tools be established to determine the gold standard for clinical practice rather than lab-based tools that evaluate additional components of breathing.

Another possible reason for the lack of differences in the current study, in regards to

motor control tests, could be that our sample of athletes only had minimal disability and were able to breathe correctly while maintaining lumbopelvic stability during motor control tasks, regardless of pain levels and duration of pain. All athletes recruited continued to participate in sports and were given full clearance from an allied health professional without the need for rehabilitation. Our athletic sample had low disability scores and may have used adaptive coping mechanisms for their LBP. These differences in aberrant breathing patterns or losses in motor control may be seen in individuals with greater levels of disability or who have acute low back pain, rather than patients with low levels of disability. When considering reasons of coping for chronic LBP, some research states that adaptive copers are those with less pain severity, slight limitation with daily activities because of pain, higher activity levels, and less distress.⁹⁵ Previous studies have investigated a variety of coping questionnaire tools that help determine coping strategies that patients may utilize.⁹⁵⁻⁹⁷ Perhaps our sample of participants with chronic LBP were able to develop adaptive coping mechanisms for using the trunk stabilizing musculature, regardless moderate levels of pain, which may be why we did not find any significant results. Future studies may have to recruit athletes with greater levels of disability in order to obtain variances between populations. In addition, more research should be conducted in this specific population and who are still able to participate in sports regardless of pain, to determine different outcomes.

We also found that there are no significant differences between lumbopelvic motor control scores (ASLR and KLAT) in the LBP group and healthy group. The ES were found to be small or trace and therefore, no clinical effect was found. Previous research has also found no significant differences between LBP and healthy participants in regards

to KLAT.³¹ This study did however, find significant differences between groups when utilizing the bent knee fall out (BKFO). An additional test that was used as an indicator of pelvic control and to identify history of LBP is the standing bow (SB).³² We chose two motor control tests that are used to evaluate the transference of loads unilaterally between the lumbopelvic region and the lower extremity while also stabilizing the lumbar spine during movement.^{38,41} These tests have been proven to be valid and reliable measures of lumbopelvic control in healthy patients, pregnant women, and dancers when used with a pressure biofeedback unit.^{31,32,37,41,90} Maybe using the BKFO and SB would provide more significant differences between groups. However, the KLAT is still considered a reliable and valid test and has been proven to have better reliability (ICC >0.85) than ASLR based on previous research.³² The ASLR may be too simple or have its own limitations. Replacing the ASLR with a functional test that is more reliable may be necessary.

Interestingly, the VAS and mODI were significantly related to each other. Previous research has also found relationships between pain and disability in patients with chronic LBP.⁹⁸⁻¹⁰¹ Kovacs^{98,99} found correlations between these variables over a number of days. Not only were there significant differences at baseline, but there was also an increase in significant differences over the course of 60 days.⁹⁸ It has been well established in literature that pain and disability have virtually a positive correlation.^{98,99,101} In addition, we found a relationship between the KLAT scores on the right and left legs. Unfortunately, this did not occur for the ASLR, nor did we find significant relationships between ASLR and KLAT even though they are both measures of lumbopelvic control. This might confirm one of the limitations of the study that these motor control tests may

not be difficult enough to detect differences in groups based on high level of activity these athletes perform on a regular basis. These physically active patients have overcome disability and have learned to tolerate pain at varying levels, while still maintaining high athletic participation despite length of chronic LBP (35.4 months). Future studies may consider investigating LBP and lumbopelvic control in patients with more moderate to severe levels of LBP to determine differences and may also want to consider how they assess lumbopelvic control and DB.

Limitations

There are limitations of this study that should be addressed in future research. First, the sample size may have been a limiting factor, such that there were not enough participants to obtain statistical significance, especially when determining the number of correct DB and incorrect DB. Also, the motor control tests may not have been challenging enough for the participants because they were physically active. Although the motor control tests utilized in this study were proven valid and reliable measures of lumbopelvic control in healthy subjects, pregnant women, and dancers, they may have limited applicability to patients with low levels of disability. Further research could incorporate other motor control tests as well as assessing changes in breathing patterns during these tests as other researchers have done to obtain significant differences. There is also very limited research on techniques used to determine DB. If there were more studies that investigated assessment techniques of DB, this could help future research in using the gold standard to assess DB clinically. Lastly, we investigated DB and lumbopelvic control in patients with chronic LBP; future research should consider using patients with acute and/or more severe levels of pain.

Conclusions

Previous research has investigated the role of the trunk stabilizers, as well as the diaphragm, in patients with chronic LBP, but there is limited research regarding DB and lumbopelvic control in physically active patients. Future studies may want to focus on sports with similar demands in order to determine significance. The results of this study suggest that athletes with chronic LBP (regardless of sport activity) do not have altered breathing patterns and both groups had similar levels of performance with the motor control tests. Continued results of this study revealed that pain and disability are related and therefore, implicate that physically active patients with moderate levels of LBP, are still able to function at high levels of activity. We encourage clinicians to expand their knowledge on DB, as previous research has revealed that it does play a role in trunk stability. However, more research is necessary to examine its relationship on physically active patients. Furthermore, we find that it's very important for researchers to investigate other motor control tests that may challenge an active patient to execute the trunk stabilizers while also observing different breathing patterns utilized during these tests.

APPENDIX A

Demographics Questionnaire

To be completed by participant as an initial screening prior to start of first session.

Today's date: _____

<u>Height:</u>	<u>Weight:</u>	<u>Sport Activity:</u>	<u>Gender:</u>	<u>Age:</u>
-----------------------	-----------------------	-------------------------------	-----------------------	--------------------

1. Are you currently experiencing and/or do you have a history of low back pain?
a. If No, please skip to #4.

Yes No

2. Were you diagnosed by an allied health care professional (physician, physical therapist, athletic trainer, nurse, occupational therapist, chiropractor, etc)?

Yes No

- By whom: _____
- What was the exact diagnosis given by the allied health care professional?
Please explain. _____

3. Have you had low back pain for at least 3 months? If yes, please explain.

Yes No

- Describe (length) _____
- Have you been cleared by a physician to participate in physical activity on behalf of your low back pain? Yes No

4. Have you ever had surgery? (knees, ankles, rib cage, or back/spine)?

Yes No

- If YES,
Which side (left or right)? _____
When (at least 6 months ago)? _____
What type(s) of surgery did you have? _____

5. Have you been cleared by a physician to begin all physical activity from surgery or any other orthopedic injuries? Yes No

6. Do you have a history of systemic disease, spinal surgery, spinal or pelvic fracture, history of hypertension, coronary artery disease, neuromuscular disease, rib fracture, history of respiratory disease, referred leg pain, radicular symptoms, or neuropathic pain resulting from any injury?

Yes No

- Neuropathic pain is defined as pain that is derived from tissues of the peripheral or central nervous system that includes the following: compressive radiculopathy, non-compressive radiculopathy, neurogenic claudication, and/or central pain.

7. Are you involved in competitive sports? Yes No

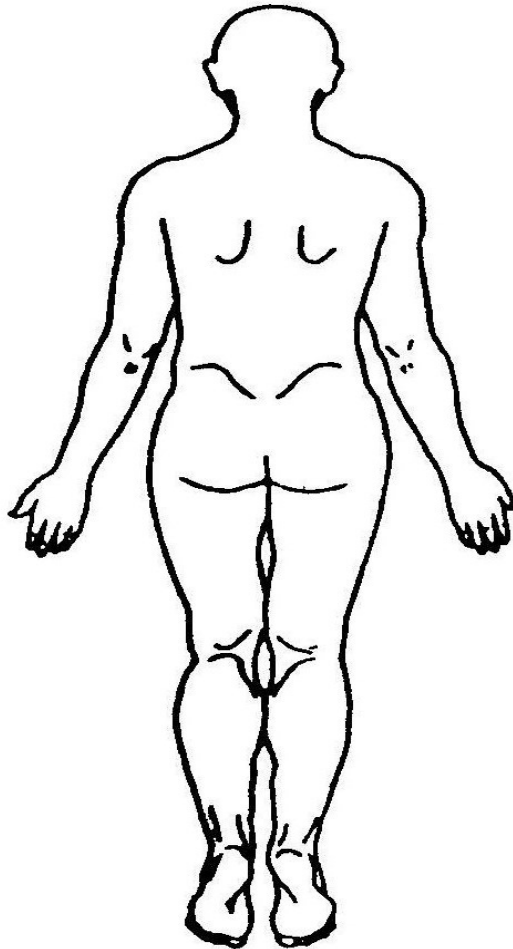
- Competitive sports are defined as sports that are sponsored by a club sports and/or intercollegiate athletics at a college or university and who has regular practices and competitions during a competitive season.

APPENDIX B

On this line below, please mark a vertical line indicating your level of pain over the past week.

No pain _____ Extreme Pain

On the diagram below, please indicate where you experience the highest level of pain on the low back. If you have more than one painful area, please use an “X” for highest level pain and an “O” other areas of pain that are not extreme.



APPENDIX C

The Modified Oswestry Low Back Pain Disability Questionnaire

The Modified Oswestry Low Back Pain Disability Questionnaire will be used to assess patients with low back pain by determining its impact on the activities of daily living.

Questionnaire description:

- 10 sections describing the pain and its impact
- Please choose a number from 0 to 5. Higher values indicating more severe impact.

Section 1: Pain Intensity

- I can tolerate the pain I have without having to use pain killers. [0 points]
- The pain is bad but I manage without taking pain killers..... [1 point]
- Pain killers give complete relief from pain. [2 points]
- Pain killers give moderate relief from pain. [3 points]
- Pain killers give very little relief from pain..... [4 points]
- Pain killers have no effect on the pain and I do not use them. [5 points]

Section 2: Personal Care

- I can look after myself normally without causing extra pain. [0 points]
- I can look after myself normally but it causes extra pain. [1 point]
- It is painful to look after myself and I am slow and careful..... [2 points]
- I need some help but manage most of my personal care..... [3 points]
- I need help every day in most aspects of self-care. [4 points]
- I do not get dressed/wash with difficulty and stay in bed. [5 points]

Section 3: Lifting

- I can lift heavy weights without extra pain. [0 points]
- I can lift heavy weights but it gives extra pain. [1 point]
- Pain prevents me from lifting heavy weights off the floor but I can manage if they are conveniently positioned for example on a table..... [2 points]
- Pain prevents me from lifting heavy weights but I can manage light to medium weights if they are conveniently positioned..... [3 points]
- I can lift only very light weights..... [4 points]
- I cannot lift or carry anything at all. [5 points]

Section 4: Walking

- Pain does not prevent me walking any distance. [0 points]
- Pain prevents me walking more than 1 mile.[1 point]
- Pain prevents me walking more than 0.5 miles..... [2 points]
- Pain prevents me walking more than 0.25 miles..... [3 points]
- I can only walk using a stick or crutches..... [4 points]
- I am in bed most of the time and have to crawl to the toilet. [5 points]

Section 5: Sitting

- I can sit in any chair as long as I like. [0 points]
- I can only sit in my favorite chair as long as I like.....[1 point]
- Pain prevents me sitting more than 1 hour. [2 points]
- Pain prevents me from sitting more than 0.5 hours. [3 points]
- Pain prevents me from sitting more than 10 minutes. [4 points]
- Pain prevents me from sitting at all. [5 points]

Section 6: Standing

- I can stand as long as I want without extra pain..... [0 points]
- I can stand as long as I want but it gives me extra pain.[1 point]
- Pain prevents me from standing for more than 1 hour [2 points]
- Pain prevents me from standing for more than 30 minutes..... [3 points]
- Pain prevents me from standing for more than 10 minutes..... [4 points]
- Pain prevents me from standing at all. [5 points]

Section 7: Sleeping

- Pain does not prevent me from sleeping well..... [0 points]
- I can sleep well only by using tablets.....[1 point]
- Even when I take tablets I have less than 6 hours sleep. [2 points]
- Even when I take tablets I have less than 4 hours sleep. [3 points]
- Even when I take tablets I have less than 2 hours of sleep..... [4 points]
- Pain prevents me from sleeping at all..... [5 points]

Section 8: Social Life

- My social life is normal and gives me no extra pain. [0 points]
- My social life is normal but increases the degree of pain.[1 point]
- Pain has no significant effect on my social life apart from limiting my more energetic interests such as dancing. [2 points]
- Pain has restricted my social life and I do not go out as often. [3 points]
- Pain has restricted my social life to my home..... [4 points]

- I have no social life because of pain..... [5 points]

Section 9: Traveling

- I can travel anywhere without extra pain. [0 points]
- I can travel anywhere but it gives me extra pain.[1 point]
- Pain is bad but I manage journeys over 2 hours. [2 points]
- Pain restricts me to journeys of less than 1 hour. [3 points]
- Pain restricts me to short necessary journeys under 30 minutes. [4 points]
- Pain prevents me from traveling except to the doctor or hospital. [5 points]

Section 10: Employment/Homemaking

- My normal homemaking/job activities do not cause pain..... [0 points]
- My normal homemaking/job activities increase my pain, but I can still perform all that is required of me[1 point]
- I can perform most of my homemaking/job duties, but pain prevents me from performing more physically stressful activities (e.g., lifting, vacuuming).[2 points]
- Pain prevents me from doing anything but light. [3 points]
- Pain prevents me from doing even light duties [4 points]
- Pain prevents me from performing any job or homemaking chores [5 points]

 Total score = SUM _____(points for all 10 sections)

Disability in percent = (total score) / 50 * 100= _____

If not all of the questions are answered then disability in percent = (total score) / (5 * (number of questions answered)) * 100= _____

Interpretation:

- 0% to 20%: minimal disability: The patient can cope with most living activities. Usually no treatment is indicated apart from advice on lifting sitting and exercise.
- 21%-40%: moderate disability: The patient experiences more pain and difficulty with sitting, lifting, and standing. Travel and social life are more difficult and they may be disabled from work. Personal care, sexual activity, and sleeping are not grossly affected and the patient can usually be managed by conservative means.
- 41%-60%: severe disability: Pain remains the main problem in this group but activities of daily living are affected. These patients require a detailed investigation.
- 61%-80%: crippled: Back pain impinges on all aspects of the patient's life. Positive intervention is required.
- 81%-100%: These patients are either bed-bound or exaggerating their symptoms.

APPENDIX D

THE LANSS PAIN SCALE

Leeds Assessment of Neuropathic Symptoms and Signs

This pain scale can help to determine whether the nerves that are carrying your pain signals are working normally or not. It is important to find this out in case different treatments are needed to control your pain.

A. PAIN QUESTIONNAIRE

Think about how your pain has felt over the last week.

Please say whether any of the descriptions match your pain exactly.

1) Does your pain feel like strange, unpleasant sensations in your skin? Words like pricking, tingling, pins and needles might describe these sensations.

a). NO - My pain doesn't really feel like this (0)

b). YES - I get these sensations quite a lot (5)

2) Does your pain make the skin in the painful area look different from normal? Words like mottled or looking more red or pink might describe the appearance.

a). NO - My pain doesn't affect the color of my skin (0)

b). YES - I've noticed that the pain does make my skin look different from normal..... (5)

3) Does your pain make the affected skin abnormally sensitive to touch? Getting unpleasant sensations when lightly stroking the skin, or getting pain when wearing tight clothes might describe the abnormal sensitivity.

a). NO - My pain doesn't make my skin abnormally sensitive in that area
..... (0)

b). YES - My skin seems abnormally sensitive to touch in that area
..... (3)

4) Does your pain come on suddenly and in bursts for no apparent reason when you're still? Words like electric shocks, jumping and bursting describe these sensations.

a). NO - My pain doesn't really feel like this (0)

b). YES - I get these sensations quite a lot (2)

- 5) Does your pain feel as if the skin temperature in the painful area has changed abnormally? Words like hot and burning describe these sensations
- a). NO - I don't really get these sensations (0)
 - b). YES - I get these sensations quite a lot..... (1)

B. SENSORY TESTING

Skin sensitivity can be examined by comparing the painful area with a contralateral or adjacent non-painful area for the presence of allodynia and an altered pin-prick.

1) ALLODYNIA

Examine the response to lightly stroking cotton tip applicator across the non-painful area and then the painful area. If normal sensations are experienced in the non-painful site, but pain or unpleasant sensations (tingling, nausea) are experienced in the painful area when stroking, allodynia is present.

- a) NO, normal sensation in both areas (0)
- b) YES, allodynia in painful area only (5)

2) ALTERED PINPRICK

Determine the pin-prick threshold by comparing the response of the Medipin by placing it gently on to the skin in a non-painful and then painful areas.

If a sharp pin prick is felt in the non-painful area, but a different sensation is experienced in the painful area e.g. none / blunt only (raised pin prick) or a very painful sensation (lowered pin prick), an altered pin prick is present.

- a). NO, equal sensation in both areas (0)
- b). YES, altered PPT in painful area (3)

SCORING:

Add values in parentheses for sensory description and examination findings to obtain overall score.

TOTAL SCORE (maximum 24).....

If score < 12, neuropathic mechanisms are **unlikely** to be contributing to the patient's pain

If score > 12, neuropathic mechanisms are **likely** to be contributing to the patient's pain

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