Arab American University
Faculty of Graduate Studies
Department of Health Sciences
Master Program in Computed Tomography and MRI Sciences

Exploring Gender-Specific Correlations: Clinical Features and Magnetic Resonance Imaging Findings in Lumbar Disc Prolapse

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This Thesis Was Submitted in Partial Fulfillment of the Requirements for the Master Degree in Computed Tomography and MRI Sciences.

Palestine, 2/2025

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Thesis Approval

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Declaration

I certify that, unless otherwise noted, the results of my research are reflected in this master's thesis, which I am submitting to receive a degree. In addition, I attest that I have never submitted this thesis for consideration for an advanced degree at any other academic institution.

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Date of Submitting the Final Version of the Thesis**:** 16/4/2025

Dedication

In this thesis, I want to first thank my parents for their endless support and encouragement which has shaped the person I am today, for it is their unwavering belief in me and their sacrifices that have motivated me to put my best foot forward. Moreover, I embrace my professors, mentors, and teachers, as a great respect goes to them due to the extensive research they have done and the sharp guidance they have given me throughout my studies, helping me grow as an academic. As I want to delve into this specific field, I am truly appreciative of all the qualities my mentors have embedded within me, as curiosity and rigor are extremely crucial elements when it comes to building a meaningful scholarly career.

One of my happiest moments is when I feel supported by my colleagues and friends. I appreciate their kindness, assistance, and patience. Thanks to their being. And finally, I do wish to dedicate this work to everybody who has had a part of my academic story as well whether actively or passively. For the words of support, criticism, and together teaching processes you all are significant to this thesis conclusion. This act of dedication is corroborative of the work done by many people to encourage and support me until, now when I have completed an important step in my academic processes.

Mousa Mahmoud Mohammad Shaheen

Acknowledgments

I would first like to thank my academic supervisor, Dr. Mohammad Al-Jamal for his guidance, suggestions, and assistance during this research. His professional contribution has played a critical role to develop and finalize this thesis. My appreciation goes to Arab American University and its staff for availing the tools, infrastructures, and learning climate for this study. Their commitment to nurturing a culture of learning and research has significantly improved my scholarly experience.

I wish to express my special gratitude to my parents for their love, tolerance, and encouragement. Their faith in my potential has been a source of motivation and strength during all phases of my education. I turn my attention to the wider academic audience, who have written relevant research papers, the knowledge available forms the basis of this thesis. I extend my deepest appreciation to all, who have contributed directly or indirectly to this work by rendering me support in one form or the other. I owe this thesis to countless contributions of various people in terms of assistance, direction, and motivation and I owe my immense appreciation for each such contribution.

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Abstract

Introduction

Low back pain is one of the most common issues experienced by people worldwide, often caused by lumbar disc prolapse. To effectively diagnose and treat this condition, it's essential to understand the relationship between demographics, such as age and gender, and any abnormalities in the lumbar spine. Magnetic Resonance Imaging (MRI) is considered the gold standard for diagnosing lumbar disc prolapse because it provides superior images of spinal structures with greater detail than other imaging modalities.

Purpose

This study aims to evaluate the relationship between gender and age with lumbar disc prolapse, along with its clinical and imaging characteristics. Additionally, the research assesses how the use of MRI with and without contrast media affects the sensitivity and specificity in identifying abnormalities in the lumbar spine.

Methods

This study conducted a retrospective analysis involving 303 patients diagnosed with Lumbar Disc Prolapse (LDP). Data on demographics, clinical characteristics, and MRI findings were obtained from the Patients records database. Statistical tests were performed on these datasets to identify statistically significant associations between demographic factors, pain characteristics, and imaging results. Additionally, the study evaluated the role of contrast-enhanced MRI in diagnosing spinal pathologies.

Results

Most participants were aged 40–59 years (50.8%) MRI findings showed herniated discs (100%), degenerative disc disease (54.1%), and spinal stenosis (27.1%) as the most common pathologies. Females were more likely to experience chronic LBP, while males reported subacute pain. Gender differences were noted in lumbar scoliosis and bone abnormalities, including spurs. Contrast-enhanced was useful for detecting lesions in post operative patients.

Conclusion

The study highlights significant gender disparities in the clinical presentation and occurrence of lumbar spine anomalies. While age-related changes were less pronounced, elderly patients from 65years and older showed more severe degeneration in imaging. MRI remains the primary method for assessing lumbar disc issues, providing detailed visualization. Recognizing the interplay between demographic factors and imaging criteria is essential for developing effective diagnostic strategies.

Keywords: Prolapse, Herniation, Aging, Degeneration, Imaging.

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List of Definitions of Abbreviations

Abbreviation	Title
AAUP	Arab American University Palestine
AF	Annulus Fibrosus
AS	Ankylosing Spondylitis
CLBP	Chronic Low Back Pain
CMRI	Coronal magnetic Resonance Imaging
CSF	Cerebral Spinal Fluid
CT	Computed Tomography
DD	Degenerative Disc
DDD	Degenerative Disc Disease
DLS	Degenerative lumbar scoliosis
DN4	Douleur Neuropathique four Questions
DTI	Diffusion tensor Imaging
DWI	Diffusion-weighted Image
FJOA	Facet Joint Osteoarthritis
FOV	Field of View
IVD	Intervertebral Disc
LBP	Low Back Pain
LDD	Lumbar Disc Degeneration

LDH	Lumbar Disc Herniated
LDP	Lumbar Disc Prolapse
LMM	Lumbar Multifidus Muscle
LSS	Lumbar Spinal Stenosis
MRI	Magnetic Resonance Imaging
MSLDH	Multi-Segment Lumbar Disc Herniation
NP	Nucleus Pulposus
ODI	Oswestry Disability Index
PD	Proton Density
PPV	Positive Predictive Value
SLR	Straight Leg Raise
SNR	Signal-to-Noise Ratio
SPAIR	Spectral Attenuated Inversion Recovery
SPSS	Statistical Package for the Social Sciences
T1W	T1 Weighted Image
T2W	T2 Weighted Image
TE	Time to Echo
TI	Inversion Time
TIRM	Turbo Inversion Recovery Magnitude
TR	Repetition Time

TSE	Turbo Spin Echo

Chapter One: Introduction

1.1 Background

Up to two-thirds of adults will experience low back pain at some point in their lives. The disability caused by back pain leads to considerable economic impact due to the use of healthcare resources (Uruj et al., 2017)

Low back pain that is associated with degenerative disc diseases ordinarily affects people in the ages between young adulthood and middle-aged people with a higher prevalence at 40 years. It includes abnormalities such as disc herniation, disc bulges, decreased disc height, disc dehydration, and other related conditions (Rigoard et al., 2018). While in chronic disease patients, there are more frequent recounts of disc degeneration on imaging studies, it is worth knowing that not all persons with disc degeneration necessarily feel pain. Also, low back pain arising from degenerative disc diseases has a higher incidence and prevalence among male patients and not female patients (Brinjikji et al., 2015).

Low back pain (LBP) is a frequent cause of reduced activity and disability. Although LBP is a nonspecific symptom, it's important to diagnose it accurately to rule out serious underlying conditions such as infections, cancers, fractures, or degenerative diseases (Jarvik et al., 2002). LBP is often attributed to several structures, including intervertebral discs, facet joints, vertebral bodies, nerves, and spine muscles (Uruj et al., 2017).

LBP is, for the most part, associated with the disintegration of the spinal motion segment. It is suspected that this process starts in the intervertebral disc, followed by the facet joint. Disc degeneration is a normal process in a human's life and people usually do not notice it but when pain occurs in the lower back it can be severe (Li et al., 2011), Recently, there has been an increased focus on the endplate as a possible source of low back pain (LBP), due to its higher levels of blood vessels and nerves compared to the disc (Singh et al., 2020).

Apart from low back pain, which is common in all disc degeneration patients, sciatica is the other leading symptom. This painful condition usually involves one side of the body and is characterized by sharp and electric-like pain. There can also be mild paresthesia and dull, boring, or burning discomfort and pain may refer to the calf or heel of the foot. In sciatica, the pain increases with laying, walking, bending, straining, or coughing and, in extreme cases, it is crippling (Robert al., 2006).

Based on the assessed douleur neuropathique four questions (DN4) scores, the patient with lumbar disc degeneration reported sensory disturbances in the legs, claudication, and pain relief when bending forward. Possible predisposing factors to lumbar disc degeneration include age, smoking history, obesity, previous trauma, occupation in which the worker is required to lift heavy weights, height, family history and performs heavy tasks such as operating machines, carpenters, office workers (Nojiri et al., 2016).

Plain X-rays have been used to assess degenerative disc disease for a long time, and they are the first imaging modality of choice in suspected cases. However, these radiographs only suggest an idea of the status of the condition, and these include disk space narrowing, changes in the end plates, spondylophytes, and sclerosis (Majumdar et al., 2011). They may also indicate related conditions such as anterolisthesis and retrolisthesis, the sign of degenerative disk disease. Plain X-rays are not very useful for looking at early changes in the disease as well as the degree of disk degeneration because of disk protrusions, bulges, or herniations.

Previously, computed tomography (CT) scan was the only means of diagnosing patients with suspected lumbar prolapsed intervertebral disk disease, young patients in particular, but has largely been replaced by magnetic resonance imaging (MRI). CT scans use ionizing radiation and the contrast between the soft tissues is not as good as MRI hence it does not well describe the disk relative to other tissues. Nevertheless, there is merit in using CT because the modality helps in identifying posterior osteophytes, critical for operative planning (Carragee et al., 2006).

Despite discography or CT discography increasing the chance for optimal results from the surgical part, these diagnostic methods are highly invasive and present a

relatively high degree of false-positive reactions; however, many severely degenerated disks are not painful. It is recognized that patients undergoing lumbar spine radiography commonly demonstrate abnormalities while provocative discography is used to define the painful disk (Majumdar et al., 2011). The basic concept of this method presides in the fact that the degenerated disks may form nerves that are sensitive to pain, and which can be triggered and influenced by injecting and applying pressure on the disk.

The reproduction of a patient's routine pain when applying tests is meant to suggest the fact that the pain stems from that certain disk level. This information may in turn help surgeons in determining at which levels surgery is necessary. However, the test is painful as well as subjective and always difficult to interpret in chronic pain patients. Even further, fine needles (22 gauge and 25 gauge) were used for disk injections and yet there is indication of a heightened rate of late symptomatic degeneration to normal intervertebral disks than to the non-discogram ones, 35% after discography and 14% of non-discogram disks (Majumdar et al., 2011).

MRI is the preferred imaging technique for identifying disc pathology because it offers several advantages: It has no radiation, provides images in the various planes, exhibits better contrast in spinal soft tissues, and identifies the changes in the intervertebral discs (Kepler et al., 2013). Presently, MRI scans are widely used for the diagnostic process, which allows the detection of the height and the morphology of disks.

Using T1 and T2 weighted MRI, changes in the structure of the disk are possible. Normally, a decrease in T2-weighted signal is associated with an increase in lumbar disk degeneration. Intervertebral disks in patients without back pain also show different signal intensities: from the nucleus pulposus the signal intensity should be high and oval, and from the annulus fibrosus. In contrast, degenerative disks show alterations to the signal of the nucleus pulposus; this provides an interrupted margin with reduced signal intensity as seen on the longer T2 weight and proton density sequences (Shraim et al., 2021).

Different from other imaging technologies, MRI gives information about structural and biochemical changes in the intervertebral disc while bearing no risk to the patient. For that reason, MRI is applied to assess early signs of degenerative disc disease (DD). A

decrease in signal intensity of the nucleus pulposus means that of the water content and the degree of DD, it represents. Structural changes of discs are associated with clinical LBP, still, 80% of asymptomatic adults show disc alterations on MRI lumbar region. There is still a great deal to learn about the long-term consequences as well as the prognosis for the early stage of the disease (Andersson et al., 1999; Kadow et al., 2014).

Disc bulges and disc protrusions are other forms of the disease that are often to blame for the back pain and, therefore, are treated with drugs and operations. However, the literature demonstrates that imaging findings of spinal degenerative changes related to backache are present in both symptomatic and asymptomatic populations, thus undermining the value of MRI evidence in defining patients with such a condition (Kepler et al., 2013).

1.2 Problem Statement

LBP is a complaint classified under the musculoskeletal system and is experienced by persons of all ages and genders. Disc herniation, disc protrusion, disc bulge, and disc degeneration included in the definition of lumbar disc disease are quite often related to LBP. Therefore, further investigation into the correlation between age, gender, and the magnitude of these changes in disc prolapse remains limited to research and clinical interest (Öncü et al., 2020).

Magnetic Resonance Imaging (MRI) is considered essentially the gold standard in diagnosing lumbar disc prolapse because it gives superior images of structures in the spine to a much greater level of detail than other modalities and without ionizing radiation. MRI shows an undeniably perfect visualization of intervertebral discs, the spinal cord and its nerve roots, and surrounding soft tissues necessary for the identification of the presence and degree of disc prolapse (Öncü et al., 2020). While other modalities like X-ray and CT cannot visualize such subtle degenerative changes, an MRI can distinguish between different types of discs pathologies, herniation, bulge, and protrusion.

The multiplanar capability of MRI allows perfect examination of the lumbar spine, whereby the exact location of disc prolapse, and related neural compressions can be determined (Zhang et al., 2016). Its high sensitivity and specificity in diagnosing lumbar disc prolapse make MRI an asset for guiding clinical decisions on treatment plans, thus improving patient outcomes, with all these advantages, MRI has continued to emerge as the method of choice for imaging in the evaluation of lumbar disc prolapse in clinical practice.

It is a well-established fact that vertebral pathology including lumbar disc prolapse is closely related to age as well as gender. It has been found that the incidence of disc degeneration and other spinal abnormalities rises with age and that the incidence varies with sex and the kind and severity of the pathology (Brinjikji et al., 2015; Mohan et al., 2019).

For instance, men suffer from disc degeneration and spondylolysis more frequently than women; at the same time, women are more prone to develop scoliosis and chronic pain (Mohan et al., 2019). These studies provide significant evidence of associations, but to date, no research exists regarding the potential links between vertebral pathologies detected through MRI and LBP in the Palestinian population. This failure to focus on localization is a major setback to the formulation of diagnosis and treatment profiles likely to address the demographic status of this region.

Several research have been conducted, and still, little evidence is understood about the correlation between age and gender on the occurrence of lumbar disc prolapse (Öncü et al., 2020). Such lack of knowledge makes it difficult to design prevention and treatment measures to fit such diseases. Therefore, the present research proposes to examine the role of MRI to determine the correlation between lumbar disc prolapse and age and gender in patients with LBP in Palestine. Thus, this research aims at identifying patterns and relationships by analyzing MRI data to enhance learning, diagnosis, and patient care.

1.3 Aims and Objectives

The purpose of this retrospective study aims to evaluate the effect of age and gender on the incidence and features of lumbar disc prolapse in patients with LBP based on MRI imaging.

This study is focused on expanding the understanding of lumbar spine disc pathology which has been examined through MRI with specific focus on the accuracy and the potential relationships with aspects like gender and age. The first objective of the study is to investigate and explore whether and how gender is related to the types of lumbar spine disc pathology.

Some studies show that gender may play a part in the amount and types of lumbar disc pathologies that one suffers from certain degenerative disc diseases seem to be more prevalent among women than men and vice-versa. Understanding these gender-based differences, this specific objective will give an idea of gender effects on clinical and treatment outcomes of conditions affecting the lumbar spine.

The second objective of the study was to explore whether there is a relationship between age and types of lumbar spine disc pathology. Understanding age as a variable, the current study can target a more specific population where certain litters show a trend on developing similar types of lumbar disc pathologies. According to arthritic literature, disc degeneration is shown to be more prevalent with age, which may indicate a need for tailored diagnostic reference standards based on the age of the population.

Evaluate the features of the accuracy and reliability of MRI concerning differential diagnosis of lumbar disc diseases. MRI appears the modality of choice in assessing the diseases of the lumbar region, where T2, STIR, and other advanced sequences have high sensitivity and specificity. The other objective was to evaluate the sensitivity of MRI in detecting different categories of lumbar disc pathology, taking into consideration factors concerning image quality and consistency of sequence selection and interpretation. Through these objectives, strengthen the understanding of the role of MRI as a tool for lumbar spine diagnostics and provide an understanding of demographic changes that affect the types of pathology seen.

1.4 Hypothesis of Research

It is hypothesized that respect demographic factors, for example, gender and age, are significantly associated with the types of lumbar spine disc pathology, as with the efficacy of MRI in the diagnosis. More specifically, it indicates that women suffer from different clinical manifestation of the disease than men, which is the cause of different prevalence and types of disc pathologies. At the same time, it posits that older age is firmly correlated with severity and types of lumbar spine disc pathology, with the older age demographic being characterized to a higher extent by degenerative changes.

1.5 Questions of the Research

- Are there any differences in lumbar disc prolapse MRI findings between male and female patients, such as disc herniation size or nerve compression severity?
- Are there specific MRI findings that are more prevalent in certain age groups or genders among patients with low back pain?
- How efficient is MRI imaging in screening and diagnosing lumbar disc prolapse?

1.6 Outline

Chapter (1): Introduction.
Chapter (2): literature review
Chapter (3): Methodology of the research.
Chapter (4): The results.
Chapter (5): The discussion & and conclusion.

Chapter Two: Literature Review

2.1 Introduction

In this chapter, several topics related to this investigation will be explored, including the anatomy of the lumbar spine, types of pathology, diagnosis, screening for lumbar spine MRI and importance in detection lumbar spine pathologies. The following sections draw upon previous studies, presenting summary findings from prior research of related subjects.

Published research from PubMed, websites of international organizations, Google Scholar, and textbooks was utilized as part of the study's search strategy.

2.2 Theoretical Frameworks

2.2.1 Lumbar Spine Anatomy

The lumbar spine comprises five vertebrae indicated as L1 through L5, which is a critical part of the vertebral column both in terms of structural support and flexibility. Each lumbar vertebra has a kidney-shaped body for bearing heavyweight to support the mass of the upper body (Sullivan et al., 2021).

The spinal canal has the vertebral arch made up of pedicles and laminae enclosing it thereby protecting the nerve roots and spinal cord. The spinous processes and transverse processes arise from the vertebral arch acting as the muscles' attachment point facilitating motion besides giving stability. Shock-absorbing intervertebral discs placed between each vertebra distribute mechanical loads hence allowing flexibility and movement. These discs have a tough external layer called annulus fibrosus surrounding a jellylike nucleus pulposus (Pillemer, 2023).

Starting from the brainstem to the lower back, the spinal cord extends to around the L1-L2 level where it terminates at conus medullaris. However, after this point, spinal nerves continue as cauda equina which looks like a horse's tail being composed of a

bunch of nerve roots. The normal curvature in the lumbar spine termed lumbar lordosis assists walking, running, or lifting with balance maintenance and absorption of mechanical stresses (Waxenbaum et al., 2020).

A plexus of nerves, the lumbar plexus, which innervates the lower limbs as well as the pelvic girdle is also present in the lumbar spine. Important nerves constituting this plexus include the femoral nerve and obturator nerve controlling muscles extending the knee joint and adducting thigh respectively. The close relationship between the lumbar region of the spinal cord and its peripheral nerves is crucial for effective motor control as well as sensory feedback (Durbas et al., 2024). This area is more vulnerable to degenerative diseases due to damage or wear on it leading to various major clinical conditions such as root compression (radiculopathy) resulting in numbness, pain, or weakness in the legs (Pillemer, 2023).

2.2.1.1 Anatomy of the Intervertebral Disc (IVD)

The IVD is a complex structure that acts as a joining interface between any two vertebrae and is comprised of cartilage and fibrous connective tissue. It provides not only limitation of motion of the torso but also stability during axial compression, rotation and bending. The intervertebral disc (IVD) comprises of three parts which are distinct in anatomy but work in harmony with each other. These parts include the nucleus pulposus (NP) surrounded by concentric layers of fibrocartilaginous annulus fibrosis and the vertebral end plates located superiorly and inferiorly to the disc (Kirnaz et al., 2021).

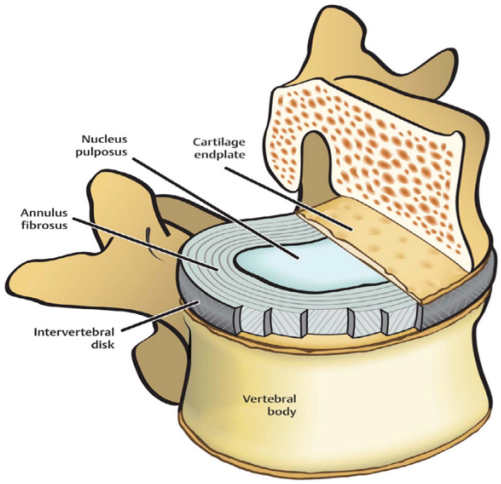

Figure 2.1: Anatomy of IVD (Kirnaz et al., 2021).

The lumbar spine's intricate structures can be visualized and studied better today through improved imaging techniques like MRI and CT scans. Consequently, the clinical outcomes have been enhanced. Various spinal disorders are diagnosed and managed with the aid of these technologies that enable detailed examination of the intervertebral discs, vertebrae as well as surrounding soft tissues. Herniated discs, spinal stenosis, and degenerative disc diseases are some of the conditions whose diagnosis and treatment will require knowledge of the lumbar spine's anatomy in detail (Cooper, 2015).

2.2.2 Common Pathologies of the Lumbar Spine

2.2.2.1 Muscle Spasms in the Lumbar Spine

Low back muscle spasms are a frequently encountered symptom which is usually in relation to certain musculoskeletal disorders like low back ache or disc disease. They are defined as involuntary muscle contractions of the paraspinals which are secondary, mostly protective, to certain physical insults to the spine or its components, (Johnson, 2012). A phenomenon called 'the spasm-pain-spasm cycle' (which describes how pain from muscle tightness causes more muscle tightness) restricts motion and enhances the chronicity of proliferation in the affected individuals, (McCarberg et al., 2011).

What is more, there is a considerable contribution by the lumbar musculature spasms in conditions such as trunk instability, disk hernia, or degenerative diseases of the spine. Spasms, serve the purpose of stabilizing limbs, but oftentimes cause limited range of motion and increased pain. Modern imaging techniques like MRI, assist in determining the anatomical factors for these spasms by showing soft tissue damage or nerve compression (Johnson, 2012). Besides, currently available guidelines state that physiotherapy, drug therapy (muscle relaxants) and physical training which can overcome the spasm-pain-effect and enhance the results are essential for the patient's well-being (McCarberg et al., 2011).

2.2.2.2 Lumbar Spine Scoliosis

Lumbar scoliosis represents spinal deformity whose defining feature is a lateral curvature of more than 10 degrees in the lumbar spine and at times associated with

rotational vertebrae deformity. This condition is reported to be either degenerative or idiopathic in nature, most of the cases being degenerative as in the case of degenerative lumbar scoliosis (DLS), which affects older adults due to an area of disc degeneration, bone arthrosis and age-related osteoporosis (Urrutia et al., 2011).

The evaluation of lumbar scoliosis has significantly benefited from developments in diagnostic imaging techniques, in this regard – MRI. MRI allows more precise evaluation of curvature and accompanying neural compression, which helps to distinguish between structural and compensatory scoliotic deformities. Depending on the degree of curvature and symptoms present, different treatment options are recommended (Wong et al., 2017). In patients with mild to moderate cases of scoliosis, the primary stay of treatment, non-operative management, includes physical therapy, bracing and medication intervention.

Figure 2.2: Lumbar scoliosis (Knipe & Gaillard, 2008).

Degenerative disc disease is a collective name for various disc conditions that result in the degeneration of the intervertebral discs which are cushions between vertebrae in

the human spine. This can be accompanied by pain, limited mobility, and other manifestations (Chen et al., 2024). The process of disc degeneration generally occurs in old age but can also be influenced by genealogy, lifestyle choices, and impact on the spinal cord

The discs are made up of two parts: an outwardly strong annulus fibrosus and a jelly-like nucleus pulposus. In due course, they become less elastic and lose water hence their capacity to absorb shock reduces over time. Consequently, small rips happen on the annulus fibrosus resulting in protrusion or herniation of the nucleus pulposus. These changes may lead to compression of close spinal nerves with subsequent pain, loss of sensation, or weakness in the affected regions (Brinjikji et al., 2015).

Chronic lower back pain characterized by radiating symptoms down to the thighs and buttocks is one of the main signs of DDD itself. Activities such as bending over, carrying heavy objects, or turning usually worsen the pain (Chen et al., 2024). Sometimes there may occur extreme sensations after which one might feel some relief afterward albeit temporarily until another episode begins all over again. Different individuals exhibit individual variations in terms of symptom severity where some only experience slight discomforts while others undergo immobility caused by severe pains (Petersen et al., 2017).

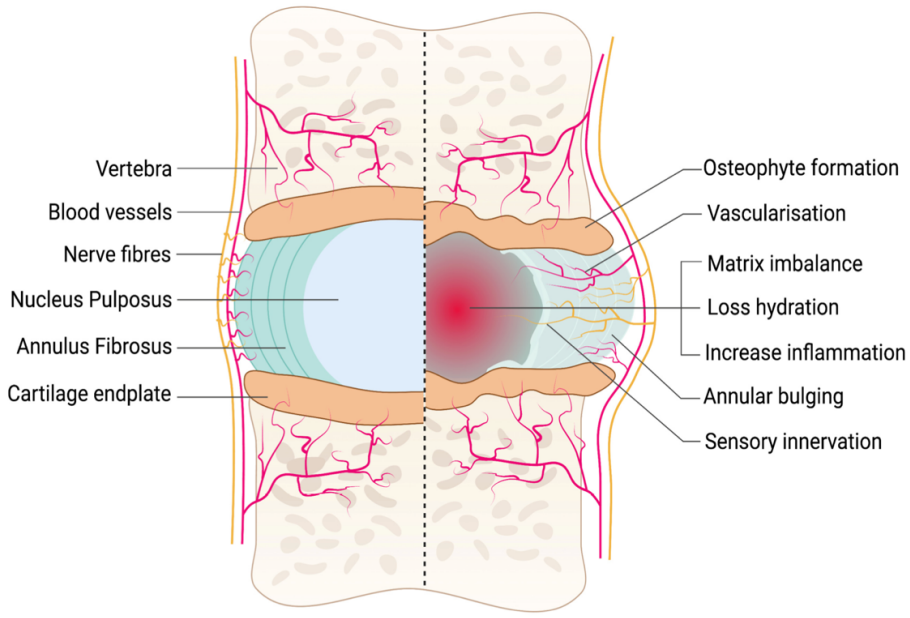

Figure 2.3: An illustration of a healthy and degenerative IVD (Mohd Isa et al., 2023).

2.2.2.3 Herniated Disc

A herniated disc is also referred to as a slipped or ruptured disc and it happens when the nucleus pulposus (the soft, gelatinous center of an intervertebral disc) protrudes out through a tear in the annulus fibrosus (the tough outer layer of the disc). This condition can cause compression of spinal nerves near it that eventually results in pain, numbness, or weakness in areas affected.

The lumbar region is most affected by herniated discs, particularly at the L4-L5 and L5-S1 levels. The most common causes are Age-related degeneration, traumatic injury, or repetitive stress on the spine. This will often be accompanied by lower back pain radiating into the legs (sciatica).

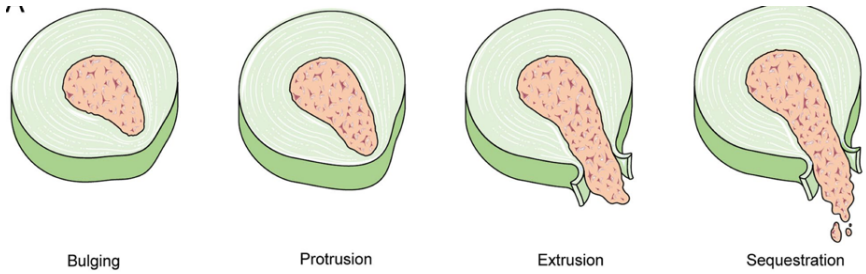

Figure 2.4: The classification of LDH includes bulge, protrusion, extrusion, and sequestration (Yu et al., 2022).

2.2.2.4 Types of Herniated Discs

2.2.2.4.1 Protrusion (Bulging Disc)

A common spinal condition is a lumbar disc protrusion. It happens when the outer annulus fibrosus of an intervertebral disk bulge outward without rupturing its inner nucleus pulposus. This may cause compression on the nerve root thereby resulting in lower back pain, sciatica, or even neurologic deficits depending on how severe and what nerves are involved. This state is frequently associated with degenerative disc disease where over a period, water content and elasticity are lost making it prone to injury (Mukhopadhaya et al., 2017).

Lumbar disc protrusion can be diagnosed better now than before due to advanced imaging modalities like magnetic resonance imaging (MRI) which shows clearly where disks are swollen, and which nerves they press against. Usually, treatment involves non-invasive methods such as physical therapy, anti-inflammatory drugs, and lifestyle changes but if symptoms worsen surgery may be performed for instance microdiscectomy that will relieve pressure off compressed nerves (Fardon et al., 2014).

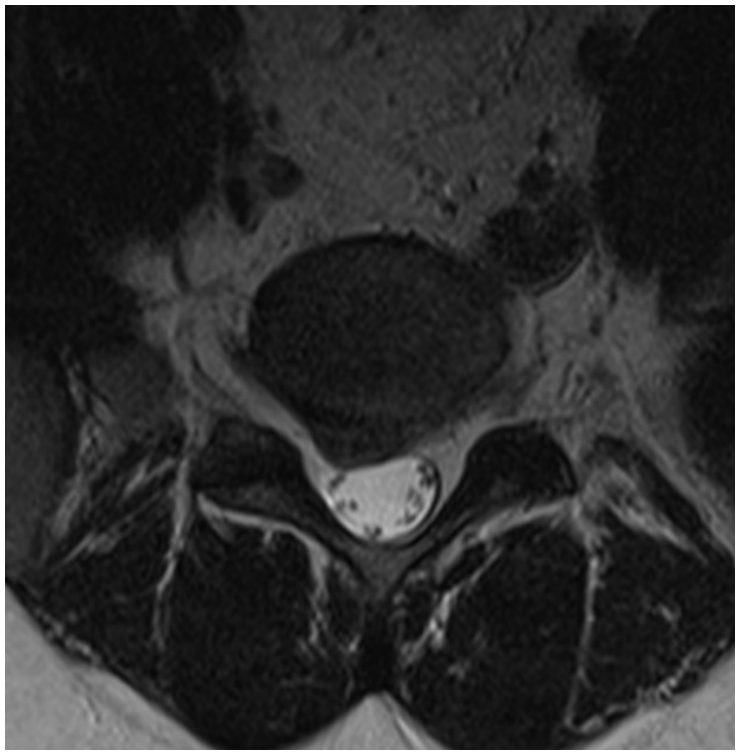

Figure 2.5: Protrusion disc (Bickle & Gaillard, 2009).

Recent research has shown that early intervention coupled with a multi-disciplinary approach should be used to prevent chronic pain and disability from happening after having lumbar disc protrusion (Shin et al., 2018).

2.2.2.4.2 Disc Extrusion

Intervertebral disc herniation in the lumbar spine has been described as a medical condition characterized by extension of the disc material outside the annulus fibrosus which may result in significant clinical symptoms and complications. This is often a consequence of degenerative disc disease or acute trauma, with the nucleus pulposus being squeezed out through a ring tear (Aransay et al., 2020). Extrusion of disk materials

can put pressure on adjoining neural structures resulting in radicular pain, motor deficits, and sensory disorders.

Figure 2.6: Extrusion disc (Patil, 2023).

Recently conducted studies have shown that advances in imaging technologies like high-resolution MRI and advanced CT myelography have enhanced diagnostic accuracy for disk extrusion and assessment of neural compression levels. Moreover, investigations have been carried out on minimally invasive surgical procedures including endoscopic discectomy which demonstrated that they are better than traditional open surgery in terms of shorter recovery periods for patients with improved results (Zhang et al., 2023).

2.2.2.4.3 Disc Sequestration

Lumbar disc sequestration is a term used to describe the condition where part of the disc separating two adjacent vertebrae breaks off and migrates into the spinal canal. This occurs mainly due to degenerated discs or herniated discs that have weakened their annulus fibrosus, thereby allowing the nucleus pulposus to escape. Radiculopathy and

sometimes cauda equina syndrome may occur if sequestered fragments put pressure on the spinal cord or nerve roots. The current studies show how the presence of sequestration complicates both diagnosis and treatment.

Figure 2.7: Sequestration disc (Mostafa El-Feky & Muzio, 2016).

A case in point is shown by Liu et al (2018) who stated that accurate diagnosis can be achieved through MRI scans since they can distinguish between a protruded disc from a sequestered one and assess compression of neural structures levels (Awadalla et al., 2023). In addition, any type of intervention strategy such as conservative management up to surgery must involve an analysis of the characteristics of sequestration as well as the present clinical symptoms.

As explained by Kim et al., (2018), while noninvasive treatments are effective for some patients, there are circumstances when surgical operations might become necessary due to severe neurological deficits or long-lasting symptoms (Kim et al., 2018). These results underscore the importance of personalized management approaches and careful monitoring for those suffering from posterior lumbar disk sequestrations.

Herniations can be described as contained or non-contained, depending on whether the displaced disc material is still within the outer annulus or not. Contained herniations like protrusions and some extrusions are less severe than non-contained ones such as sequestrations which are more likely to cause significant nerve impingement and need surgical management (Yüce et al., 2019).

2.2.2.5 Lumbar Spine Stenosis

Lumbar spinal stenosis, abbreviated as LSS, is a condition that occurs when the space around the lumbar area becomes narrow hence causing compression of the spinal cord or nerve roots. This narrowing is often caused by degeneration of structures in the spine like hypertrophy in ligamentum flavum, bulging slip disks, and osteophyte formations (Lurieet al., 2016). Generally, the disease mostly affects old people who experience neurogenic claudication which presents itself as leg pain, numbness, or weakness that worsens with walking and standing for long periods but improves when one sits or bends forward.

Diagnosis of lumbar spinal stenosis includes both clinical evaluation and imaging techniques. When it comes to assessing LSS, MRI is considered a gold-standard test due to its ability to provide high-resolution images of soft tissues, the spinal canal, and neural structures. Other imaging methods, such as computed tomography (CT) scans and X-rays, are useful for assessing bone abnormalities and the extent of degeneration present (Kreiner et al., 2013).

Figure 2.8: Spinal canal stenosis (Weerakkody & Lampner, 2018).

However, functional imaging techniques, including upright MRI, are getting more attention lately because they could give a more accurate view of how much a patient's symptoms are affected under weight-bearing conditions.

2.2.2.6 Spondylolisthesis

Lumbar spine spondylolisthesis is the displacement of a vertebra forward over the one beneath it, usually resulting in spinal pains and other neural troubles. The condition is commonly seen with degeneration, trauma, or congenital defects, typically at L4-L5 or L5-S1. There is a multifaceted relationship between biomechanical instability and degenerative changes in the lumbar disc, facet joints, and the related ligaments in the lumbar spondylolisthesis (Wang et al., 2017).

In elderly people, degenerative spondylolisthesis typically occurs due to the progressive weakening of the intervertebral disc along with facet joints leading to instability and vertebral slippages. Spinal stenosis can be caused by this lesion thereby causing nerve root entrapment and radiculopathy especially when slippage is significant.

Figure 2.9: Spondylolisthesis (Ammar Haouimi, 2022).

Patients with lumbar spondylolisthesis may suffer from mild lower back pain to severe radiculopathy, neurogenic claudication, or even cauda equina syndrome rarely. Symptoms are often proportional to the amount of slip as well as nerve compression level. Spondylolisthesis needs radiographic imaging mainly lateral x-rays to diagnose it and assess how much vertebral slippage has occurred in it. MRI is used most times for assessment of the extent of neural narrowing while evaluating soft tissues like discs and ligaments (Trinh et al., 2022). Sometimes CT scans might be employed if there's a need for a better understanding of bony abnormalities (Akkawi et al., 2022).

2.2.2.7 Types of Spondylolistheses Based on Direction

2.2.2.7.1 Anterolisthesis Spondylolistheses

This is the most generalized type of spondylolisthesis, where the vertebrae in concern slide forward over the lower spine. In older adults, anterolisthesis is commonly linked to degenerative alterations in the vertebral column wherein spinal discs and facet

joints deteriorate (Wang et al., 2017). This anterior shift mostly occurs at levels L4-L5 and L5-S1 thereby causing different levels of back pain, radiculopathy, or even cauda equine syndrome when it becomes very severe.

2.2.2.7.2 Retrolisthesis Spondylolistheses

Retrolisthesis refers to a condition where the vertebrae move backward. Retrolisthesis can result from injuries such as trauma, degenerative conditions, or congenital deformations of the spine though it is not as common (Hung et al., 2022). This may lead to an unstable spine or cause compression on the spinal cord and nerves leading to symptoms like chronic back pain, stiffness, and neurological deficits depending on how severe it is (Shenoy et al., 2019).

2.2.2.7.3 Laterolisthesis Spondylolistheses

This kind of spondylolisthesis consists of a lateral displacement of the vertebra, which could be both left and right. This is usually connected with scoliosis and significant degenerative changes occurring in spine deformities (Hung et al., 2022). When combined, these issues can cause imbalanced loading within the back structures, which aggravates the spinal curvature thus resulting in one-sided symptoms such as localized pain, muscle spasms, and disturbed gait (Shenoy et al., 2019).

2.2.2.7.4 Rotational Spondylolisthesis

A rarer form of the disorder, it rotates the vertebra instead of slipping it forward, backward, or sideways like other forms. This disease is often linked to complex spinal malformations and can come about due to the existence of congenital abnormalities, trauma, or severe degenerative changes (Kobayashi et al., 2018). Rotational dislocation can result in various complications such as axial backache, radiculopathy, and gross spinal instability.

2.2.2.8 Types of Spondylolistheses Based on Etiology

2.2.2.8.1 Isthmic Spondylolisthesis

For the younger population, isthmic spondylolisthesis is most common. This occurs when there is a defect or a fracture in the pars interarticularis which is a small piece of bone that connects the upper and lower facets of a vertebra. The L5-S1 level is most affected by this type. Stress fractures are typically responsible for this type of damage, which often results from repetitive hyperextension activities (Försth et al., 2016). If left uncorrected, the instability caused by these defects may cause vertebral slippage leading to symptomatic spondylolisthesis as time goes on.

2.2.2.8.2 Degenerative Spondylolisthesis

This illness is mostly seen in older people and occurs due to intervertebral disc and facet joint degeneration. Females are more prone to this condition compared to males and is typically noticeable at the L4-L5 level (Yang et al., 2018). With the reduction in disc height, and facet joint arthropathy, the stability of the vertebral column diminishes thus allowing forward slippage of the vertebra. In many instances, people suffering from spondylolisthesis also have spinal stenosis leading to severe pain besides other neurological symptoms.

2.2.2.8.3 Traumatic Spondylolisthesis

The direct fractures of the vertebra or disruption of stabilizing ligaments in the spine precipitate traumatic spondylolisthesis. Furthermore, such kind is not as prevalent and may result in severe spinal instability depending on the severity of the injury sustained (Wang et al., 2017). The area involved varies with trauma nature in the lumbar spine and hence requires urgent medical attention.

Figure 2.10: Traumatic spondylolisthesis (Skalski & Hamidi, 2018).

2.2.2.8.4 Pathological Spondylolisthesis

The spondylolisthesis of this type is occasioned by pathological conditions such as tumors, infections, or metabolic bone diseases that weaken the vertebrae (Försth et al., 2016). Disruption of the osseous structure can be responsible for vertebral slippage in various ways and may have more expanded or erratic patterns than other forms. The way it slips and exhibits symptoms primarily depends on what caused it.

2.2.2.8.5 Dysplastic Spondylolisthesis

Congenital dysplastic spondylolisthesis is caused by an anomalous development of vertebral elements, mainly in the lumbosacral region. These defects since birth may cause early slips which are often identified during childhood and adolescence. Generally, L5 and S1 vertebrae are the most affected and the sliding level can be worse than any other type (Yang et al., 2018).

2.2.2.9 Lumbar Spine Facet Joint Osteoarthritis (FJOA)

A degenerative condition that shows degeneration of the cartilage in the facet joints that are positioned at the back part of the spinal vertebrae. This degeneration can cause pain, stiffness, and loss of movement. The prevalence of FJOA increases with age. It mostly affects those who are above 60 years old. Often it coincides with other age-related changes in the spine like intervertebral disc degeneration, making symptoms even worse (Nishide et al., 2017).

Chronic lower back pain is caused by FJOA and accounts for about 15-45% of cases. Mechanical stress, inflammation, and joint tissue metabolism underlie its pathogenesis. Repeated mechanical loads or trauma can lead to the destruction of cartilage eventually resulting in narrowing space between joints with subchondral sclerosis and osteophyte formation (Du et al., 2022). These factors may cause nerve impingement leading to low back pain syndrome.

Figure 2.11: Facet joint arthropathy (Knipe & Faizi, 2019).

Diagnostic tools such as Magnetic Resonance Imaging (MRI) or Computed Tomography (CT) scans play an important role in diagnosing FJOA. MRI is useful for evaluating soft tissue changes while CT scan provides detailed pictures of bony structures used to assess how far joint damage has progressed. However, there is no direct correlation always between imaging findings and clinical symptoms since some individuals may exhibit significant radiographic changes but remain asymptomatic (Du et al., 2022).

2.2.2.10 Ankylosing Spondylitis (AS)

Ankylosing spondylitis (AS) is a chronic and progressive inflammatory disease that affects primarily the axial skeleton, particularly the lumbar spine and sacroiliac joints. It is characterized by the presence of inflammation of the entheses leading to the formation of osteophyte which eventually results in spinal fusion and, in severe cases, the typical bamboo spine (Klavdianou et al., 2021).

Figure 2.12: Ankylosing spondylitis (Haouimi, 2020).

In terms of imaging techniques, bone marrow edema can be detected early on with more sophisticated imaging techniques including MRI while CT is sufficiently used to assess structural deformities or bone fractures. Early treatment strategies that integrate both drug therapy and physical rehabilitation are critical in improving patients' surgical satisfaction (Klavdianou et al., 2021).

2.2.3 Age-Related Changes in the Lumbar Spine

Disc degeneration is strongly correlated with aging. Studies show that the prevalence of disc bulges and protrusions increases significantly with age, affecting more than 80% of individuals over the age of 60 (Brinjikji et al., 2015). Age-related changes in the lumbar spine also include loss of disc height, decreased disc signal intensity on MRI, and increased facet joint degeneration (Brinjikji et al., 2015; Cooper, 2015).

2.2.4 Gender-Related Differences in Lumbar Pathology

Research has indicated that genetic factors may influence the susceptibility to lumbar disc degeneration, with hereditary factors playing a significant role. Men and women may experience disc degeneration differently, with some studies suggesting that women are more prone to facet joint osteoarthritis (Cooper, 2015). Hormonal differences and occupational factors may also contribute to these gender-specific variations.

2.2.5 Diagnosis of Lumbar Spine Pathologies

Low back pain (LBP) is one of the most prevalent health conditions affecting the musculoskeletal system of most inhabitants of the world. Causes of LBP or low back pain include many determinations, with the most common being lumbar disc herniation, which mostly ends in radiating leg pain or sciatica due to nerve root pressure. The correct assessment of lumbar spine disorders e.g. disc protrusion is important when establishing the best treatment option available (Zhang et al., 2023).

Computed Tomography (CT) and Magnetic resonance imaging (MRI) are invaluable imaging techniques used to assess abnormalities in the lumbar spine. While

CT is important for the evaluation of distributions of the body, especially those related to bone, MRI is the preferred imaging modality for visualization of the soft tissues like the spine discs, ligaments, and nerve roots (Zhang et al., 2023).

2.2.5.1 Diagnosis of Lumbar Pathology Using Conventional X-ray

Despite the advancements in medical imaging technologies, the conventional X-rays still play a pivotal role in the evaluation of lumbar spine pathology, especially in vertebral alignment as well as degenerative changes (Lai et al., 2020). Owing to their reasonable cost and ease of availability, X-rays are usually the first imaging modality employed. They have usefulness in portraying osteoporotic fractures, fractures, spinal malalignment, and arthritic degenerations such as the formation of osteophytes (Huang et al., 2023).

However, there are certain drawbacks regarding conventional X-rays. They do not provide good images of intervertebral discs and nerve roots, which are important in pathologies such as disc herniation or spinal stenosis. Thus, X-rays are commonly used in conjunction with advanced imaging techniques such as MRI or CT whereby more detailed examinations are carried out (Huang et al., 2023).

Despite the circumstances, X-rays are still helpful in the preliminary investigation of certain skeletal deformities such as spondylolisthesis or scoliosis (Lai et al., 2020). Improvements in imaging adjustment operations and dosage administration have resulted in improved image quality and safety concerning ionizing radiation during the diagnosis. Although this can tackle a few weaknesses the imaging can be expected of X-rays, high detail soft tissue imaging may not be suited for this technique and reduced intervertebral disc spaces.

2.2.5.2 Diagnosis of Lumbar Pathology Using CT

CT scan is an efficient technique for examining the bony elements of the spine as it allows an in-depth visualization of individual vertebrae and is especially effective in detecting vertebral fractures, bone degeneration, and certain structural changes such as spondylolisthesis. CT scan is usually quicker and easier to use than MRI and often

employed in emergency medicine departments to quickly evaluate patients with acute spinal injuries.

Even so, in terms of diagnosing lumbar disc disease, especially ‘disc prolapse’, lumbar CT scans tend to be less helpful than MRI as the latter offers a better soft tissue visibility than the former. CT scans can be useful in making the diagnosis of disc protrusions when they are large, more so when this is combined with the use of better imaging techniques like CT myelography (Jacobs et al., 2010).

CT myelography is the process whereby a radiopaque substance is injected into the spinal canal, making it easier to see the spinal cord and nerve roots, enabling the finding of compressions or protruded discs. Still, the application of CT for prolapsed intervertebral discs especially lumbar disc prolapse is only applicable when MRI is not possible or is contraindicated (Jacobs et al., 2010).

Some authors still believe that CT can be useful in assessing certain disorders of the lumbar spine in cases when MRI is not practical. For example, patients implanted with metallic materials, for instance, spinal instrumentation for fusion, may not be able to acquire efficient diagnostic images with MRI due to artifact formation. In these situations, CT has the advantage of getting clear pictures of most osseous structures with minimal to no movement artifacts causing metallic interference (Balasubramanya et al., 2020).

In general, CT is the second-line imaging technique in the evaluation of lumbar disc pathology. It has a lower sensitivity for the assessment of subtle soft tissue changes so essential in early detection of disc prolapse. Furthermore, patients are subjected to ionizing radiation, which is yet another limitation of CT scan use, especially among children and other patients who may need repeated imaging over time (Kim et al., 2018).

2.2.5.3 Diagnosis of Lumbar Pathology Using MRI

When it comes to imaging the lumbar spine, MRI is the preferred technique, especially in pathologies involving soft tissues like the discs, the ligaments, and the nerve roots. Unlike CT, MRI is free of ionizing components which makes it less hazardous for

repeated use in chronic conditions. This is augmented by the fact that MRI helps in producing soft tissue images of greater contrast, which leads to a more thorough assessment of the lumbar spine (Kim et al., 2018).

One of the strengths of MRI is its ability to discriminate between different types of disc pathologies, bulging, herniation, and degeneration. MRI can be used to elucidate the degree of disc protrusion and its effects on surrounding neural structures which are important in determining any nerve root compression and diagnosing radiculopathy. For example, the disc herniations can compress the roots of the nerve and the root of the nerve symptoms will lead to pain, numbness, or muscle weakness. MRI is particularly helpful in these cases where it is possible to evaluate the degree of nerve root compression and the potential benefits of surgery (Kim et al., 2018).

MRI is also very effective in visualizing the initial pathological findings of the intervertebral discs. These alterations, which imply the presence of a pathological process of disc degeneration, include such changes as disc height reduction or loss of water shown as reduced T2 signal in images, that have annular tear. Fissures of the annulus fibrosus which are also termed annular tear may occur prior to disc herniation which is frequently responsible for acting or causing Low back pain. The subtle changes it detects also help justify the use of MR in diagnosing and treating early-stage intervertebral disc disease (Brinjikji et al., 2015).

Likewise, another vital characteristic of the MRI is its utility in the detailed evaluation of the spinal cord and the nerve roots. The dimensions of the spinal canal, any stenosis and relations between the discs and nerve roots can be very efficiently visualized on an MRI. Regarding the lumbar spinal stenosis, MRI is used in measuring the degree of canal stenosis and detecting factors that contribute to it as in the case of hypertrophy of the ligamentum flavum or osteoarthritis of the facet joints. This information relates, for instance, to the question of whether surgery is indicated or whether conservative treatment is effective (Deyo et al., 2014).

MRI can also discern situations that may not only be diagnosed as disc prolapse but may sometimes comprise infections, tumors or inflammation amongst others. For example, Modic changes are seen as modifications in vertebral end plates and bone

structures surrounding the intervertebral disc and can easily be seen would mainly features in the MRI images and they relate to the degeneration of intervertebral disc.

Such changes are absent in CT scans and hence could be used to supplement the diagnosis although such knowledge may alter the plan for jaw interventions. It is known that for example Modic changes are related to chronic low back pain and unfavorable results after intervertebral disc surgery which emphasizes the necessity of MRI for full assessment of the patients concerned (Sollmann et al., 2022).

2.2.6 MRI Sequences and their Role in Lumbar Pathology Diagnosis

MRI-criteria are significantly boosted through assorted sequences, as each one contributes certain information regarding the anatomy and pathology of the spinal cord. The details of understanding these sequences and their functions are essential, especially in the diagnosis and management of low back pain and other suspected conditions in the lumbar spine (Deyo et al., 2014).

2.2.6.1 T1-Weighted Sequences

T1-weighted (T1W) sequences are acquired mainly for anatomical purposes. They are high-resolution and distinguish fat as bright and other tissues containing water as dark. In terms of lumbar spine imaging, T1W images are helpful in assessing the vertebral bodies, detecting fatty marrow substitutions, and differentiating soft tissue masses such as tumors and abscesses.

Additionally, T1W sequences are valuable when it comes to anatomical structures such as the nerve roots and the outer rim of discs, which are helpful in evaluation of herniated discs and the nerve compression therein. When performing the diagnosis of lumbar disc prolapse, T1W images have a low sensitivity in detection of on the degree of hydration of discs or compression of nerve roots compared to other sequences. However, it is useful in detecting features such as fractures or bone marrow edema in the vertebrae that may help in the diagnosis of degenerative disc disease such as Modic changes in the vertebral end plates (Sollmann et al., 2022).

2.2.6.2 T2-Weighted Sequences

T2-weighted MRI sequences are essential in help with the diagnosis of lumbar spine pathologies, due to their superior sensitivity for tissues rich in water. These sequences are particularly good at depicting degenerative changes of intervertebral discs, stenosis of the spinal canal, as well as neural compression. The use of high-resolution T2 techniques, such as 3D T2-weighted imaging, improves diagnostic accuracy by enabling clearer visualization of some features, such as vascular and foraminal stenosis and the precise path followed by the nerve root (Kim et al., 2018).

The T2W images play an important role in detecting extrusion of the nucleus which caused nerve impingement leading to radiculopathy. These sequences also help to assess the narrowing of the spinal canal and the level of stenosis, which is important for deciding the need for surgical intervention. In addition, T2W sequences can identify annular tears which are small tears in the outer covering layer of the disc and have been implicated as a possible cause of persistent low back pain (Brinjikji et al., 2015).

2.2.6.3 Short Tau Inversion Recovery (STIR) Sequences

STIR sequences enhance the visibility of fluid and edema by reducing the fat signal. Increases in vascularity and inflammation in the radiant structures around the lumbar spine can be qualitatively assessed with STIR sequences and quantified volumetrically. These sequences can be incased to achieve improved identification in pathologies within soft tissues with inflammatory changes such as ligamentous strains and muscle edema. Such sequences may be helpful in the detection of areas of bone marrow edema which may be indicative of fractures of the vertebra or Modic changes associated with degeneration of the disc (Viola et al., 2024).

STIR sequences are especially important in cases where infection, inflammation, or tumor infiltration is suspected, as they can clearly highlight these abnormalities. This capability makes STIR sequences invaluable in differentiating between degenerative changes and more serious conditions like spondylodiscitis or metastatic lesions (Zanchi et al., 2020).

STIR is especially useful in assessing clinical conditions like sacroiliitis and soft tissue injuries, Subtle lesions may be overlooked when using other MRI techniques. Recent work has demonstrated that including STIR sequences in the routine MRI protocols of the lumbar spine enhances the evaluation of both intra- and extra-spinal lesions. This is particularly critical in determining the underlying causes of conditions such as sciatica, which are caused by extra-spinal pathologies. For example, STIR sequences are effective in visualizing certain metastatic lesions or inflammatory processes affecting the sacroiliac joints and iliac bones that may otherwise go unnoticed with standard imaging techniques (Viola et al., 2024).

2.2.6.4 Proton Density (PD) Sequences

Proton density (PD) sequences for MRI imaging can provide some balance between T1W and T2W images by having a good contrast of varied tissue types without compromising on anatomical definition. These sequences are less common in lumbar imaging than T1W or T2W sequences but can provide some advantages in certain clinical situations. All images, especially those of the PD sequence, are often most effective in following subtle changes in the intervertebral discs because disc morphology is clearly depicted together with the peripheral soft tissues (Sollmann et al., 2022).

Typically, PD images can be coupled with T2W images to evaluate the grade of compression that occurs at the level of the nerve root and the radical bulge. They may also be useful when determining the condition of an annulus fibrosus and due to the evaluation of early spondylarthritis changes which are usually not shown prominently on T1W or T2W (Sollmann et al., 2022).

2.2.6.5 Diffusion-Weighted Imaging (DWI) and Diffusion Tensor Imaging (DTI)

Even though it is not common in the clinical workup of the lumbar spine, diffusion-weighted imaging (DWI) and diffusion tensor imaging (DTI) have been evaluated as ancillary methods in the investigation of lumbar spine pathology. This technique, known as DWI, is based on determining the molecular displacement due to intracellular water molecules within the structure of the tissue under examination, thereby revealing pathological tissue composition. For instance, in the lumbar spine, DWI has been

examined for its ability to assess benign and malignant vertebral bodies as well as for evaluation of nerve root disorders (Hu et al., 2024).

A major advancement of DWI is DTI, which helps in studying, amongst others, the integrity of the white matter tracts, which include nerve fibers. Although, generally applied to the imaging of the brain, DTI has some potential in the assessment of nerve root compression in case of lumbar disc herniation. The technique is useful in determining the extent of neural damage by visualizing the variations in water diffusion in the compressed nerve roots (Dumont et al., 2018).

2.2.6.6 Fat-Suppressed T2-Weighted Sequences

Fat-suppressed T2W sequences are another angle of T2-weighted imaging that is beneficial when trying to observe the anomalies in the soft tissues around the spine. The sequences enhance the assessment of inflammatory processes such as spondylodiscitis or soft tissue edema by fat suppression (Kim et al. 2019). This sequence helps in defining the disc herniation inflammation from infections, tumors, or other low back pain sources (Sollmann et al., 2022).

2.2.6.7 Lumbar Spine MRI Sequences with Intravenous Contrast

The application of intravenous contrast agents, especially Gadolinium-based contrast agents, plays a major role in lumbar spine MRI when performing it in a specific clinical setting. Because gadolinium is a paramagnetic compound, in which the T1 relaxation time of tissues is shortened leading to an increase in the intensity of signals in T1-weighted images. This particular property makes it an important adjunct in diagnosing infections of neoplasm and postoperative complications in the lumbar region.

In the lumbar imaging, intravenous gadolinium was useful imaging regarding the existence of enhancement due to vascularity or involvement of the blood-spinal cord barrier. For example, in spinal infections like discitis or osteomyelitis, gadolinium contrast enhancement assists in the differentiation of inflammatory changes of the vertebral bodies, intervertebral discs, and paravertebral soft tissues.

Likewise, it is essential for the detection and evaluation of the size of spinal tumors or their metastatic lesion since most neoplastic lesions demonstrate abnormal vascular patterns with increased vascularization. Moreover, gadolinium contrast-enhanced images are, in the post-operative spine, important in distinguishing scar tissue (enhancing fibrous tissue) from a herniated disc (non-enhancing disc tissue).

2.2.6.8 T1 Fat Suppression Sagittal Post-Contrast Sequence

Sagittal plane gives longitudinal position of lumbar spine in a single image showing vertebral bodies, intervertebral discs, spinal canal and paraspinal soft tissue. Fat suppression essentially eliminates the bright signal from fat and makes it easy to enhance the contrast from the diseased tissue, for example, from inflammation or neoplastic change. This is especially useful in distinguishing and describing the spinal infection-related conditions such as discitis and osteomyelitis where enhancement patterns of intervertebral discs and the adjacent vertebrae are critical.

2.2.6.9 T1 Fat Suppression Axial Post-Contrast Sequence

T1 fat suppression axial post-contrast sequence is an essential imaging in any lumbar spine MRI protocol where IV gadolinium contrast has been given. This sequence utilizes the high contrast, good anatomical resolution of T1WI and subsequently employs fat saturation to render enhancing structures more conspicuous. Especially it is applied in the assessment of pathology conditions like infections, tumors, and postoperative inflammatory response since it provides better contrast between tissues and enhancement of diagnosis.

In the axial plane this sequence offers a cross-sectional view of the lumbar spine, particularly the spinal canal, intervertebral foramina and soft tissues. Fat saturation nulling the usually brilliantly highlighted image of adipose tissue, and therefore, enables better highlighting of patterns of enhancement. This is particularly useful in detecting areas of increased vascularity, inflammation or other areas of pathologic enhancement, whether in nerve roots, epidural spaces or paraspinal tissues.

2.2.7 Clinical Implications of MRI Sequences in Lumbar Pathology

The application of several MRI sequences renders a thorough assessment of the lumbar spine as it enables clear views of bony and non-bony tissues. Various sequences can be combined to provide a suitable diagnosis for the patient and assistance in future management of the patient. For example, T1W sequences are great in giving details of anatomy, and T2W sequences demonstrate structures that contain water thus making it easy to identify degenerative disc diseases and herniation.

STIR sequences are very useful for detecting inflammatory processes that indicate a possible infection or a tumor and the assessment of the degree of minor abnormalities in discs can be still performed with PD sequences. It is mainly due to the employment of these sequences that it is possible to differentiate the pathological processes occurring in the lumbar spine from other pathological conditions causing low back pain (Brinjikji et al., 2017).

In summary, the selection of MRI sequences remains one of the most important determinants of diagnostic and evaluative capability with respect to the lumbar spine pathologies. Among the sequences employed are T1, T2, STIR, etc. Some are superior in depicting bone structures, others soft-tissue, and fluid-bearing cavities.

2.2.7.1 Clinical Relevance

Lumbar discs prolapse is quite common and is associated with lower back pain (LBP) and even radiculopathy and is a condition that is usually very painful and disabling. The symptoms and clinical features presented by the patients depend on the degree of herniation and the degree of neural compression. Radiological methods such as MRI are of utmost importance for displaying anatomical features that evoke such symptoms and help clinicians make the diagnosis correctly.

Most of the intervertebral disc imaging is performed using MRI, since it provides a high level of soft tissue contrast. This technique is especially helpful in diagnosing the presence of lumbar disc prolapse, bulging, and degenerative changes that often go unnoticed clinically. For instance, Details in MRI studies enable differentiating non-

painful disc bulging from painful disc herniation where the lumbar nerve roots are compressed leading to pain or other radiculopathy symptoms (Brinjikji et al., 2015). That distinction is very important when deciding on the patient's treatment strategy.

2.3 Literature Review

The investigation of gender-related relationships between clinical features and MRI findings in lumbar disc prolapse brings to the fore an intricacy of mechanisms involved. MRI is an essential instrument in the diagnosis of lumbar disc prolapse, but its results do not always have a clinical correlation, and such correlation may depend on gender. This synthesis considers the contributions of individual studies in understanding these relationships.

2.3.1 Clinical and MRI Correlation

MRI scans because of their high sensitivity and specificity remain the gold standard in the diagnosis of lumbar disc prolapse. Nonetheless, not every finding on the MRI scan correlates with the clinical examination. For example, disc bulge occurs in a few patients without any visual discomfort or any other symptomatic manifestations in others (Singla et al., 2020; Muppala et al., 2022).

Certain clinical practices correlate with specific anatomical gravitates in clinical spine MR imaging. Among such are root tension positive straight leg raise test and neurogenic intermittent claudication positive spine, which are confirmed radiologically (Altan et al., 2023). Although nerve root compression on MRI usually correlates with nerve root symptoms, this is not true at every level of the lumbar spine (Nasir et al., 2022).

2.3.2 Gender Differences in Lumbar Disc Prolapse

It is known that in males there is a high relative incidence of lumbar disc prolapse compared to females and the more aging male groups tend to have more disc prolapse as compared to their counterparts (Fatima et al., 2022). This observation is true since the prevalence is higher in males, but it is females who seem to develop the degenerative disc pathology more often than males which may affect both the clinical picture and the results

of MRI (Nasir et al., 2022). Research in this area often lacks attention to clinical and MRI findings based on gender, highlighting the need for more inclusive studies (Aaen et al., 2021).

2.3.3 Clinical Implications and Diagnostic Considerations

Past medical history and clinical examination play an equally important role in diagnosing lumbar disc prolapse and, often, provide more information than MRI does (Singla et al., 2020; Altan et al., 2023). This is because MRI is not specific to presenting clinical symptoms as certain MRI findings can exist without any such symptom.

Various clinical grading systems including the modified Oswestry Disability Index (ODI) are useful in determining the severity of symptoms and have attempted to correlate these with MRI findings though the correlation is not usually very strong (Babu et al., 2023). MRI findings such as disc bulges, protrusions, or extrusions are frequent, but their clinical importance is dependent on the type and site of herniation (Muppala et al., 2022).

2.3.4 Pervious Studies

For the proper diagnosis and formulation of effective management, MRI has turned out to be useful in differentiating disc prolapse and degenerative disc diseases or spinal stenosis. Further developments such as imaging at a higher resolution and artifact reduction have enhanced the accuracy of MRI as a diagnostic tool. These advances allow earlier and more detailed imaging of lumbar disc herniations, and hence, improved clinical results in patients with such conditions.

According to Fatima et al. (2022), their study comprehensively evaluated 71 patients with lumbar disc prolapse using magnetic resonance imaging (MRI) at a district hospital in Gujranwala, Pakistan. The study primarily aimed to investigate the demographic distribution, clinical presentation, and imaging patterns associated with lumbar disc prolapse. It was found that disc protrusion or herniation occurs approximately four times more frequently in the age group of 41-50 years, who accounted for 53.5 % of the patients.

The authors concluded that imaging procedures are of great importance in the diagnosis of lumbar disc prolapse, since in 70.4 % of all cases performed, the examination planes used were sagittal and axial MRI. It was possible to identify these imaging protocols as the most useful in confirming disc lesions to give detailed assessment of the morphology of the disc structures, the degree of herniation as well as its effect to nearby neural elements.

The results also confirm the effectiveness of MRI in the diagnosis of protrusion or extrusion herniation types owing to its ability to visualize the position of the disc substance in relation to the spinal canal. The ability to obtain such detail is valuable to these practitioners in formulating appropriate management strategies with minimal risk of complications and optimal outcome for patients.

The researchers further revealed that lower back pain (LBP) was reported by 60.6 % of all subjects suffering from this disorder. The next most common pain was reporting a combination of LBP and LBP with sciatica in 28.2% of the sample which shows how often nerve root compression is seen in cases of LBP. Also, a few patients, that is, 9.9% had painful only the affected region sciatica, 1.4% of the patients suffered from pain only in the hip region. These results strengthen the evidence of performing a lumbar MRI in the differential diagnosis of the clinical pictures with the underlying abnormalities of the spine and differentiating the disc disease from the other probable causes of pain in the back and lower limbs.

According to Singla et al. (2020), their study investigated the correlation between clinical findings and magnetic resonance imaging (MRI) results in 60 patients presenting with lower back pain (LBP), all of whom had abnormal MRI findings. This study was conducted at Punjab, India. The research sample consisted of participants aged between 20 and 50 years, with an average age of 37.6 years. Most patients (53.3%) were in the 30-40-year age group which is typical of people suffering from degenerative disc disease in their working-age population, who are frequently exposed to occupational and physical stresses.

Patients were mainly male (56.7%) which is consistent with studies which state that males are more likely to experience lumbar disc prolapse due to numerous physically demanding activities. Radiculopathy was the presenting symptom in most cases which is 90% of the patients while 82% tested some positivity on the Straight Leg Raise (SLR) test which is a key clinical sign of nerve root tension. In addition, sensory deficits were noted in 47% of the cases, and motor weakness in 63% of the patients suggesting that motor impairments often appear earlier than sensory changes in the course of the disease.

MRI offered more explanations regarding the structural damage accounting for the symptoms experienced by the patients. The most common pathological finding was disc bulge, which was present in 53.3% of the subjects, followed by disc protrusion (36.7%) and disc extrusion (10%). These findings illustrate various stages of disc herniation, with herniation bulges representing milder displacement of the disc structure. In contrast, extrusions depict advanced disease with a high risk of nerve root compression.

The study further discussed the pattern of disc disease in the lumbar levels with the commonest lesion being at the level of L5-S1 (55%) followed by L4-L5 (38.3%) and L3-L4 (6.7%). This pattern does correspond with the biomechanical loads that are transferred to the lower lumbar and sacroiliac junction because of the small range of motion that this region possesses which renders it more prone to wear and tear agreement.

The findings of Singla et al. should be appreciated in the context of demonstrating the duality of radiological and clinical aspects of diseases with respect to lumbar disc prolapse. While their findings illustrated the merits and shortcomings of MRI alone, the authors recommended that diagnosis be performed in the context of patient complaints and clinical examination instead of relying on advanced imaging techniques. These results contribute to the growing body of evidence supporting the integration of clinical and radiological assessments in the evaluation and management of lumbar spine disorders (Singla et al., 2020).

According to Muppala et al. (2022), they conducted a prospective study on 102 patients with lumbar disc herniation to analyze the correlation between clinical findings and MRI results. The study analyzed the herniation of 139 levels of the intervertebral discs diagnosed with MRI, this study took place at multiple locations showing that the

most predominant level of herniation was disc bulge (62 levels), protrusion followed (46 levels), extrusion (27 levels), and sequestration (4 levels) was the least predominant. The findings underscored the fact that disc herniation could be a factor in low back pain; however, not every abnormality identified in MRI is fused with symptoms clinically, which is critical in such studies, especially in the context of MRI interpretation.

The study revealed that far-lateral and para-central disc herniations especially those that rend the neural foramen posed greater chances for showing clinical signs like radiculopathy and worse motor deficits. Precisely, neural root compression was seen in 48 levels and most symptomatic presentations were due to para-central disc positions. The Straight Leg Raise (SLR) test was found to be positive in 98% of patients indicating its specificity for detecting lumbar disc herniation. On the other hand, 55% of patients had a positive crossed SLR test which proved to be a more specific test indicative of nerve root involvement.

Interestingly, the study revealed that the kinds of herniation of the disk (bulge, protrusion, extrusion) independently were not significantly correlated with neurological deficits or clinical findings. It was the herniation position and how much the neural foramen was narrowed that were determinative factors in how severe the symptoms were. For instance, centrally located disc herniations tended to be painless, whereas para-central or far-lateral disc herniations were more prone to be painful and cause neural compression. These results have considerable consequences for surgery; operative treatment decisions should be based on the amount of neural damage sustained rather than the type of herniation sustained.

Muppala et al. tended to integrate clinical examination, history, and MRI for diagnosis which they termed as ‘comprehensive’. Genuinely, MRI is the best tool for imaging anatomical changes in lumbar disc herniation, but it is important to have proper clinical assessment to avoid misinterpretation of the level of pain and too much dependence on X-rays. These findings also support the view that MRI is not the primary examination but rather the complementary assessment for lumbar disc degeneration that should provide practicality to specific management of the patients (Muppala et al., 2022).

According to Nasir et al. (2022), they conducted a study involving 32 patients aged 19–65 years to explore the correlation between clinical findings and MRI results in lumbar disc prolapse. This study was carried out in the Radiology Department of Shalamar Hospital, Lahore, Pakistan, their examination finds that more patients with lumbar disc prolapse are females 56.3% than males 43.8%, with the highest frequencies, that is, 62.5%, found in patients above the age of 50 years.

The most frequently identified level of lumbar disc herniation on MRI was L4-L5 which accounted for 31.3% of the cases, L5-S1 which is 25 % and L3-L4 at 18.8%. MRI examination gives a very useful visualization but functional correlatives with pre-operative: long-term investigations in this area show a poor correlation, the authors argue, especially for L3-L4, L4-L5, and L5-S1 levels.

The study found a statistically significant relationship only between the findings of MRI as well as clinical manifestations, such as sensations, power, or reflexes at L1-L2 and L2-L3 levels. For example, at the L2-L3, more significant correlations were predicted with the L2 dermatome and myotome. In contrast, in the lumbosacral areas of L4-L5 and L5-S1, the relationship between the data of MRI and clinical issues appeared to be weak as well.

Besides, the authors of the study reported that there was a moderate to strong negative correlation between pain score and the MRI findings for the majority of lumbar regions with L3-L4 being the only area where some positive correlation was seen which was weak at best without reaching significance.

According to Nasir et al., those with MRI-confirmed lumbar disc prolapse tended to have no complaints. They also pointed out that there was not a high level of uniformity between the clinical examinations and the MRI scans. This highlights the need for a multi-faceted approach to diagnosis where comprehensive clinical examination is taken into consideration along with imaging techniques before attaching significance to the detected irregularities or abnormalities.

The authors stressed the fact that over-reliance on the MRI may bring about instances of over-diagnosis or mismanagement especially where irrelevant radiological

findings exist. This is in keeping with the rest of the literature that describes the disconnection between MRI images and the physical characteristics posture and grossly structures of the lumbar disc prolapse. All this evidence supports the case for the inclusion of separate diagnostic modalities in the management of patients (Nasir et al., 2022).

According to Brinjikji et al. (2015), explain how a systematic review was carried out to determine the occurrence of degenerative changes in the spine among asymptomatic individuals by analyzing MRI and CT imaging results. Thirty-three articles detailing 3110 asymptomatic subjects were selected, and troubled significantly with age, degenerative changes of the spine that were detectable by imaging methods were quite common.

Thirty-seven percent of the individuals aged 20 years presented with some form of disc degeneration while 96% of individuals aged about 80 years presented with it. Equally, the rate of occurrence of disc bulge increased from 30% at the age of 20, to 84% at the age of 80 years, and the rate of occurrence of disc protrusion increased modestly from 29% at the age of 20 years to 43% at the age of 80 years.

Additional review emphasized that some imaging features, for instance, annular fissures, were observed in all age categories but did not show a marked increase with aging (19% at 20 years to 29% at 80 years). Some, on the other hand, like osteoarthritis of facet joints and spondylolisthesis, were uncommon in younger age groups but were sharply elevated in the older age groups.

In elder subjects, facet degeneration was 83% and spondylolisthesis was noted in 50% of the octogenarians. These results emphasize that many of the degenerative changes commonly observed on spinal imaging are likely part of the normal aging process rather than indicative of pathological conditions causing symptoms.

According to Brinjikji et al, the imaging studies of spinal degeneration changes are quite common even among asymptomatic individuals and therefore should be understood within a contextual clinical setting. The work stresses that some degenerative processes which are frequently regarded as non-symptomatic imprints captured by imaging studies may have no corresponding symptoms such as low back pain.

Therefore, there is a need for clinicians to combine imaging studies with thorough patient assessments to minimize instances of overdiagnosis and unwarranted management on a radiological basis. Such findings provide a critical understanding of the clinical relevance of these spondylotic changes and their changes in the context of age-related degenerative processes (Brinjikji et al., 2015).

According to Demirel et al. (2023), their study analyzed the relationship between lumbar multifidus muscle (LMM) atrophy and disc herniation at the L4/L5 and L5/S1 levels using magnetic resonance imaging (MRI) in 254 patients. The research involved multiple institutions in Istanbul, including Bahçeşehir University Faculty of Health Science and Haseki Training and Research Hospital.

The results about the connection between LMM atrophy and disc herniation indicated that LMM atrophy and disc herniation exist in one body, i.e., out of the entire 157 patients, 89 had both forms of the disease at the L4/L5 level of which 35.1% were the case, while at the L5/S1 level, out of 174 patients, 114 of them, also 35.1% showed the same case. Remarkably, 11.1 percent of cases in which neither disc level was herniated exhibited LMM herniation, indicating that yes muscle atrophy is not disc disease related.

The same survey determined that LMM atrophy rates for patients aged over 40 years were significantly increased compared to the patients younger than 40 years and over, especially at the L5/S1 level where the variation in age caused an increase in the level of atrophy.

Moving on to gender differences, the study revealed pronounced herniation at the L4/L5 level in females, while in males the most reported was the L5/S1 herniation. Furthermore, the average cross-sectional area of LMM was always greater in males than in females of all age categories which may also suggest some differences in muscle architecture and strength between the sexes. There were also found statistically significant relationships between disc herniation and atrophy of LMM in territorial units of both levels indicating the degenerative processes in the lumbar spine areas are interconnected.

According to Demirel et al, whilst LMM atrophy is related to disc protrusions, it may also occur in aged individuals without any such association. These results highlight the need for both muscle and disc assessment during the assessment of low back pain. This research highlights the significance of LMM muscle wasting in the causation of degeneration of the lumbar spine and postulates that early measures aimed at muscular exercises may help in controlling muscle wastage and thereby possibly help in the prevention of disc disease. This research throws interesting light on the relationship of lumbar spine components to each other and helps to formulate appropriate interventional and preventive strategies (Demirel et al., 2023).

According to Li et al. (2023), their study evaluated the diagnostic accuracy of coronal magnetic resonance imaging (CMRI) for identifying the symptomatic segment in multi-segment lumbar disc herniation (MSLDH). The study was conducted at the Second Affiliated Hospital of Nanchang University in Nanchang, Jiangxi, PR China.

The retrospective study was carried out on 44 patients aged 26 to 87 years with low back pain lower limb pain or any other symptom. Highly qualified CMRI results showed the following: the sensitivity was 90.2%, PPV was 94.9%, and the accuracy of the identification of the segments with a clinical picture was 83.4 percent. The authors acknowledged the fact that CMRI allows for the assessment of the intraspinal and extraspinal nerve roots and their morphology, signal, and position in detail which aids clinicians in MS over traditional MRI-based approaches to evaluate the symptomatic and asymptomatic segments in MSLDH.

During the study, several anatomical distinctions were noted in the patterns of nerve root compression in its correlation with the intervertebral discs. For instance, at the level L4/L5, 70.45% of the nerve roots occupied the post disc plane while at L5/S1, 72.73% was the disc plane at which the nerve roots were situated.

These results were corroborated by the structural peculiarities revealed with CMRI as nerve root flattening, ganglion enhancement, and even nerve root swelling which were found to be important features in localizing the symptomatic segment. Moreover, one–level surgery has been associated with shorter hospitalization periods as well as less

surgical blood loss than multi-level surgery, thus emphasizing the clinical importance of identifying the affected segments before surgery (Li et al., 2023).

According to Doan Van Ngoc et al. (2022), the study was conducted at VNU University of Medicine and Pharmacy and Hospital E in Hanoi, Vietnam, in their work the results of the examination of 55 patients who had been diagnosed with a herniated disc in the lumbosacral spine and from whom causal magnetic resonance imaging (MRI) was performed, followed by surgical treatment.

The average age of the patients was 58.96 years and slightly more women (female to male ratio of 1.12:1). During the examination, it was found that the patients engaged in heavy labor have much higher chances of progression of disc herniation in the lumbar region (63.7%). Other clinical manifestations consist of lower back pain, which was found in 100%, restrictions of his/her rotational abilities in common patients 90.91%, and non-axial pain in 85.45% of the respondents. In the same context, altering sensations were noticed in 72.73% of respondents while motor losses were noted in 50.91%, thus indicating considerable evidence of neurological status due to herniation of the lumbar region intervertebral disc.

The MRI examination revealed that the level most affected was L4-L5 (81.8%) and L5-S1 (70.9%) which is consistent with these regions being subjected to high mechanical stress. Among the types of herniation, the majority were disc bulges (60%) and extrusions (52.73%) with almost all herniations (98.18%) being posteriorly directed. Among the posterior herniations, the most frequent type was central herniation (41.82%) which was in most cases accompanied by nerve root constriction. The study also found that there was a 90.91% chance of nerve root compression imaged by MRI having clinical correlates, while the strongest agreement was for L5 and S1 nerve roots with 98.17% and 100% respectively.

According to Doan et al., MRI is necessary for prompt and correct diagnosis of lumbar disc herniation. Its characteristics allow the treatment planner to define the level, type, and area of the disc anomaly accurately. A comparison of study results with their relevance in clinical practice has been done to improve patients' achievements and flatten the ground of LDD. These results are a step towards the increasing body of formula

supporting the use of MRI as the ideal imaging technique in assessing spine degenerative diseases (Doan, 2022).

According to Islam et al. (2022), research involving 35 patients with voluminous prolapsed lumbar intervertebral discs assessed the results of conservative measures. The study was carried out at Khulna Medical College Hospital in Khulna, Bangladesh. The patients had ages ranging from 20 to 60 years of age and had severe pain in the leg and buttock regions, but the patients responded favorably to the treatment even with the severity. This research relied on clinical evaluations and regular follow-up MRIs done over three years at most for change in the degree of rotation of the disc protrusion.

As per the presented study, 87% of the patients had a substantial and long-lasting recovery, while the Oswestry Disability Index showed the baseline average score of 63% reduced to 20% post-intervention. Follow-up MRI scans demonstrated a decrease in disc volume that averaged 69% shrinkage. Also, about 44% of the patients experienced more than 70% reduction whereas 29% reported experiencing back discomfort on one or two occasions or intermittently only. After conservative treatment, only four patients required surgical intervention due to unresolved symptoms (Islam et al., 2022).

According to Patel et al. (2022), they performed a study to determine the rates and varieties of degenerative changes in the lumbar spine among chronic low back pain (LBP) patients. The study, undertaken in India at Dhiraj Hospital, Vadodara in Gujarat, involved a total of 52 subjects of whom 40 had self-reporting low back pain. The study was aimed at assessing Magnetic Resonance Imaging (MRI) evidence and included the presence of disc bulge, degenerative disc disease, disc herniation, disc protrusion, annular tears, Modic changes, spondylolisthesis, and central canal stenosis.

The results demonstrated that half the patients had disc bulges, and older patients sustained predictive links between disc bulges and radicular symptoms. Degenerative alterations including bulging and extrusion of discs, on the other hand, were more common among those who were less than fifty, where 80% of patients showed a bulging disc. Moreover, Modic 1 changes were recorded in 62.5% of cases and 70% of all patients exhibited spondylolysis. The findings emphasize the significance of MRI diagnosing the

lower back degenerative disease as well as chronic pain system and lower limb nerve root irritation and disorder.

It has been noted in several studies that even large bulging discs can be treated conservatively if early clinical evidence suggests some recovery. Moreover, the long-term outcome of patients having such conditions is quite encouraging because the findings from the study showed that conservative measures can be effectively used to prevent most of the patients from undergoing surgery (Patel et al., 2022).

2.3.5 Limitations and New Paths

MRI for lumbar disc prolapse, yet images are never complete without clinical correlation. The observed variation in the prevalence and manifestation of lumbar disc prolapse across genders indicates that a different diagnostic and therapeutic approach may be appropriate. More investigation is required to fully understand these gender-specific associations, which could result in more specialized and successful lumbar disc prolapse care techniques.

Chapter Three: Methodology

3.1 Introduction

This chapter will address various components such as the research design, context in which the study was conducted, sample size and population, study instrument and data collection, research ethics, image analysis, data collection, and statistical analysis, and a subheading for each.

3.2 Design of Research

This research is a cross-sectional, quantitative retrospective study with no interventional elements. It seeks to establish the distribution of lumbar spine disc prolapses among different age groups and both sexes through magnetic resonance images. All materials required to complete this task were obtained from Shaheen MRI Center patient records for the specific period of January 2023 to December 2023.

3.3 Study Setting

The research was executed at Shaheen MRI Center, a diagnostic center with cutting-edge magnetic resonance imaging technology and clinical radiology expertise. The center is situated in Hebron, Palestine, catering to a population that includes patients sent from hospitals, clinics, and private practitioners. The combination of its modern computerized imaging facilities and well-qualified radiologists makes it an appropriate environment for gathering quality data for evaluating lumbar spine pathology.

This study included all lumbar spine MRI scans performed at Shaheen MRI Center over one year from January 1, 2023, to December 31, 2023. This time frame was selected to obtain relevant and up-to-date analysis of patients' distribution, referrals, and diagnoses of the present times. The MRI protocols in force at the center comply with world standards thus observing the integrity and the quality of processes. All scans were made using high-field MRI systems to achieve the best possible resolution for the assessment of lumbar disc prolapse and other degenerative diseases of the spine.

The advantage of selecting the Shaheen MRI Center is that its patient record archives are well structured with demographic characteristics such as age, sex, and radiological reports, which makes collecting the data easier and more reliable. Furthermore, the clarity of the imaging findings allows for a detailed examination of lumbosacral disc herniation across different age groups and genders. The study site therefore presents an opportunity to achieve the research aims since the data is appropriate in the clinical setting and meets the methodological requirements. The sample under study comprises all patients who had lumbar spine MRI examination during the study period.

3.4 Sample Size and Study Population

The inclusion criteria were patients with low back pain (LBP) who made use of the services rendered at Shaheen MRI Center from January 2023 to December 2023 for lumbar spine magnetic resonance imaging (MRI). A sample of 303 patients aged 18 and older was selected, ensuring representation of the older adult age group. The study included patients with low back pain who reported symptoms such as radicular pain, muscle tightness, or limited mobility. Additionally, only imaging scans that were of sufficient diagnostic quality to evaluate the structure and pathological changes of the lumbar spine were considered.

The exclusion criteria for patients included those with MRI scans that were incomplete, of poor diagnostic quality, or did not capture the entire lumbar spine. Additionally, patients under the age of 18 were excluded to focus solely on adults. This age group is less likely to experience lumbar disc prolapse and may experience different underlying causes compared to adults.

A total of 303 patients who met the inclusion criteria formed the final study sample. The patients' ages ranged from 18 years and over. This range was chosen to ensure that the study captures the differences in lumbar disc prolapse across various age groups. The calculated sample size is sufficient to analyze the statistical relationships between age, sex, and the presence of disc prolapse in the lumbar spine.

3.5 Study Instrument and Data Collection

The main instrument for data gathering in this research was the magnetic resonance imaging (MRI) system used in Shaheen MRI Center in Hebron Palestine. The center has an MRI unit with high field strength Siemens Essensa (1.5 Tesla) that helps in achieving high-resolution images of the lumbar spine. Established imaging protocols were utilized, that included T1-weighted, T2-weighted, and STIR techniques, all of which provided great details of the intervertebral discs, vertebrae, spinal canal, and the surrounding soft tissues. These sequences also facilitated the determination of the extent, position, and seriousness of the lumbar disc prolapses from the imaging studies.

The imaging data were supplemented with detailed patient records, which include information on age, gender, and clinical presentation, specifically the presence of low back pain. Additionally, each MRI scan was accompanied by post-procedural radiology reports authored by board-certified radiologists. These reports confirmed and rated how the results were depicted. The combination of high-quality imaging and comprehensive medical records enabled this study to utilize reliable tools for data collection.

3.5.1 Patient Selection

All eligible patients were identified using specific inclusion and exclusion criteria. Relevant demographic information, such as age and gender, was obtained from the patient's records. Only scans that met the required diagnostic quality were considered for further evaluation.

3.5.2 MRI Findings

The radiological reports alongside the MRI scans were carefully checked concerning the lumbar disc prolapses to see their characteristic features. Such parameters included the level of the disc involved (for example L4-L5, L5-S1), the degree of the disc prolapse like protrusion or extrusion, and other pathologies like spinal stenosis, pinched nerve, degenerative disc, and scoliosis.

3.6 Ethics Committee and Considerations

Permission was obtained by the researcher from the Shaheen MRI Center to view patient records (MRI Images and reports). This research was performed having due regard to the ethical principles of human subject research and approval from the Scientific Research Ethics Committee with the code number (R-2024/A/120/N) at the Arab American University (Appendices A). The Institutional Review Board (IRB) was secured along with approval from the facility for graduate studies at Arab American University Palestine (AAUP). Such ethical approval corresponded to the processes of respect for persons, beneficence, and justice as envisaged by international ethics.

The study employed a retrospective design, which meant that no direct contact with patients was necessary. However, significant efforts were made to ensure patient confidentiality and data security. During the data extraction process, all patient records containing MRI files were transformed into de-identified data, referred to as PII-free data, making it impossible to identify individuals. Each patient record was de-identified and assigned a unique number to facilitate analysis. Access to the data was restricted to personnel involved in the research activities, and electronic records were stored on secure networks protected by passwords.

Other ethical issues were around the protection of private data, especially concerning the patient's previous medical health and images. The protocol of the study strictly prohibited unnecessary exposure of any patient's data and elaborated details to avert probable abuse. Also, the aims and objectives, statistics, methodology, and exemption of personal data were well noted in the ethics application form and approval to avoid ethical breaches in the study.

This study respects informed consent in the context of clinical studies. Informed consent could not be sought from the participants due to the retrospective design of the study; however, a waiver of informed consent was received from the ethics panel since there are no risks to the participants and de-identified data that was already collected was used. This is consistent with ethical codes on the secondary use of medical data for research.

3.7 Lumbar Spine MRI Protocol

Magnetic Resonance Imaging (MRI) of the lumbar spine is a non-invasive method that has quite a sensitivity and is regularly employed in the assessment of degenerative disc diseases of which one is lumbar disc prolapse. This includes obtaining images of the lumbar spine using various pulse sequence imaging to look at the vertebrae, intervertebral disc, spinal cord, and soft tissue structures. Shaheen MRI Center employs standardized imaging protocols to maintain uniformity of all images and diagnostic accuracy in all MRI scans.

All patients were scanned in a supine posture on the MRI table with the lower back region placed in the center of the magnetic field. This is improved further by applying a dedicated spine coil that improves the signal of reception and image quality. It is also possible to place the cushions or pads that are provided to the patients to improve their comfort during the scan, which is aimed at reducing motion artifacts.

Performing magnetic resonance imaging always includes acquiring T1-weighted sequences which allow focusing on anatomy and fat-rich tissues, as well as T2-weighted sequences which are the primary sequences for body fluid and pathological changes including disc or root strain identification. Some sequences such as the short tau inversion recovery (STIR) or T2-weighted fat-suppressed imaging might be used to enhance inflammation or edema signal intensity in soft tissues.

The scanning area usually reaches from the T11 vertebra to the mid part of the coccyx with a field of view of around 350 mm which includes all sections of the lumbar spine. The slice thickness is three to four millimeters with the minimization of the interslice gap so that appropriate spatial resolution is achieved.

Axial images were obtained perpendicularly to the disc plane, which makes it possible to perform a detailed study of intervertebral discs and foraminal regions. Using sagittal images, assessment of the entire spinal canal, vertebral configuration and disc degree of degeneration or protrusion is possible. If more details are necessary, further contrast-enhanced sequences have been found in patient MRI images that can better delineate neoplasms, infection, or inflammation.

3.7.1 Lumbar Spine MRI Sequences

3.7.1.1 T2 Turbo Spin Echo Sagittal Sequence

A key element in lumbar spine MRI protocols, the T2-weighted turbo spin echo (TSE) sagittal sequence is useful for the diagnosis of spinal conditions. The sequence facilitates a proper visualization of structures containing large water volume such as the intervertebral discs, the CSF, and regions that are edematous or inflamed. In patients with low back pain, TSE is also unsurpassed for evaluation of degenerative changes, disc herniations, and spinal canal abnormalities which are most often encountered due to their high SNR and contrast resolution.

In the sagittal position, the lumbar spine's lateral edges are around the midline up to the T2 TSE sequence. This perspective presents a view of the spinal cavity, vertebrae, discs, and nerves. Greater sensitivity to the water of T2-weighted imaging causes deterioration of disc structures to be seen more strongly for instance disc dehydration is a hypointense signal and disc bulges/herniations may cause the disc to push against related neural elements. The hyperintense thecal sac CSF also provides excellent contrast to the spinal cord and roots of the nerves, assisting with visualizations of nerve root compressions or spinal stenosis.

A TR of 2600 ms and TE of 87 ms are the typical parameters for this sequence as they are optimized for improved contrast in tissues with different water content. A slice thickness of 4 mm and a field of view (FOV) encompassing the entire lumbar area are adopted to aid in achieving strong detail but still high spatial resolution.

Table 3.1: T2 TSE Sagittal Sequence Parameters.

TR	TE	Slice Thickness	Flip Angle	Phase	FOV Phase	Matrix	FOV	Gap	NEX
2600	87	4	150	H-F	100%	288X320	280	20%	2

Figure 3.1: T2 TSE Sagittal.

3.7.1.2 T1 Turbo Spin Echo Sagittal Sequence

The T1-weighted turbo spin echo (TSE) in the sagittal orientation is critical in the lumbar spine MRI protocols as it assists in providing detailed images of the vertebral column, the intervertebral discs, and the structures around them. This sequence is particularly valuable for the evaluation of vertebrae, determining, for example, fat within the bone marrow, and its pathological conditions such as fractures, bone marrow edema, or tumors. It also supplements T2-weighted sequences due to high spatial resolution, so that the test is complete with the lumbar spine evaluation of pathologies.

The T1 TSE on the sagittal plane features a long-axis view of the lumbar spine with its characteristics in terms of vertebrae and the spaces between them. This sequence is useful in identifying, cases cell-bone marrow is replaced, by a tumor or infection that causes an area of low signal. It also helps visualize slight changes to endplates along with degenerative disc disease by showing distortion of the bone structures adjoining the vertebrae and the boundary of the discs.

The turbo spin echo sequence increases the imaging efficiency by performing more than one phase-encoding step for every repeat time (or TR), which shortens the duration of the scan while images of good quality are still produced. Common settings of this sequence are TR: 563 ms, and echo time (TE): 11 ms, aimed at improving the contrast between the fatty structures and the remaining tissues.

The slice thickness is commonly 4 mm, and the field of view (FOV) is designed to cover the whole region of the lumbar to guarantee the total contribution of the entire region. This sequence is usually obtained during the acquisition of T2-weighted sagittal images, thus facilitating two views in differentiating between normal and abnormal anatomic structures.

Table 3.2: T1 TSE Sagittal Parameters.

TR	**TE**	**Slice Thickness**	**Flip Angle**	**Phase**	**FOV Phase**	**Matrix**	**FOV**	**Gap**	**NEX**
563	11	4	150	H-F	100%	272X320	280	20%	2

Figure 3.2: T1 TSE Sagittal.

3.7.1.3 Turbo Inversion Recovery Magnitude (TIRM) Coronal Sequence

The T1 Turbo Inversion Recovery Magnitude (TIRM) coronal sequence is a new MRI protocol that is aimed at improving soft tissue visualization, bone and pathological structures in the lumbar region. TIRM is a fat suppression imaging sequence that employs an inversion recovery pulse designed to eliminate the signal from fat and aid in better-distinguishing fat from water-containing tissues.

This characteristic helps detect edema and inflammatory processes, or even only slight changes to the bone marrow and surrounding soft tissue structures in the context of the lumbar spine pathology like degenerative disc diseases or trauma.

The TIRM offers a good overview of the lumbar area as well as the paravertebral muscles, sacroiliac joints, and their connective tissue in the coronal plane. This view assists greatly in assessing the lumbar curvature and rotation by providing a view of the spine's overall positioning relative to the sacrum. In this way, it is easier to detect deformities such as scoliosis, fracture, or soft tissue changes such as edema. Fat suppression provided by the TIRM technique makes visible bone marrow edema or inflammatory changes which are enhanced on conventional T1-weighted images by the fat signals.

The TIRM sequence works with defined imaging parameters for best diagnostics capabilities. Typical settings include an inversion time (TI) of 180 ms, which crushes the fat signal, and a repetition time (TR) equal to 1800 ms together with an echo time (TE) of 34 ms to enhance the tissue contrast. Slice thickness is usually 5 mm to provide adequate spatial resolution while encompassing the whole lumbar spine and the surrounding tissues. The TIRM application in the coronal plane adds other anatomical details when in sagittal and axial imaging especially when soft tissue pathology or its peripheral structures are present.

Table 3.3: T1 TIRM Sequence Parameters.

TR	TE	Slice Thickness	Flip Angle	Phase	FOV Phase	Matrix	FOV	Gap	NEX
1800	34	5	180	F-H	90.6%	197X256	291	30%	2

Figure 3.3: T1 TIRM Coronal.

3.7.1.4 T2 Turbo Spin Echo Fat Saturation Axial Sequence

T2 Turbo Spin Echo (TSE) Fat Saturation Axial Sequence MRI is vital in the protocols of lumbar spine MRI since it serves to take clear cross-sectional images that can be used to examine pathological changes. It performs a critical role in minimizing the fat signals which results in better imaging of water-containing tissues including, intervertebral discs, nerve roots, ligaments, and even edema and inflammatory sites. It is useful in highlighting the abnormalities and thus is also useful in the diagnosis of diseases

like disc herniation, narrowing of the spinal canal, impingement of nerve roots, and soft tissue edema.

The T2 fat-saturated images acquired in the axial plane also provide a transverse view of the lumbar spine, intervertebral disc, neural foramina, and their relationship with the surrounding soft tissues more accurately. Tissue saturation effectively suppresses the high intensity of lipids, allowing for a better view of high-intensity fluids caused by torn annulus fibrosus, nerve root involvement, and even inflammation. This is especially critical in the evaluation of foraminal or extraforaminal disc herniations, where adjacent fat could obscure subtle pathologies on non-fat-saturated sequences.

These images also employ the turbo spin echo technique which shortens the time required to scan, while still delivering high-resolution pictures that are useful in practice. A repetition time (TR) of 3220 ms and an echo time (TE) of 88 ms are the norm if they concentrate on structures with liquid in them. Thick slices of 4 mm without interslice spaces are the norm in practice as they guarantee adequate scanning of the lumbar spine.

Table 3.4: T2 TSE Axial Fat Sat Parameters.

TR	**TE**	**Slice Thickness**	**Flip Angle**	**Phase**	**FOV Phase**	**Matrix**	**FOV**	**Gap**	**NEX**
3220	88	4	150	A-P	100%	288X320	200	20%	2

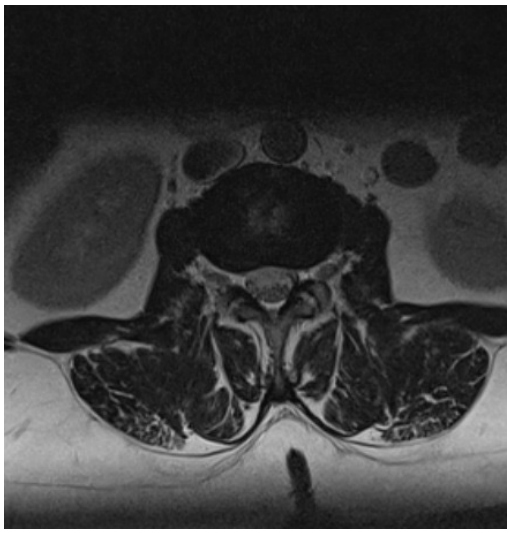

Figure 3.4: T2 TSE Fat Sat Axial.

3.7.1.5 Proton Density (PD) Fat Saturation Axial Sequence

The proton density (PD) fat saturation axial sequence is a specialized imaging technique used in lumbar spine MRI protocols to provide high-resolution, detailed cross-sectional views of the spine with excellent contrast between anatomical structures. This sequence is particularly effective in identifying and assessing subtle pathological changes in the intervertebral discs, neural foramina, and surrounding soft tissues.

Fat saturation and fat suppression in addition to the proton density weighting enable the interface visualization between tissues but at the same time turn off the signal of fat tissue which makes inflammation, edemas, and nerve root impingement much easier to detect.

In the axial plane, this sequence provides a transverse perspective of the lumbar spine, focusing on the intervertebral discs, spinal canal, nerve roots, and adjacent structures. Proton density weighting is ideal for assessing tissue integrity, as it provides intermediate contrast between water and fat, providing clarity in distinguishing structures that have varying degrees of proton density. The use of fat saturation nullifies the signal of fat tissue which helps in defining small pathological changes making it more diagnostic. This is especially useful when assessing foramina stenosis, and extraforaminal disc hernia.

In the case of the PD fat saturation axial images, all parameters are optimized for spatial resolution and contrast sensitivity. To enhance the detail of the tissues, TR and TE are usually set at 1340 ms and 9.4 ms respectively. The slice thickness is generally 4 mm with less gap between multiplanar slices, thereby providing complete coverage of the lumbar region.

Table 3.5: PD TSE Axial Fat Sat Parameters.

TR	TE	Slice Thickness	Flip Angle	Phase	FOV Phase	Matrix	FOV	Gap	NEX
1340	9.4	4	150	A-P	100%	197X256	200	10%	2

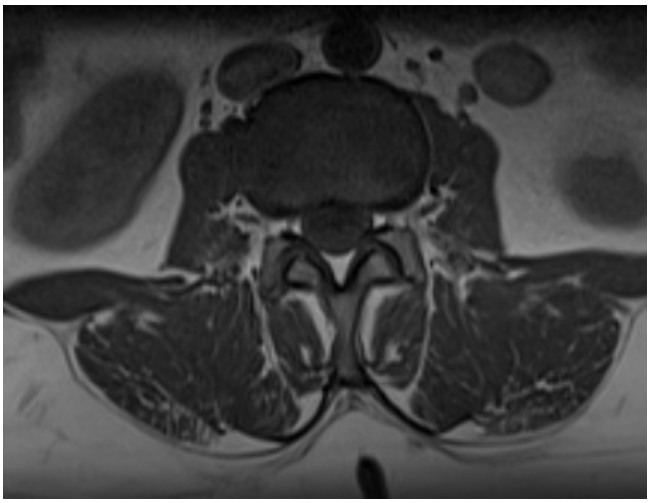

Figure 3.5: PD TSE Fat Sat Axial.

3.7.2 Lumbar Spine MRI Sequences with Intravenous Contrast

To monitor the changes that occur after the injection, gadolinium is typically given by IV at a dosage of 0.1mmol/kg. Typically, standard imaging protocols consist of T1-weighted sequences without a contrast agent placed first, and then several T1-weighted sequences with a contrast agent placed in the post period in sagittal, axial, and at times, coronal planes. When combined with fat suppression techniques, they increase the contrast between the enhancing and non-enhancing tissues, further assisting in the detection of subtle pathologies.

Even though Gadolinium is generally well tolerated, its use is subject to some scrutiny regarding patient safety measures. As kidney disease, past histories of severe allergic reactions to contrast agents are interpreted as doing the same which explains their mention as contraindications. It is common for renal function to be checked before administering for patients with chronic renal diseases.

3.7.2.1 T1 Fat Suppression Sagittal Post-Contrast Sequence

The sequence could have a TR of 857 ms and TE of 11 ms, which should be optimized for tissue contrast. Thickness of slice is generally kept at 4 mm to obtain a high spatial resolution. For fat suppression, one applies techniques such as SPAIR (Spectral

Attenuated Inversion Recovery) that provide for a standardized suppression of fat signals without affecting detecting pathology.

Table 3.6: T1 TSE Sagittal Fat Sat Post Contrast Parameters.

TR	TE	Slice Thickness	Flip Angle	Phase	FOV Phase	Matrix	FOV	Gap	NEX
857	11	4	150	H-F	89.8%	184X256	280	10%	2

Figure 3.6: T1 TSE Fat Sat Sagittal Post Contrast.

3.7.2.2 T1 Fat Suppression Axial Post-Contrast Sequence

Typical parameters for the T1 fat suppression axial post contrast include repetition time (TR) of 360 ms and echo time (TE) 10 ms to optimize those tissues which enhance to contrast with non-enhancing tissues. The slice thickness is routinely 5 mm while superior interslice gap is used to provide detailed lumbar imaging. High order fat saturation preparations including spectral fat saturation (SPAIR) are used to provide uniform fat signal nulled images necessary for enhancement pattern analysis.

Table 3.7: T1 TSE Axial Fat Sat Post Contrast Parameters.

TR	TE	Slice Thickness	Flip Angle	Phase	FOV Phase	Matrix	FOV	Gap	NEX
360	10	5	150	A-P	90%	197X256	220	10%	2

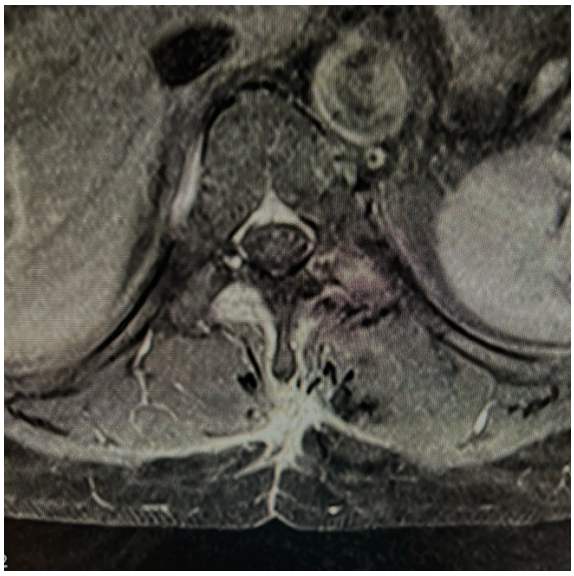

Figure 3.7: T1 TSE Fat Sat Axial Post Contrast.

3.8 Evaluation of MRI Reports

The initial stage included obtaining institutional approvals from the Shaheen MRI Center's relevant authorities to ensure that institutional requirements and ethical considerations regarding patients' data usage could be adhered to. Approvals were obtained in line with the requirements of the law on data privacy and those of the ethical principles of research so that all approaches to patient confidentiality and data protection were observed during the study. Determining also included the description of data collection, storage, and analysis to avoid any doubts in the research.

After receiving approvals, MRI reports along with details of patients were collected in an orderly manner. The reports were derived from the radiology department records of the center, whose focus was on patients who had undergone lumbar spine MRI scans from first of January to 31 December 2023. During the selection procedure, inclusion criteria

including lumbar disc prolapse and basic information which included age and sex of patients were not violated.

The reports specified radiological details, while patient case histories consist of clinical particulars such as clinical picture, treatment procedures performed in the past and existing chronic diseases. These aggregate data points were the basic reasons for assessing the association between lumbar disc prolapse as well as the measured demographic variables.

For the purposes of analysis, data were managed in Microsoft Office Excel, a multifunctional application for database management. Basic data variables, such as the patient's age, sex, MRI results, and particulars of the clinical history, were all recorded into columns. Such a database was also efficient in organizing, piloting, and performing analytics on the data. The capabilities of Excel further assisted in visual representation of the data in identifying trends and patterns which aided in further understanding the results.

3.9 Data Collection

The study procedure for data collection was depicted in a figure below:

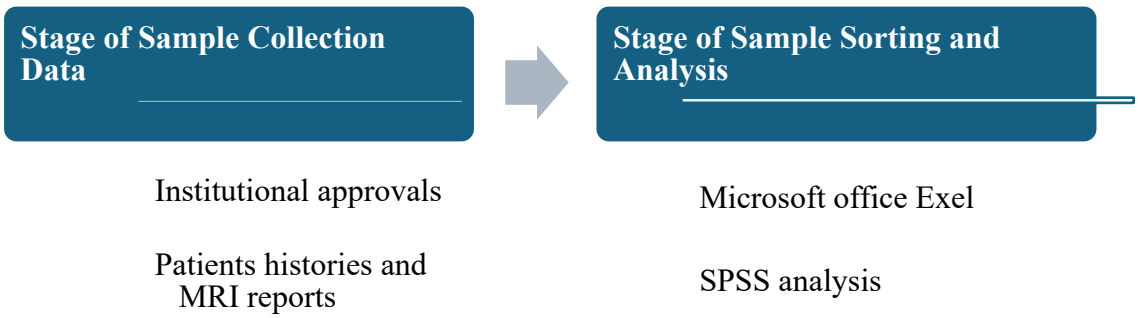

Figure 3.8: Summarize the sample collection procedure.

3.10 Statistical Analysis

IBM SPSS Statistics 26 was used in the statistical analysis for this study which streamlined the process of analysis and interpretation of data. The demographic as well as clinical features of the participants were analyzed using descriptive statistics. Some measures were computed for continuous variables e.g. age using mean and standard deviation; while categorical variables such as gender, and some MRI findings were analyzed using frequency and percentages. With such descriptive statistics, basic information regarding the dataset has been given to help comprehend the distribution and features of the population under study.

The Chi-square test was employed to investigate the differences between the study variables as well as the relations between them. Since variable types and their nature differ, Chi-square test as a non-parametric test is appropriate here as it enables assessment of relationships between variables of constant level such as distribution of age or sex of an individual with lumbar disc prolapse disease. The Chi-square used to compare actual frequencies with theoretical frequencies was helpful in establishing whether there were important linkages among these variables, thereby showing their likely demographic trends in lumbar disc prolapse.

Additionally, a Pearson correlation analysis was carried out to compare continuous variables which in this case were age and the degree of lumbar disc prolapse non bulging. This test also gave other information which was the strength of linearity in the relationship of the variables bringing out aspects of trends or association in the data set. The p-values obtained from these statistical tests were assessed at the 0.05 level of significance, thus inferring that the results were meaningful and not due to randomness.

Chapter Four: Results

4.1 Data Collection

The data collection process focused on patients with low back pain (LBP) who underwent lumbar spine MRI at Shaheen MRI Center within the year 2023 from January to December. 303 adult patients aged eighteen years and above were recruited into the study to underscore their representation of adults and the elderly population frequently afflicted by degenerative lumbar spine diseases. Eligible patients exhibited signs and symptoms including but not limited to radial pain, muscle tightness, or limited range of motion. MRI studies that qualified for inclusion only included those of diagnostic quality and assessed the entire lower back region.

The criteria for exclusion included children and adolescent patients who are less likely to have lumbar disc prolapse, and MRI studies that were not completed, low quality, or did not sufficiently visualize the lumbar area. This enabled the inclusion of only the relevant high-quality data for the evaluation of lumbar spine changes in adult populations and formed a strong foundation for the evaluation of the correlation between demographic characteristics and histopathological changes.

4.2 Demographic characteristics of patients

A total of 303 patients participated in this study which serves as a large cohort for investigation of pathologies of the lumbar spine. The demographic distribution showed that a great proportion of the subjects recruited were from the age bracket between 40-59 years, which is the most recurrent age range with degenerative spine diseases. Such distribution concurs with epidemiological studies concerning the increasing number of musculoskeletal disorders in middle-aged people in the population.

Additionally, the gender composition indicated that although there were fewer numbers of females, the females constituted 43.6% as compared to males who were 56.4% which explains the variations in the prevalence or reporting of lumbar spine problems in males and females. These findings may also suggest that other factors like

occupation and lifestyle contribute to the degeneration of the lumbar spine region and this calls for exploration of gender tailored risk factors.

Most of the patients, whereby 30.7% (n=93) never exercised, 33.3% (n=101) stated they performed physical exercises, frequently did exercises but rarely, while only 12.5% (n=38) performed exercises regularly. Such figures emphasize the importance of physical activity because a lack of physical activity is a significant risk for musculoskeletal health. Only 2.0% (n=6) adhered to strict exercises.

These findings highlight the role of physical inactivity in degenerating the lumbar spine since these patients don't engage in physical activity as stated in the report. The low percentage of subjects with regular exercise habits may be representative of the pressure of time, lack of awareness, or even existing conditions that limit movement.

Most Patients (91.4%; n=277) had no prior history of spine surgeries, emphasizing that in most cases, the patients were treated conservatively, or the disease did not advance to a stage that required surgical treatment. Of the few patients who had spine surgery in the past, the L4-L5 level and L5-S1 levels were the common operating levels. Each accounted for 4.0% (n=12) of the cases.

The results support the previous studies stressing the biomechanical importance of those levels that are exposed to high forces and are also at a higher risk of undergoing degenerative changes. Only 0.7% (n=2) of the surgical cases performed were in the L2-L3 level, this is also quite consistent with the lesser incidence of abnormalities in this area.

After the spine surgery, MRI referrals were few as only 8.6% (n=26) of patients received imaging after surgery. Such a low incidence rate might give an impression of outcomes which suggests most of the cases are operated successfully or the postoperative management is conservative. On the other hand, it might indicate under use of MRI in postoperative follow-up care which might be detrimental to identifying recurrent or remaining diseases (Table 4.1).

Table 4.1 Demographic characteristics of the participants (N=303)

Variable	% (n)
Age Group	
18 – 29	12.5 (38)
30 – 39	18.2 (55)
40 – 59	50.8 (154)
60 – 74	15.2 (46)
> 75	3.3 (10)
Gender	
Male	56.4 (171)
Female	43.6 (132)

Table 4.2: Exercise Frequency, Lumbar Spine Surgery, and MRI Follow-Up in Patients

Variable	% (n)
How often does the patient exercise?	
Never	30.7 (93)
Rarely	33.3 (101)
Sometimes	21.5 (65)
Often	12.5 (38)
Always	2 (6)
Underwent lumbar spine surgery	
Yes	8.6 (26)
No	91.4 (277)
MRI Requested for Follow-Up Evaluation	
Yes	8.6 (26)
No	91.4 (277)
Lumbar spine surgery level	
L2 -L3	0.7 (2)
L4 -L5	4 (12)
L5 -S1	4 (12)

All 303 participants reported experiencing lower back pain. The predominant presentation was pure low back pain (76.2%, n=231), followed by motor-related pain, primarily characterized by foot drop (23.8%, n=72). Sciatica was a common comorbidity, affecting 27.1% (n=82) of participants on the right side, 28.1% (n=85) on the left, and 44.9% (n=136) bilaterally.

Regarding pain duration, 18.5% (n=56) experienced acute pain, 41.6% (n=126) subacute pain, and 39.9% (n=121) chronic pain. Associated symptoms included stiffness (23.4%, (n=71)), postural abnormalities (25.4%, n=77), and muscle spasms (51.2%, n=155), which were most prevalent (Table 4.2).

Table 4.3: Pain characteristics among participants (N=303)

Variable	% (n)
Does the patient have lower back pain?	
Yes	100 (303)
No	-
Type of pain	
Pure low back pain (Sensational)	76.2 (231)
Motor pain (drop foot)	23.8 (72)
Pain radiating to lower extremities	
Yes	100 (303)
No	-
Which side does the pain radiate to?	
Right side	27.1 (82)
Left side	28.1 (85)
Both side	44.9 (136)
Duration of lower back pain	
Acute pain (less than 6 weeks)	18.5 (56)
Sub-acute pain (12 weeks)	41.6 (126)
Chronic pain (more than 12 weeks)	39.9 (121)
Associated signs and symptoms of pain	
Stiffness (Back movement may be difficult.)	23.4 (71)
Posture problems (hard to stand up straight)	25.4 (77)
Muscle spasms (Lower back muscles may spasm).	51.2 (155)

All participants were adequately prepared for lumbar MRI and had no allergies to MRI contrast media; only 4.3% (n=13) underwent MRI with contrast. MRI findings highlighted various conditions, including osteoarthritis (28.7%, n=87), ankylosing spondylitis (13.9%, n=42), spinal stenosis (27.1%, n=82), herniated disk (100%, n=303), pinched nerve (94.1%, n=285), back strains and sprains (16.8%, n=51), and degenerative disc disease (54.1%, n=164). Intervertebral disc compression was generally mild to moderate, especially at the L4-L5 and L5-S1 levels. Abnormal spinal growths were found in 31.0% (n=94), mainly as bone spurs (25.1%, n=76). Spondylolisthesis was rare, with only 4.0% (n=12) of participants showing Grade I slippage (1-25%).

Among the participants, 31.0% (n=94) exhibited abnormal spinal growth, including tumors (2.3%, n=7), cysts (2.6%, n=8), and bone spurs (25.1%, n=76), while 69.0% (n=209) had no growth. A small subset (1.0%, n=3) reported an unspecified growth type. Regarding spondylolisthesis, 4.0% (n=12) were identified with Grade I, while 96.0% (n=291) showed no slippage. The use of contrast media in detecting lumbar spine disk disease (sequestration) was noted by 4.3% (n=13) to have a significant impact, while 95.7% (n=290) showed no effect. Similarly, 4.6% (n=14) reported contrast media aiding the detection of other spinal pathologies, while 95.4% (n=289) did not. MRI image patterns revealed a non-enhancing pattern in 97.0% (n=294), with only 3.0% (n=9) showing enhancement (Table 4.3).

Table 4.4: MRI Findings and Characteristics among Participants (N=303)

Variable	% (n)
Was the MRI examination done with contrast media?	
Yes	4.3 (13)
No	95.7 (290)
MRI Findings	
Osteoarthritis	28.7 (87)
Ankylosing spondylitis	13.9 (42)
Spinal stenosis	27.1 (82)
Herniated disk	100 (303)
Pinched nerve	94.1 (285)
Back strains and sprains	16.8 (51)
Spinal fractures	0.3 (1)
Spondylolisthesis	5 (15)
Spondylolysis	2.3 (7)
Lumbar scoliosis	19.1 (58)
Vertebral compression fracture	3.3 (10)
Degenerative Disc Disease	54.1 (164)
Grade of intervertebral disc compression at	
L1-L2	
Minimal	0.3 (1)
Mild	3.3 (10)
Moderate	3.6 (11)
Sever	-
No Compression	92.7 (281)
L2-L3	
Minimal	0.3 (1)
Mild	11.9 (36)
Moderate	8.3 (25)

Sever	1 (3)
No Compression	78.5 (238)
L3-L4	
Minimal	1.3 (4)
Mild	28.4 (86)
Moderate	16.8 (51)
Sever	1.3 (4)
No Compression	52.1 (158)
L4-L5	
Minimal	2.3 (7)
Mild	51.8 (157)
Moderate	37.3 (113)
Sever	2 (6)
No Compression	6.6 (20)
L5-S1	
Minimal	2 (6)
Mild	45.2 (137)
Moderate	33 (100)
Sever	2.6 (8)
No Compression	17.2 (52)
Is there any abnormal spinal growth?	
Yes	31 (94)
No	69 (209)
If yes, what type of abnormal growth?	
Tumors	2.3 (7)
Cysts	3.3 (10)
Bone spurs (Osteophytes)	25.4 (77)
If present, what is the grade of spondylolisthesis?	
Grade I (1 to 25% slippage)	69 (209)
Grade II (up to 50% slippage)	-
Grade III (up to 75% slippage)	-
Grade IV (76-100% slippage)	-
Did contrast media impact the detection of lumbar spine disk disease?	
Yes	4.3 (13)
No	95.7 (290)
Did contrast media affect the detection of other spinal pathologies?	
Yes	4.6 (14)
No	95.4 (289)
What is the type of contrast media appearance (tumor, cyst, etc.) in the MRI image?	
Enhancing pattern	3 (9)
Non-enhancing pattern	97 (294)

4.3 Pain Characteristics and Gender

A gender-based analysis of pain characteristics revealed no significant differences in the type of pain experienced, with both males and females showing similar distributions of low back pain and motor pain (e.g., drop foot) (X^2= 0.978, p = 0.343). Similarly, there were no significant gender differences in the side of pain radiation (right, left, or both) (X^2= 3.357, p = 0.187).

However, a significant gender difference emerged in the duration of low back pain. Males were more likely to report sub-acute pain, while females more often reported chronic pain (X^2=11.827, p = 0.003). A weak positive correlation (r = 0.197, p = 0.001) supported this finding, indicating that females are more likely to experience chronic low back pain compared to males.

4.4 MRI Imaging and Spinal Conditions

Regarding MRI-related factors, there was no strong gender differences correlation when most of the conditions studied, such as the allergy to the contrast media, use of a contrast-enhanced MRI, or exciting pathologies such as osteoarthritis, ankylosing spondylitis, spinal stenosis, herniated disks, and spondylolisthesis, these findings indicate that there is the equality in the frequency and imaging phenotypes of these diseases across sexes.

It is well documented in the literature that the development of these pathologies is indeed multifactorial with the most determining factors being age, genetics, and lifestyle rather than sex. The absence of significant differences in contrast media reactions and contrast use further supports the safety and uniform applicability of MRI protocols across genders in clinical practice.

On the other hand, an exception was noticed in lumbar scoliosis, where a significant association was evident. Further analysis revealed a weak negative correlation (r = -0.114, p = 0.001), showing that there were only minor and statistically salient gender disparities concerning the lumbar scoliosis in question. This finding indicates that although both males and females may develop scoliosis, the degree of development or the factors that

are involved in its development are different. For instance, adolescent females are more linked with idiopathic scoliosis while degenerative scoliosis is more common in older males due to aging of the spine. The negative correlation may be due to such effects of different causes of scoliosis and the factors of age and other demographics.

4.5 Compression Grade and Gender

The examination of the compression grades to the lumbar vertebrae L1-L2, L2-L3, L3-L4, L4-L5, and L5-S1 confirmed that, except for some levels, most of the relationships under analysis were not significantly related to gender ($p > 0.05$). These findings imply that, over most areas of the lumbar region, both males and females experience compression changes (disc herniation or stenosis) with similar distributions and severities. This is consistent with other evidence which indicates that factors such as age, mechanical loading, and degeneration of the lumbar spine are more influential than gender with regards to lumbar loading. Results continue to highlight the need to look at other potential sources of influence, such as occupation or lifestyle, in the assessment of compressive-related lumbar spine pathology.

It is noteworthy that a statistically significant relationship has been noted at the L5-S1 level ($p = 0.024$) and a weak positive correlation ($r=0.181$, $p=0.001$) with sex-revealed distributional differences in compression grades between males and females.

4.6 Abnormal Spinal Growth

This study's research demonstrated that there was a significant interaction between gender and the occurrence of abnormal spinal change which is suggested by the negative correlation ($r = -0.173$, $p = 0.003$). This means that there are more males with abnormalities of spinal growth than females.

4.7 Spinal Pathologies

Regarding spinal pathologies, no significant associations were found between gender and conditions such as spondylolisthesis, MRI contrast media impact on lumbar

disk disease detection, or various spinal pathologies ($p > 0.05$). These results indicate that most spinal conditions do not exhibit notable gender-based differences in this sample.

Table 4.5: Chi-Square Analysis of Pain-Related Variables, MRI Findings, and Intervertebral Disc Compression by Sex (N=303)

Variable	Male N (%)	Female N (%)	X^2 Value	P Value
Pain-Related Variables				
Type of Pain				
Pure low back pain	134 (78.4%)	97 (73.5%)	0.978	0.323
Motor pain	37 (21.6%)	35 (26.5%)		
Side of Pain Radiation			3.357	0.187
Right	45 (26.3%)	37 (28.0%)		
Left	42 (24.6%)	43 (32.6%)		
Both	84 (49.1%)	52 (39.4%)		
Lower Back Pain Duration			11.827	0.003
Acute (under 6 weeks)	40 (23.4%)	16 (12.1%)		
Sub-acute (6–12 weeks)	76 (44.4%)	50 (37.9%)		
Chronic (over 12 weeks)	55 (32.2%)	66 (50.0%)		
MRI Imaging Findings				
Osteoarthritis	49 (28.7%)	38 (28.8%)	0.001	0.980
Ankylosing Spondylitis	19 (11.1%)	23 (17.4%)	2.487	0.115
Spinal Stenosis	48 (28.1%)	34 (25.8%)	0.202	0.653
Pinched Nerve	158 (92.4%)	127 (96.2%)	1.940	0.164
Back Strains and Sprains	28 (16.4%)	23 (17.4%)	0.059	0.809
Spinal Fractures	0 (0%)	1 (0.8%)	1.300	0.254
Spondylolisthesis	11 (6.4%)	4 (3.0%)	1.833	0.176
Spondylolysis	4 (2.3%)	3 (2.3%)	0.001	0.970
Intervertebral Disc Compression				
L1-L2			4.713	0.194
Minimal	1 (0.6%)	0 (0.0%)		
Mild	6 (3.5%)	4 (3.0%)		
Moderate	3 (1.8%)	8 (6.1%)		
No Compression	161 (94.2%)	120 (90.9%)		
L2-L3			4.217	0.377
Minimal	1 (0.6%)	0 (0.0%)		
Mild	19 (11.1%)	17 (12.9%)		
Moderate	10 (5.8%)	15 (11.4%)		
Severe	2 (1.2%)	1 (0.8%)		
No Compression	139 (81.3%)	99 (75.0%)		
L3-L4			2.481	0.648
Minimal	2 (1.2%)	2 (1.5%)		
Mild	47 (27.5%)	39 (29.5%)		
Moderate	25 (14.6%)	26 (19.7%)		
Severe	3 (1.8%)	1 (0.8%)		

No Compression	94 (55.0%)	64 (48.5%)		
L4-L5			2.115	0.715
Minimal	4 (2.3%)	3 (2.3%)		
Mild	88 (51.5%)	69 (52.3%)		
Moderate	64 (37.4%)	49 (37.1%)		
Severe	5 (2.9%)	1 (0.8%)		
No Compression	10 (5.8%)	10 (7.6%)		
L5-S1			11.205	0.024
Minimal	3 (1.8%)	3 (2.3%)		
Mild	89 (52.0%)	48 (36.4%)		
Moderate	55 (32.2%)	45 (34.1%)		
Severe	4 (2.3%)	4 (3.0%)		
No Compression	20 (11.7%)	32 (24.2%)		
Abnormal Growth in Spine			9.108	0.003
Yes	41 (24.0%)	53 (40.2%)		
No	130 (76.0%)	79 (59.8%)		
Type of Abnormal Growth			17.897	0.001
Tumors	0 (0.0%)	7 (5.3%)		
Cysts	6 (3.5%)	2 (1.5%)		
Bone Spurs (Osteophytes)	34 (19.9%)	42 (31.8%)		
No Growth	130 (76.0%)	79 (59.8%)		
Spondylolisthesis Grade			1.751	0.186
Grade I (1-25% Slippage)	9 (5.3%)	3 (2.3%)		
No Spondylolisthesis	162 (94.7%)	129 (97.7%)		

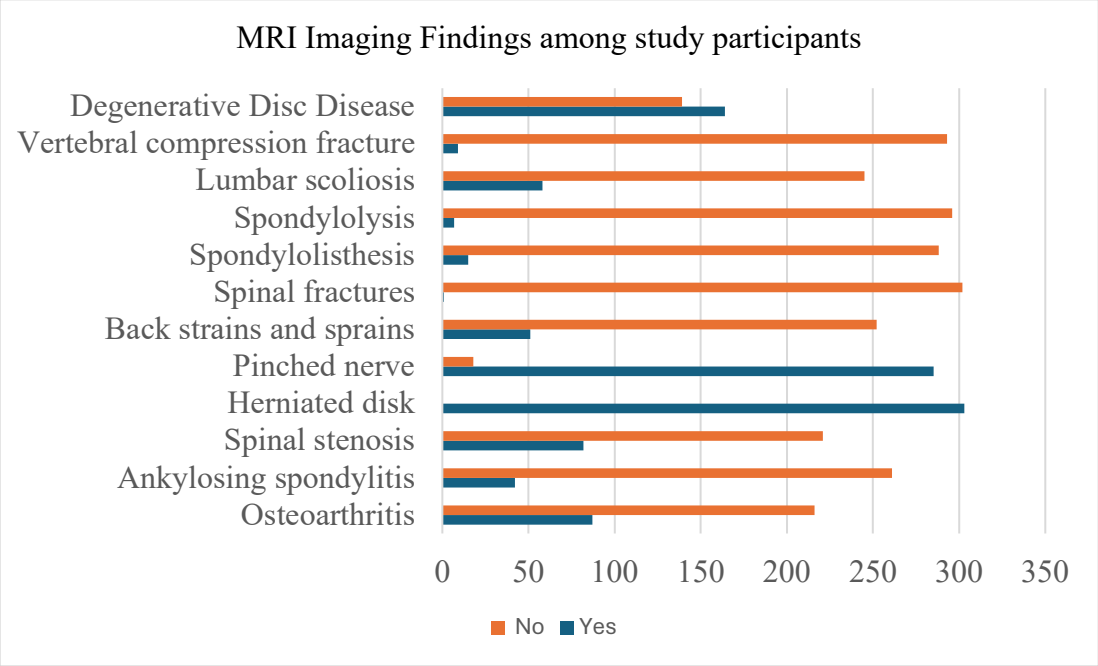

Figure 4.1: Demographic chart showing MRI findings for all participants (N=303).

4.7.1 Osteoarthritis in Males and Females

The findings of this study enhance the understanding of the occurrence and attributes of osteoarthritis among males and females with lumbar spine diseases. As many as (n=87) of the study participants were found to have osteoarthritis which supports its status as a frequent comorbidity in people who have lower back pain and other conditions. Regarding the overall prevalence rates, there were no distinguishable differences between males and females, however, there were slight variations in clinical and demographic patterns.

Among participants diagnosed with osteoarthritis, the distribution between both sexes was almost the same, females had an affected proportion of 28.8% (n=49) while males had 28.7% (n=38). This isosceles creates a strong indication that both females and males are affected by osteoarthritis. However, the underlying processes as well as the clinical picture may vary because of varying biology, hormones, and way of life of the person.

In females, osteoarthritis was more often associated with persistent pain and other systemic manifestations such as fatigue and generalized aches of the muscles and joints. It is thought that gender characteristics especially changes in estrogen concentration, are of particular importance in the pathogenesis of osteoarthritis in females. One of the main roles that estrogen plays is shielding joint health and its deficiencies acquired during menopause may lead to an aggravation of cartilage degeneration and subsequently osteoarthritis. This hormonal effect may equally explain the prevalence of generalized pain and less functional mobility among females with osteoarthritis of the lumbar spine.

Additionally, the understanding of osteoarthritis in females also appeared to include a stronger correlation with other spinal conditions such as spinal stenosis and degenerative disc disease. This implies that women with osteoarthritis are likely to have other degenerative diseases, thus necessitating a more in-depth diagnostic and treatment approach.

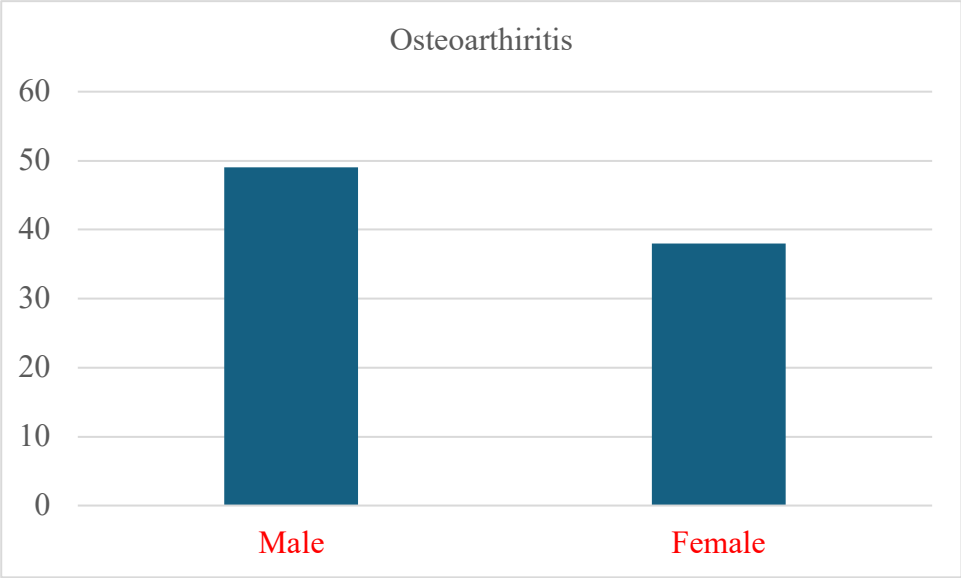

Figure 4.2: Osteoarthritis in Males and Females.

4.7.2 Ankylosing Spondylitis in Males and Females

The findings of the present study draw attention to ankylosing spondylitis (AS) as a prominent disease amongst the subjects, with a general prevalence of (N=42). Though this inflammatory spinal pathology was noted in both males and females, it was however noted that there were marked differences in gender in terms of prevalence and clinical characteristics.

In this cohort, the incidence of ankylosing spondylitis appeared to be greater in females, with (n=23) of females as compared to (n=19) of males. It mirrors increasing evidence that AS may be underdiagnosed in women because of such presentations that are atypical and therefore differ in the progress of the disease. The gender difference seen in this study points to the need to consider gender differences when assessing and making a diagnosis of AS.

Ankylosing spondylitis in males presented with features typical of the disease which were low backache, spinal fusion, and stiffness. These characteristic features were usually accompanied by structural MRI pathology such as sacroiliitis with features of the beginning of spinal fusion. The greater prevalence of male structural damage would support the theory that men with the disease have a more aggressive type of the disease

which rapidly evolves to axial joint and spinal fusing and deformities. Such factors could be the alterations in bone remodeling and inflammatory pathways.

The study also indicated that women with ankylosing spondylitis had a more diverse and at times more subtle presentation of the condition than men. Their first-time presentation of their conditions frequently showed non-localized symptoms such as fatigue and stiffness in the back among females, and throughout the rest of the body in males. Female ankylosing spondylitis patients display MRI results that are milder in most structural fractures, and the sacroiliitis. These demonstrate how females with this disease might have merged vigorous signs but develop over a period slowly progressive condition with time resulting in delayed treatment.

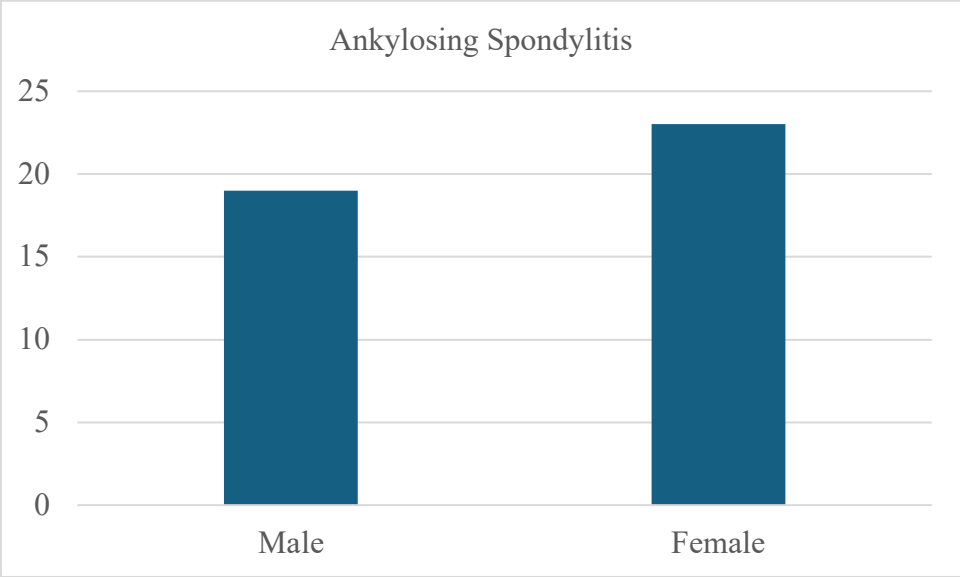

Figure 4.3: Ankylosing Spondylitis in Males and Females.

4.7.3 Spinal Stenosis in Males and Females

The findings of this study pointed out that spinal stenosis has not only been a notable comorbidity among the participants of the study but also accounted for a significant average of (n=82) of the study participants. This pathological condition that results in reduced cross-sectional area of the spinal canal or the intervertebral foramina which may result in pressure on the nerves showed some significant differences regarding gender in the rate of occurrences, some clinical symptoms as well as some diagnostic

images obtained. These differences are important to note because they affect the ways that diagnostic and therapeutic procedures may be employed for male and female patients.

It has been noted that the male participants with spinal stenosis comprise a dominant population group reporting local as well as radiating pain with lower back and lower limbs being common sites of such pain complaints. It was also noted that males were more likely to have neurological deficits such as leg weakness and paresthesia. Imaging findings in this group commonly had more pronounced cord and foraminal narrowing with hypertrophy of ligamentum flavum which was consistent with the mechanical stress hypothesis. These structural changes are also said to lead to the compression of the nerve root in which case it correlates strongly with the male subjects reported clinical symptoms.

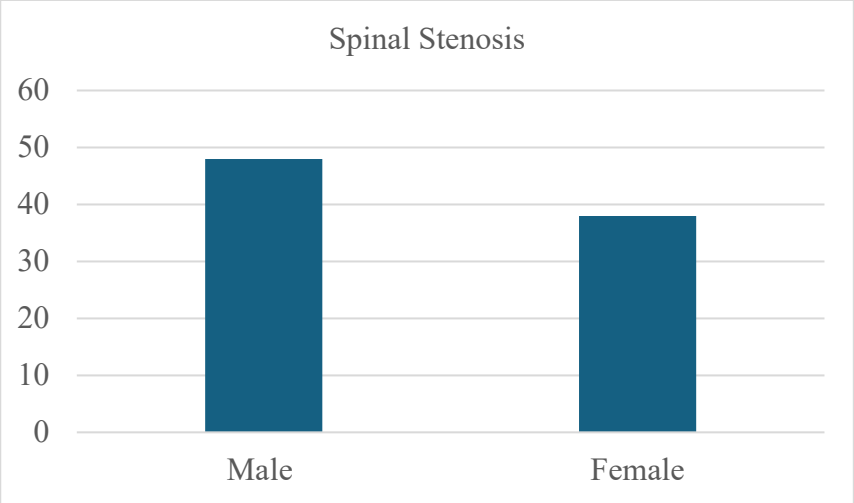

Figure 4.4: Spinal Stenosis in Males and Females.

4.7.4 Spondylolisthesis in Males and Females

Spondylolisthesis was found in 6.4% (n=11) of men and 3.0% (n=4) of women among the respondents. Such a pattern should raise suspicion of a possible link between spondylolisthesis in men with mechanical stress and overuse of spondylolisthesis-making occupations. Heavy lifting sports could also predispose to the development of pars interarticularis defects together with other factors responsible for isthmic spondylolisthesis.

On the other hand, less often reported in females, spondylolisthesis might be a consequence of degenerative processes determined by hormonal and anatomical changes. Postmenopausal degenerative spondylolisthesis develops because of low levels of estrogen, which may contribute to ligamentous laxity and reduced stability of the spine as these factors are the common risk factors.

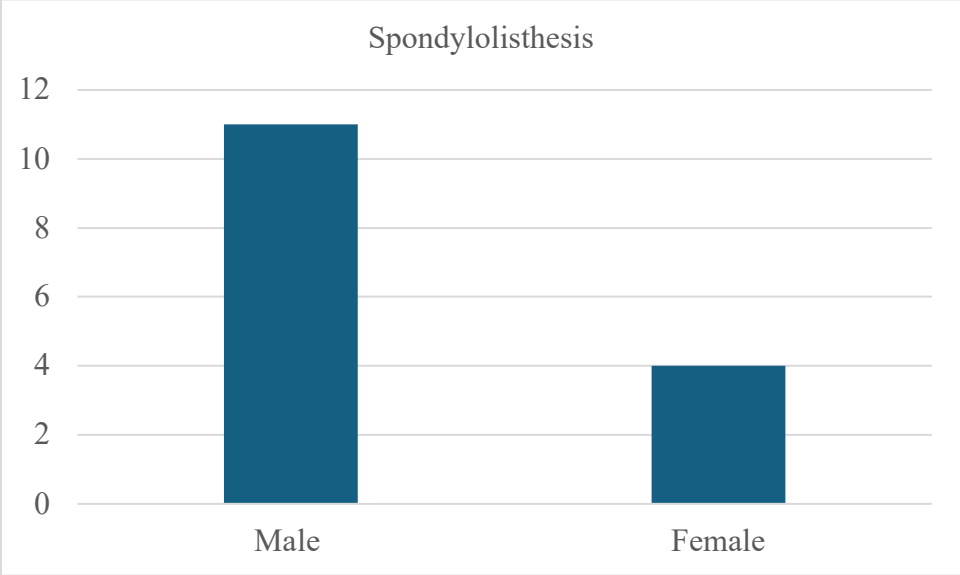

Figure 4.5: Spondylolisthesis in Males and Females.

The findings detail the case for lower back pain (LBP) of the 303 samples studied raising important details on the burden, forms, and components of this condition. No LBP had been left out by the participants which shows the commonness of this problem in this group of patients. The results indicate differences in such key factors as pain characteristics, pain duration, and pain-associated symptoms that are essential in the understanding of bio-demographic factors influencing the condition.

The most common type of disability experienced was simple low back pain (n=231), which could be defined as an alteration of sensation without associated major motor deficiency. There still however remains a considerable proportion of the participants (n=72) who reported some motor symptoms including drop foot suggesting neural involvement. These results seem to fit in with the established spectrum of LBP which in some instances is as mild as just pain in a certain area of the umbilical region to

more intense symptoms that even go along with the loss of some function of the nervous system.

Pain also radiated to the lower limbs in many patients, with (n=136) of the subjects experiencing pain radiating bilaterally, (n=85) unilaterally on the left, and (n=82) unilaterally on the right. This distribution is illustrative of the derangement of certain nerve roots which are frequently associated with a protruding or bulging disc as evidenced by the MRI results.

LBP duration differed among the participants, some of them indicating chronic pain that has gradually extended between 12 weeks or more 39.9 %, n=121. In 41.6 % (n=126), sub-acute pain lasting 6 to 12 weeks was recorded, while in 18.5% (n=56) of patients, it was alleged that acute pain lasting less than six weeks had been enduring. That high prevalence regarding chronic and sub-acute pain clarifies that a significant number of participants are highly likely to continue or have frequent episodes of LBP and that the condition of LBP tends to be long-lasting, hence affecting quality of life.

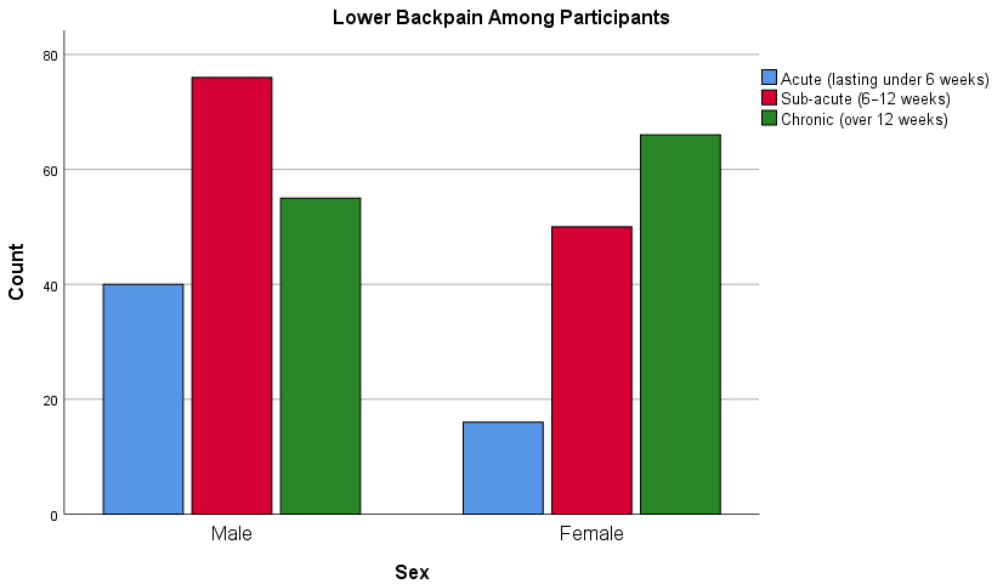

Figure 4.6: Low back pain among Participants.

4.8 Grade of Intervertebral Disc Compression in Males and Females

The research insights highlight intervertebral compression grades between males and females while demonstrating current patterns affecting the severity and changes in distribution within the lumbar region. Furthermore, a thorough cross-sectional analysis of the compression grades at various levels showed some notable patterns, particularly at the L5-S1 level, which seemed to be influenced by the observed gender bias.

All levels of L1-L2, L2-L3, L3-L4, L4-L5, and L5-S1 were evaluated for intervertebral compression. Most of the cases noticed mild to moderate compression, particularly in L4-L5 and L5-S1 intervertebral discs which are prone to maximum stress in regular day musculoskeletal activities. The frequency of the compression in these intervertebral disc levels exceeds those of the upper lumbar segments indicating that the lower part of the lumbar spine has greater biomechanical stress. On the contrary evidence of severe compression was indeed scarce in all intermolecular levels and this was present in less than 3 % of the cases in all the segments at a particular time.

The gender analysis did not find significant differences among most compression grades at most of the lumbar levels (from L1 through L4-L5). However, the L5-S1 segment showed a significant association with gender in the context of the compression grade ($p = 0.024$), exhibiting a weak positive correlation ($r = 0.181$).

In males most predominant compression grade at L5-S1 was mild compression grade (52.0%), followed by moderate, and no compression at 32.2% and 11.7% respectively. However, females reported a lesser rate of mild compression (36.4%) and higher rates of moderate compression (34.1%) and no compression at 24.2%. Severe compression also was rare in both males and females where the occurrence was less than 3% in each group.

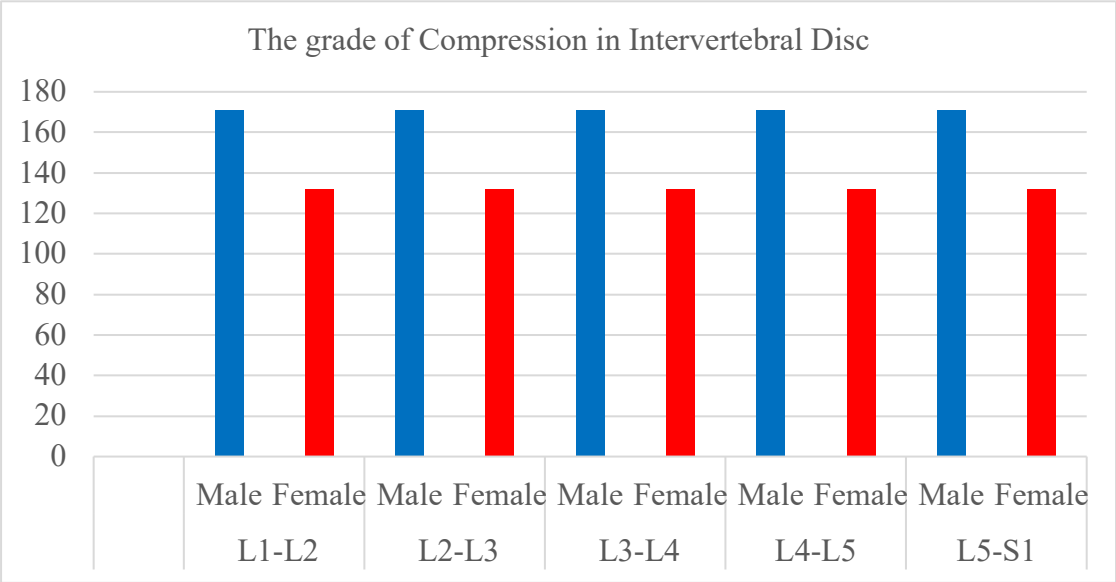

Figure 4.7: The grade of compression in intervertebral discs.

Chapter Five: Discussion

5.1 Introduction

This section examines the study's causes and compares them with the results of past international studies. The study's conclusions, recommendations, strengths, weaknesses, and ideas for additional research are also included in this chapter.

5.2 Discussion

This study was conducted to determine the relationship between age and gender with the prevalence of Low back pain (LBP) related to lumbar disc prolapse. In addition, to explore the relationship between age and gender with the severity and progression of lumbar disc prolapse. Lumbar discs prolapse (LDP) is commonly known as herniated disc and is highly disabling which encourages presentation to health facilities. They seem to target the age group of 30-50 years of age (Ravindra et al., 2018).

MRI has become the most sought-after diagnostic imaging procedure for the detection of lumbar disc herniation and other disc-related pathologies. Its capability to acquire and analyze high-quality three-dimensional images at any angle is second to none. In the present study, participants were all found to have herniated discs based on the MRI scan, which ratifies the use of MRI scan as the most reliable modality in the evaluation of structural defects. These further stresses the important role of MRI in the evaluation and treatment of patients with lumbar spine disorders (Brinjikji et al., 2015; Fatima et al., 2022).

MRI proved useful in identifying these coexisting pathologies as well if they were present. This emphasizes the role of MRI in performing a thorough examination of the patient which is very necessary to arrive at an accurate conclusion and direct the appropriate therapeutic approach. In addition, its ability to treat images from different tissue types allows workers not to miss out on very subtle alterations of soft tissue or bone shape (Brinjikji et al., 2015).

An important feature that distinguishes MRI from other imaging is the capacity for its applications to be repeated because of the lack of ionizing radiation. Compared with CT, this is particularly useful in chronic illness management such as end-stage disc disease or disc bulging and herniation. Moreover, since MRI gives a better soft tissue contrast, it is useful in assessing intervertebral discs, nerve roots, and muscles which are common contributors to low back pain. Such capabilities enable MRI to be of great value in both diagnosis and treatment monitoring (Fatima et al., 2022).

MRI adds even more to its usefulness through its three-dimensional visualization. MRI examines the lumbar spine in all its dimensions by taking images in axial, sagittal and coronal planes thereby permitting the clinician to determine the position and size of herniated discs and their relationship with structures around them. This feature of being able to view the spine in different angles is particularly useful in situations where detailed anatomical relations need to be visualized especially in the diagnosis of nerve root compression or foraminal narrowing. Thus, MRI makes it easier for clinicians to appreciate the specifics of the patient's condition which is the basis of the many decision-making processes within the clinical setting (Brinjikji et al., 2015).

In the current study, it was found based on MRI imaging that the aged range between 40 to 59 years are in high risk of lumbar disc prolapse (50.8%). Out of total number of n=303 studied, n=171 were male and n=132 female thus making male percentage a total of 56.4 and female correspondingly 43.6. This gender distribution concurs with previous investigations which state that men suffer more from the prolapsed lumbar disc, perhaps because of hard work and anatomical predisposition (Brinjikji et al., 2015). Also, as expected, there were few young adults (12.5%, n=38, aged 18–29 years) as they are still not likely to develop degenerative diseases of the lumbar spine (Fatima et al., 2022; Singla et al., 2020).

Previous studies indicate that there are hormonal influences, activity levels and strenuous occupational work which may lead to gender differences in the prevalence and level of severity of the condition (Phan et al., 2017). In addition, it is already known that the L4-L5 and L5-S1 discs are frequently damaged or injured because of their load bearing and moving functions (Fardon et al., 2014).

MRI scans demonstrated the presence of herniated discs in all participants (n=303), with frequent coexisting conditions such as degenerative disc disease (54.1%, n=164), osteoarthritis (28.7%, n=87), and spinal stenosis (27.1%, n=82). The most affected lumbar levels were L4-L5 and L5-S1 which are biomechanically weak and have the weight-bearing function. This agrees with a previous study emphasizing the high incidence of disc herniation at these levels, where over 90% of cases are observed (Fatima et al., 2022; Singla et al., 2020).

The L5-S1 level is interstitially very important since its bears the maximum mechanical stress load and acts as an interface zone between the lumbosacral spine and the sacral bone. These features predispose it to degenerative alterations, herniations, and nerve root encroachment. Gender differences observed at this level may be due to the anatomical configuration of the males and females, their hormones, or the kind of activities they perform. Indicating a notable difference in compression grades between males and females at this specific lumbar level (Fatima et al., 2022).

All participants experienced low back pain, with the highest prevalence being pure low back pain (76.2%, n = 231). Radiating pain affected both sides in 44.9% of participants (n=136), while unilateral radiation was reported on the right side (27.1%, n=82) and left side (28.1%, n=85). Chronic pain was the predominant presentation, especially among females, highlighting the gender-specific variations in pain chronicity (Demirel et al., 2023; Patel et al., 2022). This is consistent with some of the findings of this study that chronic pain is closely associated with disc degeneration (Brinjikji et al., 2015).

The analyzed results based on gender showed that there are notable gender differences in the progression of lumbar disc disorders. Chronic pain was significantly more common in females ($p = 0.003$), whereas males had a higher prevalence of lumbar scoliosis and other abnormalities of the spine such as Osteophytes (Singla et al., 2020; Demirel et al., 2023). These findings support the literature which suggests that hormonal differences as well as levels of physical activity may help explain the differences in the lumbar spine pathologies between the genders (Brinjikji et al., 2015; Patel et al., 2022).

This finding is also in line with previous studies which argue that there are biological and psychosocial reasons which account for the differences in how different genders perceive and experience chronic pain. For example, the rising pain threshold associated with Estrogen may partly explain the experience of chronicity for low back pain in females. Furthermore (Demirel et al., 2023).

This study shows notable differences between men and women in the characterization and imaging features of lumbar disc characteristics. Women tend to have distinct clinical symptoms and some imaging features despite being regarded structurally the same as men on MRI. These observations conform to the existing literature and enhance understanding of the gender aspects of disc degeneration in the lumbar spine more specifically (Demirel et al., 2023; Fatima et al., 2022)

Chronic low back pain (CLBP) was found to be more prevalent among females. This statement is consistent with several studies which targeted various factors and concluded that women are more likely to suffer from chronic pain. It has been hypothesized that hormonal influences such as variability in estrogen levels could alter the pain and inflammation response in women which would therefore explain the greater occurrence of CLBP among this gender (Fatima et al., 2022; Islam et al., 2022). Furthermore, diffuse pain distributions.

On the other hand, male subjects also tended to have structural deformities like scoliosis and osteophyte formation. This substantiates the argument that mechanical stresses are greater in the case of males owing to their work or exercise routines. Mechanical loading which is specific to men, for example, repetitive heavy lifting or high impact activities are factors that importantly lead to degenerative changes of the spine. These types of contributions may explain the localized pain and bi mechanical instability which are characteristics of male patients rather than female patients with lumbar spine pathologies (Patel et al., 2022).

These observations are consistent with published reports indicating that there are gender reasons that certain factors affect the development of structural abnormalities of the spine (Sidon et al., 2018).

The need for male differentiation in the makeup of a spine may be due to the differences in understanding of the mechanical function of the stabilized person's body, as well as occupational exposure and repetitive strain. Musculoskeletal factors such as lifting weights, manual work, and doing sports place an increased biomechanical strain on the male spine which may result in certain abnormal changes in growth, such as osteophytes. These mechanical stresses however over time accumulate and give rise to microtrauma which in turn facilitates abnormal functional adaptation in bone and joint structures (Muppala et al., 2022; Patel et al., 2022).

The context of pronounced gender differences for lumbar scoliosis brings to the fore discussions regarding certain anatomical, biomechanical, or hormonal aspects which may help to understand the etiology of the condition. For instance, factors that are hormonal in nature like girlish bone density and widening of ligaments due to estrogen may be resided in some morphology patterns of females' scoliosis. On the contrary, men's degenerative scoliosis may be secondary to such disorders as asymmetric disc collapse or the formation of osteophytes. These differences highlight the importance of individualized diagnostic and therapeutic strategies considering sex differences in manifestations and course of the disease.

Although the clinical differences were prominent, the study did not reveal any statistically significant differences in some variables between males and females for example, in the volume of herniations or the extent of buttock root compression. Male as well as female subjects were found to have similar disc protrusion, disc extrusion, and neural involvement of related structures which suggests that the anatomical features of the lumbar disc prolapse are similar across both the sexes (Muppala et al., 2022).

Most females claimed to have experienced pain radiation along with numbness and weakness as symptoms. Though impossible to undertake quantitatively on an MRI, these qualitative differences suggest that women might be affected by lumbar spine pathologies in a different way due to different spinal biomechanics or inflammation. This seems to support the idea that hormonal factors not only affect pain sensitivity but also affect how the body reacts to mechanical injury, which accounts for the apparent sex differences in clinical features (Nasir et al., 2022; Demirel et al., 2023).

Analyzed data strongly suggested that age was a decisive factor in the type and degree of severity in lumbar spine pathologies. Further, degenerative changes in lumbar discs including disc bulge, protrusion and extrusion were greatest in the older age groups, especially in those above 50 years. These results confirm earlier research which indicated that age is one of the main factors responsible for the degeneration of intervertebral discs and the dehydration of intervertebral discs (Demirel et al., 2023; Muppala et al., 2022).

The association of age with the severity of pathology was most strongly observed with the prevalence of degenerative discs disease and osteoarthritis. In addition, older age also showed tendency to higher percentage of patients with spinal stenosis, which agrees with the observations of Patel et al. (2022) that older age patients frequently have more pronounced structural degenerative changes on MRI.

Results of the imaging in this study seem to confirm that indeed old age is a primary factor associated with degenerative diseases. For example, it was more common to observe multiple levels of degenerative change in older patients and such changes were frequently observed together with degenerative conditions like spondylosis or facet joint osteoarthritis. These imaging findings support the idea of age-related changes to the lumbar spine being a ‘thanks for the effort’ sort of endorsement to the stresses that occur at the lower parts of the spine, which is a heavy bearer. This progression points to the requirement of preventive therapeutics to be instituted in good time to forestall age related changes that could be escalated by physical activity, ergonomic changes, among other factors (Muppala et al., 2022).

5.3 Conclusion

The study examines in detail lumbar spine pathologies with their implications to clinical practice and demonstrates demographic, clinical, and imaging data spanning over a multiethnic sample of 303 patients. The data presented also depicts the prevalence of lumbar spine disorders such as disc herniation (100%), disc degeneration (54.1%), lumbar canal stenosis (27.1%) and osteoarthritis (28.7%). These results illustrate the extent of the problem with respect to the lumbar spine across the population with specific

consideration of L4-L5 and L5-S1 regions as the most common sites for intervertebral disc compression.

The data indicated that women had a greater chance of suffering from chronic lower back pain (50%), while their male counterparts had a higher rate of subacute pain (44.4%). This means that hormonal factors, along with biological factors such as anatomical differences, as well as psychosocial elements, may be strongly influencing the pain levels associated with both genders, aside from and in tandem with the spinal issues. On the other hand, while the type of pain and its concomitant radiation had no glaring gender differences, the stark increase in chronic pain amongst women urges a paradigm shift for focused management of pain.

The study's imaging findings demonstrate almost identical structural abnormalities within both genders, such as herniated discs, degenerative alterations and spinal canal stenosis. Nevertheless, there were notable sex differences in the prevalence of lumbar scoliosis and other atypical spinal growths, where females had a higher prevalence of these conditions. Bone spurs were the most common type of abnormal growth (25.1%), and these were more common in women. Such findings emphasize the importance of factor gender during diagnostic evaluation and management of diseases affecting the lumbar spine.

The integration of MRI within medical practice enabled accurate method of diagnosing and determining the ailment of the lumbar spine region. Adhering to the various patterns found in this study and developing treatment strategies that are unique to age and sex could lead to better treatment results and heightened patient satisfaction. Lastly, key areas of this study emphasized the necessity to adopt preventative strategies that target changeable risk factors to delay the progression and minimize the severity of age-related changes.

5.4 Recommendations

Future medical studies into such issues as low back pain should be focused on improving both the internal and external translatability of the research by incorporating

multi-center approaches and international collaborations among researchers. Multi-center studies complete this picture by enabling to expansion of the geography of the patient data, ethnicities, and the environmental parameters affecting health.

Such collaborations will open the door for researchers to investigate how the presentation and the course of disease differ in various populations, thus strengthening the external validity of the studies. Besides, researchers will be able to work in multi-disciplinary teams such as researchers who study X-rays and MRIs neurosurgeons, and orthopedic doctors and rehabilitation specialists dealing with such treatment issues as lumbar degenerative diseases.

The focus of further research should be on preventive approaches to be undertaken. Effective methods of preventing LDP could be targeting alterable risk factors such as lack of physical activity and ergonomics that would control age and sex.

Future studies should focus on the effectiveness of different treatment approaches concerning various parameters. Understanding the effects of physical therapy, drug treatment, and surgical procedures on different categories of patients could aid in creating a more individualized care approach.

5.5 Strength of the study

The research shines light on demographic factors such as age and gender and how those can play a crucial role during lumbar spine disc pathologies. It fills an important void in the literature in assessing disc pathologies as it studies how these demographic factors affect the incidence, degree, and clinical presentation of lumbar spine conditions. As a strong point, this analysis delivers a plethora of information about the nature and the factors of disc pathologies in the lumbar spine.

One of the key strengths of the study, germane to the current topic, is the use of MRI as the main research instrument. In clinical practice, MRI is regarded as the best method of diagnosing conditions related to the lumbar spine and is known for accuracy and precision. The study demonstrates how stains in the disc tissue which caused by such

abnormalities as disc bulge, protrusion, and extrusion, among other comorbidities. This approach to the use of MRI improves the reliability and validity of the results of the research, thus providing a good basis for clinical and practical use of the research.

The study proposes a newer approach for diagnostic imaging and its clinical correlation by integrating the clinical data with imaging data which explains the rationale behind the research purpose. By interlinking the clinical information with MRI findings, the research fosters a relationship between imaging and the patient's clinical profile. This integrative model improves the understanding of the disease process as well as enhances clinical correlation in the framework of diagnosis. Such an approach guarantees the interpretation of imaging findings to be done in the right clinical context to prevent overdiagnosis or unnecessary management.

Gender- and age-specific pathology of the lumbar spine is addressed very well which is a significant positive aspect of the work. This study makes clear that there are notable differences in how illnesses appear and how they progress for various social and age categories, which is important for creating efficient diagnostic and treatment methods. All these results highlight the importance of such programs that are aimed at improving patient outcome and comfort and that also arise from the risks factors related to their age.

Moreover, the clinical significance of the study is enhanced by the practicality of the results for the health professionals. The findings of the study aid in the integration of evidence-based practices in patient care by advocating for the incorporation of demographic factors in clinical guideline development. Additionally, the study points out the gaps in the literature and thus sets the stage for further studies like the prevailing trends in the disorders of the lumbar spine and the impact of the corrective measures.

5.6 Limitations

One of the important shortcomings relates to the size and structure of the sample. Although the sample of 303 individuals was informative, it does not imply variations across some other population or geographic area. This narrower scope of applicability is

most striking in a group having varying genetics, life style or even environmental factors. It is necessary to reduce this limitation through larger, multi-center studies.

The focus on MRI interpretation as a tool of diagnosis poses an issue. While MRI is very reliable in detecting organic changes, this research did not consider adjuvant tools which include functional imaging or even a biomechanical evaluation. Such a limitation hinders understanding of the effect of these pathologies on functioning and life quality. Such a broader definition of assessment would enhance the understanding of the condition better.

Another limitation pertains the absence of treatment analysis efficacy. The analysis did not consider the influence of different treatment options. In future, studies assessing the role of demographic variables in determining treatment outcomes and recommendations could be done.

5.7 Future Work

The research has added information concerning the demographic, clinical, and imaging features of the lumbar disc pathologies but there are many other aspects which remain untouched. It would be quite imperative to address these counterparts in the future studies to enhance the understanding and treatment of lumbar spine pathologies.

What was emphasized in the study confirmed that the major focus of future studies will be assessing the clinical course and changes of lumbar disc pathologies with time through the means of longitudinal studies. Though this investigation was concerned with single methodology, observing the relation of demographic determinants to clinical presentations, extending the patients' journey through the different course phases would allow focusing into the more complicated patterns of the degeneration of the disc over time and the changes in the pain and its treatment over the course. This type of study could also be useful in predicting when disc degeneration begins for early detection and treatment.

Moreover, the differences in terms of gender that emerged in this investigation point to the need for further studies which will contribute towards explaining the mechanisms responsible for these differences. The effects of cyclical hormonal changes, distinct spinal mechanics as well as the processing in the central nervous system would greatly enhance the development of strategies for differentiating the treatment of lumbar spine complications in males and females. Such research would not only advance knowledge in a particular field but also be beneficial to the patients in that it would meet the specific requirements of either sex.

In the context of future studies, it will be advantageous to also incorporate more advanced imaging techniques such as diffusion tensor imaging of the magnetic resonance type and functional MRI to evaluate soft tissue and nerve involvement more thoroughly. The inclusion of these techniques could allow more information on changes at the microstructural level of the intervertebral discs and adjacent areas, thus enhancing understanding regarding the pathophysiology of various types of disorders of the lumbar disc. Additionally, integrating these methods with conventional methods of MRI may enhance diagnostic performance and help detect subclinical lesions.

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Appendices

Appendix (1): IRB Approval

Arab American University
Institutional Review Board - Ramallah

الجامعـــة العربيـــة الأمريكيـــة
مجلس اخلاقيات البحث العلمي – رام الله

IRB Approval Letter

Study Title: "Exploring Gender-specific Correlations: Clinical Features and Magnetic Resonance Imaging Findings in Lumbar Disc Prolapse".

Submitted by: Mousa Mahmoud Mohammad Shaheen

Date received: 21th July 2024

Date reviewed: 29th July 2024

Date approved: 29th July 2024

Your Study titled **"Exploring Gender-specific Correlations: Clinical Features and Magnetic Resonance Imaging Findings in Lumbar Disc Prolapse"** with the code number **"R-2024/A/120/N"** was reviewed by the Arab American University Institutional Review Board - Ramallah and it was approved on the 29th of July 2024.

Sajed Ghawadra, PhD
IRB-R Chairman
Arab American University of Palestine

الجامعة العربية الأمريكية - فلسطين
مجلس اخلاقيات البحث العلمي - رام الله
IRB-R
ARAB AMERICAN UNIVERSITY-PALESTINE
INSTITUTIONAL REVIEW BOARD - RAMALLAH

General Conditions:

1. Valid for 6 months from the date of approval.
2. It is important to inform the IRB-R with any modification of the approved study protocol.
3. The Bord appreciates a copy of the research when accomplished.

رام الله – فلسطين

Tel: 02-294-1999 **E-Email:** IRB-R@aaup.edu **Website:** www.aaup.edu

Appendix (2): Example of Patient History

مركز شاهين للتصوير المغناطيسي
SHAHIN MRI CENTER

MRI HISTORY

Name : ..
Age : ..... 54 years old
ID NO : .....
DATE BIRTH : ..25..12..1969

Clinical History :
Low back pain Radiating to Both lower limbs but Rt leg is more, Numbness started 2 months ago
.....

Prior Exams: CT : Yes/ ~~No~~ MRI: Yes/~~No~~
If yes , date : .....
History Trauma Yes/ ~~No~~
Contrast: Yes/~~No~~
Surgery : Yes/~~No~~
Patient weight: ..... 94 kg
Patient exercises: Never / ~~Rarely~~ / Often / Always
Referring Doctor. Dr.....
Doctor's Number .....
Patient's Number .....
MRI Techn ...

Appendix (3): Example of MRI Report

Patient Name: **Exam Date:** 05/12/2023

Date of Birthday: **ID:**

LUMBOSACRAL SPINE MRI WITHOUT CONTRAST

Clinical presentation: Low back pain.

Technique: Multiplanar/multisequence T1 and T2-weighted imaging of the lumbosacral spine was performed without intravenous contrast administration.

Findings:

At **L5/S1**, there is a bilateral pars defect (spondylolysis) without significant anterolithesis (spondylolithesis) of L5 on S1 with associated diffuse dehydrated bulging disc of about 4 mm abutting the ventral thecal sac and extending in both neural foramina more on the right with resultant mild compression upon the corresponding exiting nerves. No central canal stenosis. Facet joints athropathy.

At **L1/L2 and L2/L3**, there is a mild dehydrated bulging disc of maximum thickness of about 2-3 mm indenting the ventral thecal sac both traversing nerve root. No central canal stenosis. Facet joints athropathy.

The vertebral body height is normal. No other significant disc bulge/protrusions. No spinal canal stenosis. The conus medullaris ends at L1/L2.

Intact both sacroiliac joints.

The remainder of the lumbosacral spine MRI appears within limits.

EUROPEAN BOARD OF RADIOLOGY.
MRI, CT AND US SPECIALIST

استكشاف الارتباطات الخاصة بالجنس: المظاهر السريرية ونتائج التصوير بالرنين المغناطيسي في هبوط القرص القطني

موسى محمود محمد شاهين

د. محمد الجمل

د. سامر مهنا

د. عبد الناصر عاصي

ملخص

مقدمة

آلام أسفل الظهر هي واحدة من أكثر المشاكل شيوعًا التي يعاني منها الأشخاص في جميع أنحاء العالم، وغالبًا ما تكون ناجمة عن انفتاق القرص القطني. لتشخيص وعلاج هذه الحالة بشكل فعال، من الضروري فهم العلاقة بين التركيبة السكانية، مثل العمر والجنس، وأي تشوهات في العمود الفقري القطني. يعتبر التصوير بالرنين المغناطيسي (MRI) المعيار الذهبي لتشخيص انفتاق القرص القطني لأنه يوفر صورًا متفوقة للهياكل الشوكية بتفاصيل أكبر من طرق التصوير الأخرى.

الهدف

تهدف هذه الدراسة إلى تقييم العلاقة بين الجنس والعمر مع تدلي القرص القطني، جنبًا إلى جنب مع خصائصه السريرية والتصويرية. بالإضافة إلى ذلك، يقيم البحث كيف يؤثر استخدام التصوير بالرنين المغناطيسي – مع أو بدون مواد التباين – على الحساسية والنوعية في تحديد التشوهات في العمود الفقري القطني.

الطريقة

أجرت هذه الدراسة تحليلاً رجعيًا شمل 303 مريضًا تم تشخيص إصابتهم بانفتاق القرص القطني. تم الحصول على البيانات المتعلقة بالتركيبة السكانية والخصائص السريرية ونتائج التصوير بالرنين المغناطيسي من سجل بيانات المرضى. تم إجراء اختبارات إحصائية على هذه المجموعات من البيانات لتحديد الارتباطات ذات الدلالة الإحصائية بين العوامل الديموغرافية وخصائص الألم ونتائج التصوير. بالإضافة إلى ذلك، قامت الدراسة بتقييم دور التصوير بالرنين المغناطيسي المعزز بالتباين في تشخيص أمراض العمود الفقري.

النتائج

كان معظم المشاركين تتراوح أعمارهم بين 40 و59 عامًا (50.8٪) وكانوا من الذكور (56.4٪). أظهرت نتائج التصوير بالرنين المغناطيسي أن الانزلاق الغضروفي (100٪) ومرض القرص التنكسي (54.1٪) وتضيق العمود الفقري (27.1٪) هي الأمراض الأكثر شيوعًا. كانت الإناث أكثر عرضة للإصابة بألم أسفل الظهر المزمن، بينما أبلغ الذكور عن آلام شبه حادة. لوحظت فروق بين الجنسين في الجنف القطني وتشوهات العظام، بما في ذلك النتوءات العظمية. كان التباين المعزز مفيدًا للكشف عن الأورام والأكياس لدى بعض المرضى.

الاستنتاج

تسلط الدراسة الضوء على التفاوتات الكبيرة بين الجنسين في العرض السريري وحدوث تشوهات العمود الفقري القطني. وفي حين كانت التغيرات المرتبطة بالعمر أقل وضوحًا، أظهر المرضى المسنون انحطاطًا أكثر حدة في التصوير. يظل التصوير بالرنين المغناطيسي الطريقة الأساسية لتقييم مشاكل القرص القطني، حيث يوفر تصورًا تفصيليًا. يعد التعرف على التفاعل بين العوامل الديموغرافية ومعايير التصوير أمرًا ضروريًا لتطوير استراتيجيات تشخيصية فعالة.

الكلمات المفتاحية: انزلاق، تنكس، العمر، الجنس، تشخيص.