Sudan University of Science and Technology

College of Graduate Studies

Evaluation of Lumbar Spine Morphology in Magnetic Resonance Images Using Cobb's Method

تقويم شكل الفقرات القطنيه في صور الرنين المغنطيسي باستخدام طريقة كوب

A thesis Submitted for Fulfillment of the Requirement of PhD Degree in Diagnostic Radiological Imaging

By:

Sara Saadeldein Galal Albadri

Main Supervisor

Professor. Mohamed Elfadil Mohamed Garelnabi

Co-supervisor

Professor. Caroline Edward Ayad

SEP 2018

الآية

بسم الله الرحمن الرحيم

الرحمن (١) علم القرآن (٢) خلق الإنسان (٣) علمه البيان (٤)

صدق الله العظيم

سورة الرحمن الآية ١-٤

Dedication

Not Enough words that can Reflect Emotions that we hold deep in our Heart Chambers for People who were and Still the Corner Stone and the Temple columns of My bright Thoughts and Dreams,,,

To those I would like to dedicate this humble work

My Mother ***Miska***

My Husband ***Mohammed Saadeldein***

My Son ***Mazin***

My Sister ***Hajer Saadeldein***

My family

Acknowledgements

First of all, I am very grateful to the almighty Allah for enabling me to complete this dissertation in time and the prayers and peace be upon the merciful prophet Mohammed.

I am extremely grateful to my main supervisor Prof. ***Mohammed Elfadil Mohammed*** *from the very beginning winding up of this study. I would like to express my sincere thanks and deepest regards to my respectable Co-Supervisor Prof.* ***Caroline Edward.***

I want to express my gratitude to all the concerned authorities who allowed me to carry out this,I would also like to offer very special thanks to my colleagues.

Special thanks for Mr. ***Abu-Bakr Bashir*** *who contribute to data analysis and for* ***Dr. Mustafa Kram-allah*** *for help me.*

Abstract

Lumbar lordosis is one of the most common postural abnormalities it is defined as increased lumbar curvature in the sagittal plane of the vertebral column. Several different methods are used to measure lumbar lordosis, the Cobb's method is commonly used for curvature analysis on sagittal lumbar images

The objectives of study to evaluate the lumbar spine morphology using cobb's method in Sudanese subjects, MRI sagittal T2 W images were done using two different MRI Machines Philips Superstar Neusoft medical system 0.35 Tesla and Machine type Siemens, symphony, mastro class 1.5 Tesla. It was conducted in Advanced Diagnostic Center and Baraha Medical City hospital in Khartoum Sudan during the period from August 2015 to August 2016, 140 patients; their ages ranged from 13-90 years. There were 85 female patients and 55 male subjects, Normal population (control) included 40 patients (10 males and 30 females), their mean age was (37.8 ± 13 years), 100 patients had disc herniation at different levels. They included (55 females and 45 males), their mean age was (47.3 ± 15.7 years), the data were collected using many variables, including Age, gender, weight, height, Body mass index, Intervertebral disc space height, Herniated disc, Body height, Angle of lumbar lordosis (Cobb angle).

The study results showed that there was significant difference between normal population and patients with disc herniation as regards the cobb angle (p-value 0.000) and intervertebral disc space of L3 (p-value 0.011); while there was no significant

difference (p> 0.05) between control subjects and abnormal patient at Lumbosacral Angle, L1-L5 body vertebrae and L1, L2, L4 and L5 IVD levels. Also there was significance difference between Cobb angle and LS angle at abnormal group (p- value 0.045) while no significant difference in control cases (p-value 0.691).

In male and female groups there was no statistically significant deference regarding the L.S angle in both groups.

In patient with disc herniation at different levels we find there is direct linear relationship between the vertebral body L5-L2 with the Cobb angle, and indirect linear relationship between the intervertebral disc spaces L5-L2 with the Cobb angle, Also an indirect linear relationship between the body diameter L5-L3and disc bulge, and direct linear relationship between the intervertebral discs space diameter and disc bulge at same levels, related to LSA there is indirect linear relationship with disc bulge at L5-SI level. Regarding the control cases results find there is direct linear relationship between the vertebral body and intervertebral disc spaces with the Cobb angle; except at L3 vertebral body level find indirect linear relationship.

MRI imaging is ideally suited in identifying pathology related to the soft tissue including the vertebral disks which are most often involved and causing low back pain.

ملخص البحث

التقوس القطني المتزايد هو واحد من أكثر التشوهات الوضعية شيوعا ويعرف بأنه تقوس قطني متزايد في المستوى السهمي للعمود الفقري. يتم استخدام العديد من الطرق المختلفة لقياس تقوس الظهر القطني ، ويستخدم أسلوب كوب بشكل شائع لتحليل الانحناء على الصور القطنية السهمية.

هدفت هذه الدراسه لتقويم الفقرات القطنية باستخدام طريقة كوب في الافراد السودانيين، تم استخدام المسح بالرنين المغنطيسي بنوعين مختلفين من الاجهزة، جهاز سيمينز(1.5 تسلا) و جهاز من شركة فيليبس (0.35 تسلا) ، تم تصوير الحالات التي درسة في مستشفي مدينة البراحة الطبية و مركز بحري المتطور في الفترة من اغسطس2015 الي اغسطس 2016. شملت هذه الدراسة 140 مريضا من كلا الجنسين (55 ذكور و 85 اناث)، تم تقسيمهم الي مجموعتين ، المجموعة الاولي الحالات ذات النتائج الطبيعيه و المجموعة الثانية المرضى الذين تم تشخيص حالاتهم بانزلاق غضروفي في فقرة واحدة او فقرات متعددة. بلغ متوسط اعمار المجموعة الطبيعيه و عددها 40 فردا(37.8 ± 13 عام)، و متوسط مجموعة المرضي و عددهم 100 من كلا الجنسين (47.3 ± 15.7)، تم مسحهم بجهاز الرنين المغنطيسي و اخذ الصورة الجانبية للفقرات القطنيه من الفقره القطنيه الاولي الي الفقرة العجزيه الاولي و تم عليها عمل قياسات الدراسة.

أظهرت نتائج الدراسة وجود فرق معنوي بين افراد المجموعه السليمه والمرضى الذين يعانون من الانزلاق الغضروفي فيما يتعلق بزاوية كوب (قيمة p 0.000) ومساحة القرص بين الفقره القطنيه الثالثه (قيمة p = 0.011). في حين لم يكن هناك دلالة لفرق (p> 0.05) بين الافراد السليمين والمرضى في(زاوية الفقره القطنيه العجزيه ، الفقرات القطنيه من الاولى الى الخامسه ،ومساحه القرص من الاولى الى الخامسه عدا الثالثه). كما كان هناك فرق معنوي بين زاوية كوب والزاوية القطنيه العجزيه عند مجموعة المرضى (قيمة p0.045) بينما لا يوجد فرق معنوي في الحالات الطبيعيه (قيمة0.691 p). في مجموعات الذكور والإناث لم يكن هناك أي إحصاء ذو دلالة إحصائية فيما يتعلق بزاوية الفقره القطنيه الخامسه والعجزيه الاولى. في كلا المجموعتين.

في مرضى انفتاق القرص عند مستويات مختلفة نجد أن هناك علاقة خطية مباشرة بين الجسم الفقري القطني من الثاني الى الخامس مع زاوية كوب ، وعلاقة خطية غير مباشرة بين ارتفاع القرص الفقري القطني من الثاني الى الخامس مع زاوية كوب ، وأيضاً علاقة خطية غير مباشرة بين ارتفاع الجسم من الفقره القطنيه الثالثه الى الخامسه و انفتاق القرص ، والعلاقة الخطية المباشرة بين ارتفاع مساحة الأقراص بين الفقرية وانفتاق القرص عند نفس المستويات ، العلاقه المرتبطة بالزاويه القطنيه العجزيه هناك علاقة خطية غير مباشرة مع انفتاق القرص عند مستوى الفقره القطنيه الخامسه والفقره العجزيه الاولى. فيما يتعلق بنتائج حالات التحكم تجد هناك

علاقة خطية مباشرة بين الجسم الفقري ومساحات القرص الفقرية مع زاوية كوب ؛ إلا في مستوى الجسم الفقري الثالث تجد علاقة خطية غير مباشرة

التصوير بالرنين المغنطيسي مثالي في تصوير الامراض المتعلقه بالانسجه الرخوة بما في ذلك الانزلاق الغضروفي و التي هي في اغلب الاحيان تسبب الالم اسفل الظهر.

List of Contents

List of Figures

List of Tables

List of Abbreviation

MRI	Magnetic Resonance Imaging
MRS	Magnetic resonance spectroscopy
CT	Computed Tomography
IVD	Intervertebral Disc
DDD	Degenerative Disc Disease
HD	Herniated disc
T2W	T2 Weighted Image
BMI	Body Mass Index
T1W	T1 Weighted Image
HIZ	High intensity zone
HNP	Herniated nucleus pulposus
FOV	The field of view
ML	Milliliter
MM	Millimeter
CM	Centimeter
TRALL	Tangential Radiologic Assessment of Lumbar Lordosis
LLA	Lumbar Lordotic Angle
LSA	Lumbosacral angle

Chapter One

Chapter One

1.1 Introduction:

Lower back pain is a global cause of life-long disability and is one of the leading causes of lost productivity (Fairbank and Pynsent 2000).

Chronic lower back pain patients require significant resources and are responsible for 80% of the costs attributed to back pain. Imaging, principally through the use of spinal MRI, is routine and is a key element of management of such patients, though, its efficacy in informing patient stratification and prognosis has not been demonstrated and is being increasingly questioned (Lurie et al. 2013, Modic and Ross 2007), (Steffens et al. 2013), (Videman et al. 2003).

Despite this, there are clinical situations in which MRI is a useful diagnostic tool, for instance with patients with suspected spinal stenosis or disc herniation, or tumors.

However, despite its limitations, MRI is still considered a mainstay of clinical practice and it is still believed that MRI could be used to better stratify patients and predict outcome, hence there is on-going research in this, with some promising results (Jensen et al. 2013).

Within the area of MRI spine imaging, there are a number of medical visionproblems that are of current research interest including: detection, labeling, and segmentation of vertebrae and discs, characterization of local and global appearance, vertebrae position and configuration, and finally, mapping to clinical findings (Meelis Lootus et al, 2015) .

There are many imaging modalities for assessing intervertebral discs (Herzog 1999).On plain X-ray films of the spine, degenerative disc disease is characterized by narrowing of the intervertebral space, endplate erosions with reactive osteosclerosis, formation of osteophytes (which often involve the spinal canal and foramina), intradiscal calcifications, and intradiscal gas (“vacuum phenomenon”). Due to its soft tissue nature, the normal intervertebral disc is not visualized on plain X-ray films (unless it contains foci of calcification or ossification). Therefore, it follows th at plain X-ray films have a limited role in the assessment of disc degeneration, since early degenerative changes within The disc cannot be detected. Recent evidence however appears to indicate that three radiographic parameters (height loss, osteophytes and intradiscal (Calcifications) are significantly correlated with the morphological degree of Degeneration of human lumbar discs harvested from cadavers (Benneker et al. 2005).

In conventional radiography, subtle differences of less than about 5 percent in subject contrast are not visible in the image. Each of these difficulties is eliminated in computed tomography. Differences of a few tenths of a percent in subject contrast are revealed in the CT image. With the display of anatomy across planes that are not accessible by conventional imaging techniques, make CT exceptionally useful for visualizing anatomy in many regions of the body. (William R. Hendee, 257)

The structure and function of the various components such as discs vertebral bodies, and spinous ligaments, and to delineate how the normal behavior of these structures is altered by age and various clinical interventions. A growing segment of spine radiology involves not just imaging but musculoskeletal Intervention as well. Radiologists now are performing tasks that previously were in the realm of neurosurgery and orthopaedics. Because procedures such as thermal ablation of the disc,vertebroplasty, and kyphoplasty not only Address pain relief but also may alter the mechanical behavior of the disc and/or vertebral body, it is important to have a fundamental understanding of the biomechanics of the spine. Knowledge of the normal biomechanics can help the clinician understand the effect a given intervention may have.

1-1-1 Spine

1-1-1-1 Structure

The spine is a complex structure that can be divided in to five regions: the Cervical, thoracic, lumbar, and sacral spines; and the coccyx. Of primary interest are the unfused vertebrae of the cervical through the lumbar regions, although recently the fused vertebrae of the sacrum, especially with regard to insufficiency fractures, have been the subject of increasing clinical interest. In the lumbar spine, which consists of five vertebrae (L1–L5), the dominant motion is flexion. There is some extension and later al bending, but almost no rotation. The curvature of the lumbar spine is normally lordotic. Regardless of the level and type of motion, motion of the spine occurs in the spaces between the vertebrae, i.e., in the disc and at the facet joints.

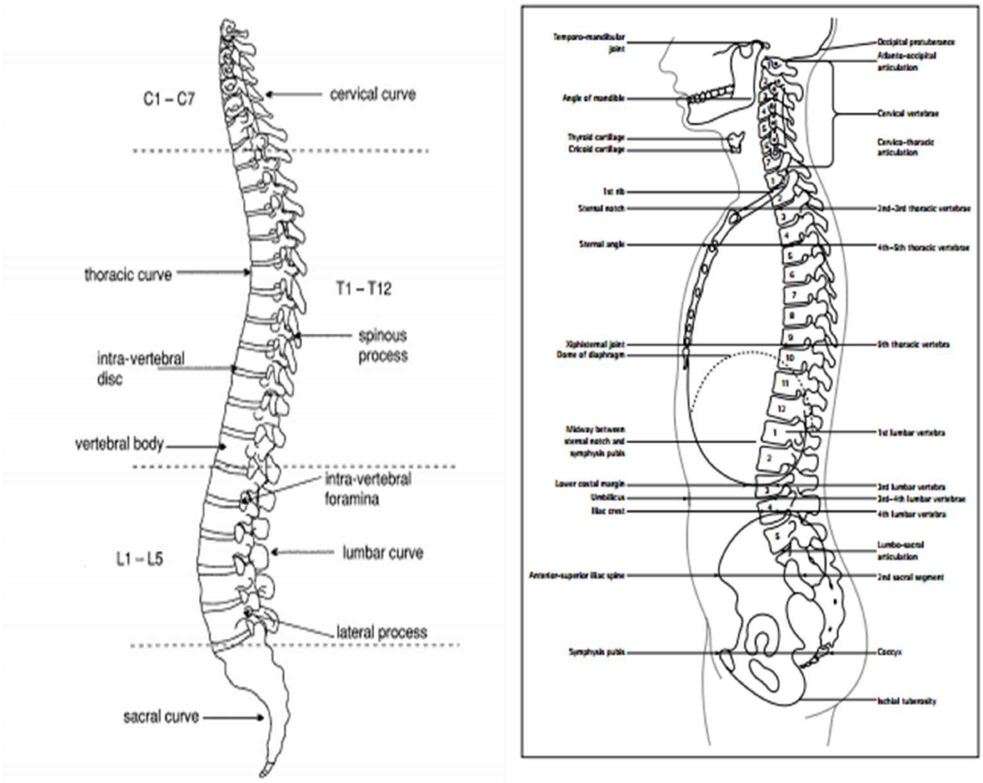


Fig (1-1) Sagittal view of the spine showing vertebral levels (Catherine westbrook 2009) (A. Stewart et al. 2005)

1-1-1-2 Function

The spine, which transmits loads from the upper body through the pelvis into the lower extremities, is conceptually divided into three columns: anterior, medial, and posterior columns (Denis 1983).Because the center of gravity of the human body is located anterior to the spinal column, the center of gravity creates a combined load resulting in axial compression and an anterior bending moment.

1-2 Research Problems:-

People from different age categories, gender, weight and occupations are share a common complain, which is a low back pain (LBP), conventional lumber spine (AP – lateral views) is Requested as first time for assessment method; But for the relatively poor information or radiological findings a referral for further assessment and closer evaluation of lumber spine compartments using MRI is the modality of choice, beca use showed higher reliability between measures than radiography. The Cobb' s method can be used to evaluate lumber curvature and to find the potential c andidate of disc problem, because the Cobb method not used in Sudanese peoples to e valuate the lumbar spine morphology. Questions to be answers are the Cobb angle ha s relation with disc herniation? Is the Cobb angle having relation with lumbar spine morphology?

1-3 Research objectives:

1-3-1 General objective:-

To evaluate Lumbar spine morphology using Cobb's method.

1-3-2 Specific objectives:-

-To measure the mean, and stander deviation of the variables.

-To determine lumbar lordotic angle (Cobb angle).

- To correlate body height, intervertebral disc height and LS angle with disc bulge.

-To measure disc bulge Length and Width in mm.

-To measure lumbar features at sagittal view (body height, intervertebral disc height, Lumbosacral angle, Cobb angle).

-To correlate Cobb angle with patient (age, gender, weight, height and BMI).

-To correlate Cobb angle with disc protrusion and lumbosacral angle.

1-4 Significance of study

Fulfilling and possible achievement of research objectives using magnetic res onance imaging as the Imaging modality of choice will hand the society of radio logy specifically and personnel in health and medical process, a valuable and clo se informative evaluation regarding lumbosacral disc problems.

1-5 Thesis outline

This study included five chapters; chapter one witch is an introduction, deals with the oretical frame work of the study. It presents the statement of the study problems, obj ectives of the study. Chapter two is divided in to two sections, section one deal with theoretical background of anatomy, physiology and pathology related to the study an d section two deal with literature review (previous studies). Chapter three presents t he material and method. Chapter four includes the result presentations, chapter five will include the discussion, conclusion, recommendation and appendices.

Chapter tow

Chapter tow

Theoretical Background and Literature Review

2-1 The Vertebral Column General Characteristics

The vertebral column consists of 26 irregular bones connected in such a way that a flexible, curved structure results. Serving as the axial support of the trunk, the spine extends from the skull to the pelvis, where it transmits the weight of the trunk to the lower limbs. It also surrounds and protects the delicate spinal cord and provides attachment points for the ribs and for the muscles of the back and neck.

In the fetus and infant, the vertebral column consists of 33 separate bones, or vertebrae (ver9tě-bre). Inferiorly, nine of these eventually fuse to form two composite bones, the sacrum and the tiny coccyx. The remaining 24 bones persist as individual vertebrae separated by intervertebral discs. (Elaine n. marib, katja hoehn 2013)

2-2 Regions and Curvatures

The vertebral column is about 70 cm (28 inches) long in an average adult and has five major regions. The seven vertebrae of the neck are the cervical vertebrae, the next 12 are the thoracic vertebrae, and the five supporting the lower back are the lumbar vertebrae. The vertebrae become progressively larger from the cervical to the lumbar region, as they must support greater and greater weight. Inferior to the lumbar vertebrae is the sacrum, which articulates with the hip bones of the pelvis. The terminus of the vertebral column is the tiny coccyx. All of us have the same number of cervical vertebrae. Variations in numbers of vertebrae in other regions occur in about 5% of people. When you view the vertebral column from the side, you can see the four curvatures that give it its S, or sinusoid, shape. The cervical and lumbar curvatures are concave posteriorly; the thoracic and sacral curvatures are convex posteriorly. These curvatures increase the resilience and flexibility of the spine, allowing it to function like a spring rather than a rigid rod. Homeostatic Imbalance

7.2There are several types of abnormal spinal curvatures. Some are congenital (present at birth); others result from disease, poor posture, or unequal muscle pull on the spine (Elaine n. marib, katja hoehn 2013).

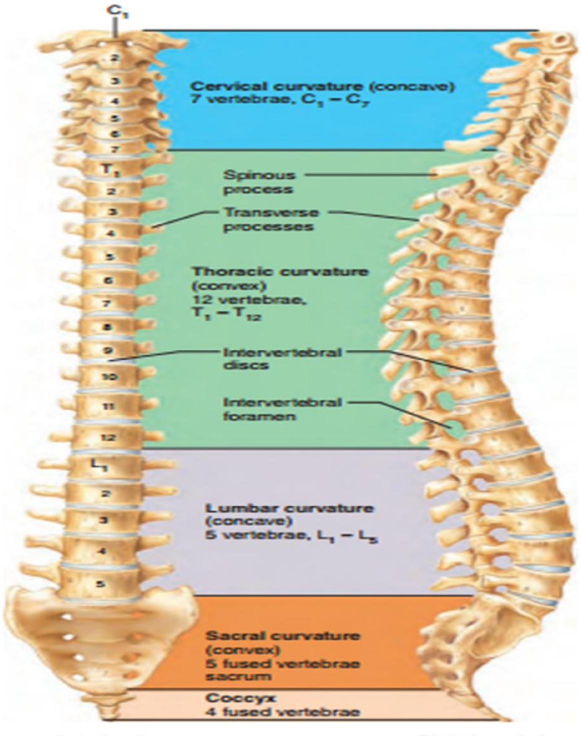


Fig. (2-1) The vertebral column, notice the curvatures in the lateral view (the terms convex and concave refer to the curvature of the posterior aspect of the vertebral column (Elaine n. marib, katja hoehn 2013)

2-2-1Scoliosis, literally, "twisted disease"

Is an abnormal lateral curvature that occurs most often in the thoracic region, It is quite common during late childhood, particularly in girls, for some unknown reason. Other, more severe cases result from abnormal vertebral structure, lower limbs of unequal length, or muscle paralysis. If muscles on one side of the body are nonfunctional, those of the opposite side exert an unopposed pull on the spine and force it out of alignment. Scoliosis is treated (with body braces or surgically) before growth ends to prevent permanent deformity and breathing difficulties due to a compressed lung.

2-2-2 Kyphosis or hunchback

Is a dorsally exaggerated thoracic curvature, It is particularly common in elderly people because of osteoporosis, but may also reflect tuberculosis of the spine, rickets, or osteomalacia.

2-2-3 Lordosis or swayback

Is an accentuated lumbar curvature, It too can result from spinal tuberculosis or osteomalacia. Temporary lordosis is common in those carrying a large load up front, such as men with "potbellies" and pregnant women. In an attempt to preserve their center of gravity, these individuals automatically throw back their shoulders, accentuating their lumbar curvature. (Elaine n. marib, katja hoehn 2013)

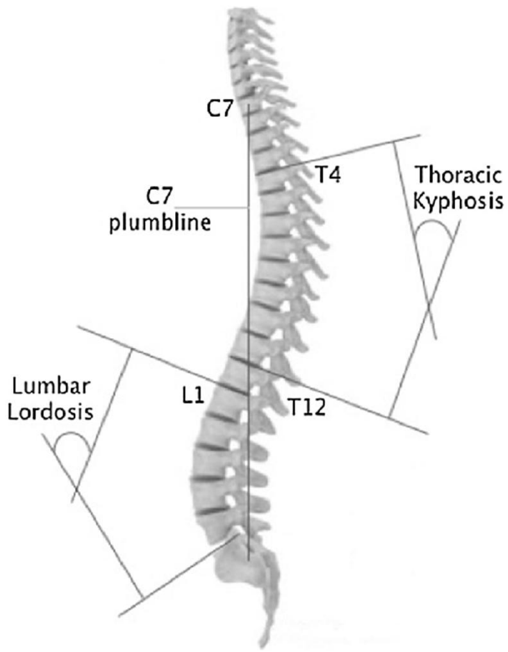


Fig (2-2) Sagittal curvature of the spine, lumbar lordosis and thoracic kyphosis

(www.researchgate.net)

2-3 Ligaments

Like a tall, tremulous TV transmitting tower, the vertebral column cannot possibly stand upright by itself. It must be held in place by an elaborate system of cable-like supports. In the case of the vertebral column, straplike ligaments and the trunk muscles assume this role. The major supporting ligaments are the anterior and posterior longitudinal ligaments. These run as continuous bands down the front and back surfaces of the vertebrae from the neck to the sacrum. The broad anterior ligament is strongly attached to both the bony vertebrae and the discs. Along with its supporting role, it prevents hyperextension of the spine (bending too far backward). The posterior ligament, which resists hyperflexion of the spine (bending too sharply forward), is narrow and relatively weak. It attaches only to the discs.

However, the ligamentum flavum, which connects adjacent vertebrae, contains elastic connective tissue and is especially strong. It stretches as we bend forward and then recoils when we resume an erect posture. Short ligaments connect each vertebra to those immediately above and below. (Elaine n. marib, katja hoehn 2013)

2-4 Intervertebral Discs

Each intervertebral disc is a cushion like pad composed of two parts. The inner gelatinous nucleus pulposus acts like a rubber ball, giving the disc its elasticity and compressibility. Surrounding the nucleus pulposus is a strong collar composed of collagen fibers superficially and fibrocartilage internally, the anulus fibrosus.

The anulus fibrosus limits the expansion of the nucleus pulposus when the spine is compressed. It also acts like a woven strap to bind successive vertebrae together, withstands twisting forces, and resists tension in the spine. Sandwiched between the bodies of neighboring vertebrae, the intervertebral discs act as shock absorbers during walking, jumping, and running. They allow the spine to flex and extend, and to a lesser extent to bend laterally. At points of compression, the discs flatten and bulge out a bit between the vertebrae. The discs are thickest in the lumbar and cervical regions, which enhances the flexibility of these regions.

Collectively the discs account for about 25% of the height of the vertebral column. They flatten somewhat during the course of the day, so we are always a few millimeters shorter at night than when we awake in the morning. Homeostatic Imbalance 7.3Severe or sudden physical trauma to the spine—for example, from bending forward while lifting a heavy object may result in herniation of one or more discs. A herniated (prolapsed) disc (commonly called a slipped disc) usually involves rupture of the anulus fibrosus followed by protrusion of the spongy nucleus pulposus through the annulus. If the protrusion presses on the spinal cord or on spinal nerves exiting from the cord, numbness or excruciating pain may result.

Herniated discs are generally treated with moderate exercise, massage, heat therapy, and painkillers. If this fails, the protruding disc may have to be removed surgically and a bone graft done to fuse the adjoining vertebrae. For those preferring to avoid general anesthesia, part of the disc can be vaporized with a laser in an outpatient procedure called percutaneous laser disc decompression that takes only 30 to 40 minutes. If necessary, tears in the anulus can be sealed by electrothermal means at the same time. The patient leaves with only an adhesive bandage to mark the spot. (Elaine n. marib, katja hoehn 2013).

2-5 Regional Vertebral Characteristics

Beyond their common structural features, vertebrae exhibit variations that allow different regions of the spine to perform slightly different functions and movements.

In general, movements that can occur between vertebrae are:

Flexion and extension (anterior bending and posterior straightening of the spine),

Lateral flexion (bending the upper body to the right or left), Rotation (in which vertebrae rotate on one another in the longitudinal axis of the spine). (Elaine n. marib, katja hoehn 2013)

2-6 Cervical Vertebrae

The seven cervical vertebrae, identified as C1–C7, are the smallest, lightest vertebrae. The first two (C1and C2) are unusual and we will skip them for the moment. The "typical cervical vertebrae (C3–C7) have the following distinguishing features:

The body is oval wider from side to side than in the anteroposterior dimension.

Except in C7, the spinous process is short, projects directly back, and is bifid (bi9fid), or split at its tip.

The vertebral foramen is large and generally triangular.

Each transverse process contains a transverse foramen through which the vertebral arteries pass to service the brain.

The spinous process of C7is not bifid and is much larger than those of the other cervical vertebrae Because its spinous process is palpable through the skin, C7can be used as a landmark for counting the vertebrae and is called the vertebra prominence ("prominent vertebra").

The first two cervical vertebrae, the atlas and the axis, are somewhat more robust than the typical cervical vertebra. They have no intervertebral disc between them, and they are highly modified, reflecting their special functions. The atlas (C1) has no body and no spinous process.

Essentially, it is a ring of bone consisting of anterior and posterior arches and a lateral mass on each side. Each lateral mass has articular facets on both its superior and inferior surfaces. The superior articular facets receive the occipital condyles of the skull they "carry" the skull, just as Atlas supported the heavens in Greek mythology.

These joints allow you to nod “yes.” The inferior articular facets form joints with the axis (C2) below.

The axis, which has a body and the other typical vertebral processes, is not as specialized as the atlas. In fact, it’s only unusual feature is the knoblike dens (denz; “tooth”) projecting superiorly from its body. The dens is actually the “missing” body of the atlas, which fuses with the axis during embryonic development. Cradled in the anterior arch of the atlas by the transverse ligament, the dens acts as a pivot for the rotation of the atlas. Hence, this joint allows you to rotate your head from side to side to indicate “no. (Elaine n. marib, katja hoehn 2013)

2-7 Thoracic Vertebrae

The 12 thoracic vertebrae (T1–T12) all articulate with the ribs The first looks much like C7, and the last four show a progression toward lumbar vertebral structure. The thoracic vertebrae increase in size from the first to the last.

Unique characteristics of these vertebrae include the following:

- The body is roughly heart shaped. It typically bears two small facets, commonly called demifacets (half-facets), on each side, one at the superior edge (the superior costal facet) and the other at the inferior edge (the inferior costal facet). The demifacets receive the heads of the ribs. (The bodies of T10–T12vary from this pattern by having only a single facet to receive their respective ribs)

- The vertebral foramen is circular.

- The spinous process is long and points sharply downward.

- With the exception of T11and T12, the transverse processes have facets, the transverse costal facets, that articulate with the tubercles of the ribs.

- The superior and inferior articular facets lie mainly in the frontal plane, a situation that prevents flexion and extension, but which allows this region of the spine to rotate. Lateral flexion, though possible, is restricted by the ribs. (Elaine n. marib, katja hoehn 2013)

2-8 Lumbar Vertebrae

The lumbar region of the vertebral column, commonly referred to as the small of the back, receives the most stress. The enhanced weight-bearing function of the five lumbar vertebrae (L1–L5) is reflected in their sturdier structure. Their bodies are massive and kidney shaped in a superior view.

Other characteristics typical of these vertebrae:

- The pedicles and laminae are shorter and thicker than those of other vertebrae.

- The spinous processes are short, flat, and hatchet shaped and are easily seen when a person bends forward. These processes are robust and project directly backward, adaptations for the attachment of the large back muscles.

- The vertebral foramen is triangular.

- The orientation of the facets of the articular processes of the lumbar vertebrae differs substantially from that of the other vertebra types.

These modifications lock the lumbar vertebrae together and provide stability by preventing rotation of the lumbar spine. Flexion and extension are possible (as when you do sit-ups), as is lateral flexion. (Elaine n. marib, katja hoehn 2013)

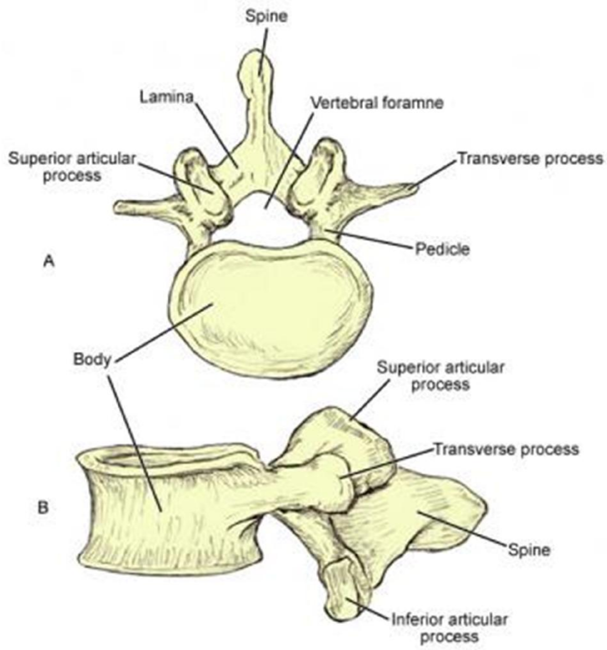


Fig. (2-3) Lumbar spine anatomy (www.medscape.com)

2-8-1 Intervertebral disc of the lumbar spine

Each intervertebral disc in the lumbar spine provides support and facilitate movement while resisting excessive movement. The disc permit slight anterior flexion, posterior extension, lateral flexion, Rotation, and some circumduction (Shankar,scarlett &Abraham,2009)

The disc is the largest a vascular structure in the body (singh et al, 2009) it is composed of the nucluse polposus and the annulus fibrosus. In some one less than 35 years old, the nuclus plposus soft, rather like crab meat texture. With aging the nuclus plposus dehydrates. The fibrus of the annulus fibrosus are concentric, like the layer of a radial tire. The concentric arrangement provide great resistance and strength. Each disc is bonded to the vertebral body below and above it by a thin cartilaginous plate, referred to as the endplate. The endplate resist herniation of the disc into the vertebral body and gives the disc its shape (hicks, weiner 2009).

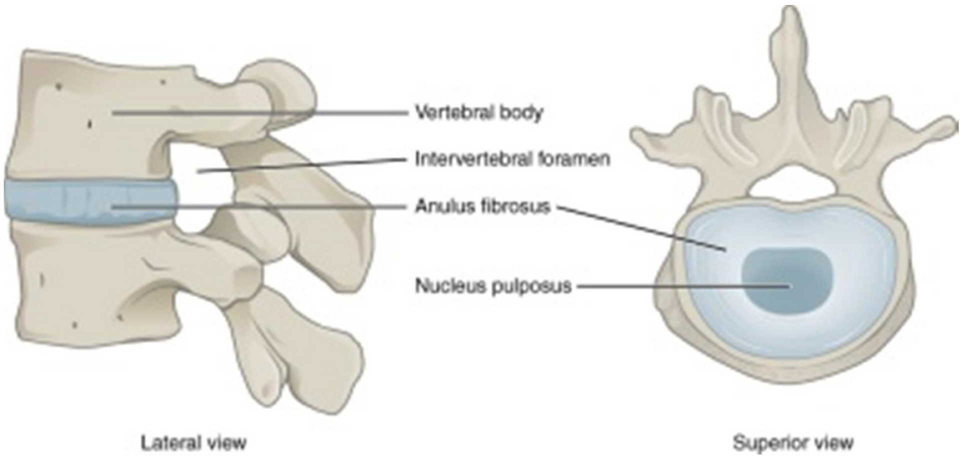
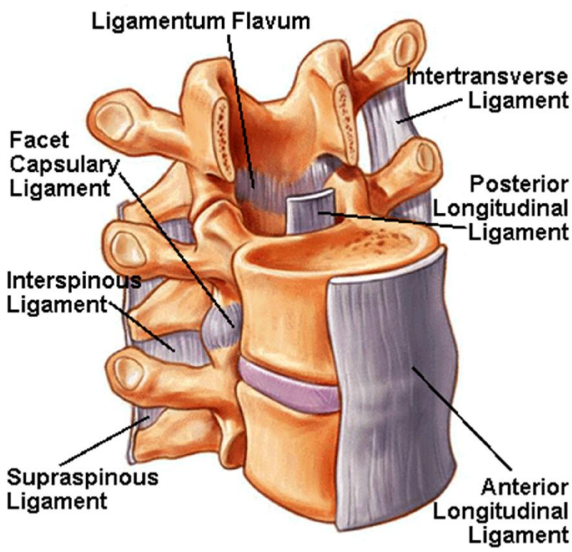


Fig. (2-4) Intervertebral disc (www.wikipedia.org)

2-8-2 Ligaments

By the posterior longitudinal ligament. The laminae are connected by an elastic yellow ligament called the flavum. . Each facet joint is connected to a capsular ligament. the transverse processes are connected by intertransverse ligaments. The rotator brevis and rotator longus ligaments connected the transverse process to the laminae of the superior two vertebrae. The spinous process are connected by the supraspinous and infraspinous ligaments, (Chou et al, 2009)



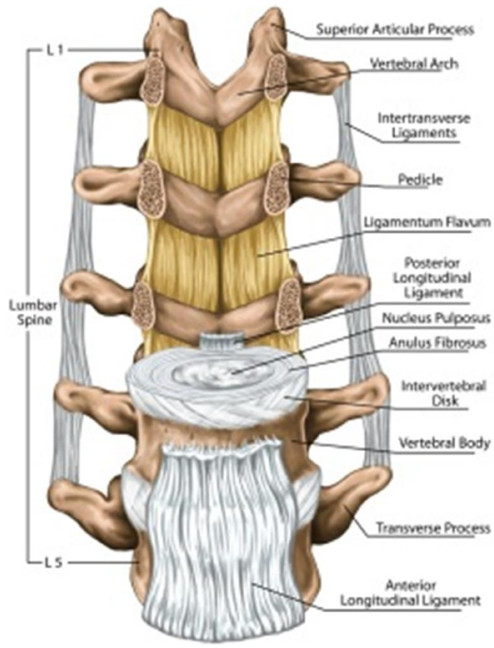


Fig. (2-5) Ligaments of the lumbar spine

(www.spineunverse.com)

2-8-3 Biomechanics

The functional unit of the spinal column is the motion segment. A motion segment is composed of two adjacent vertebrae, the disc between them, the facet joints connecting them. And the ligaments attached to the vertebrae. The geometry and health of the functional units help a surgeon determine which patients will benefit from surgery, as well as the most appropriate surgical intervention for a given patient (McGill & karpowicz 2009).

2-8-4 Spinal cord

The spinal cord ends at approximately the l1-l2 level in an adult. The conus medullar is the end of the spinal cord. The filum terminale is an extension of the pia matter, which descends below the conus medullaris and is anchored to the coccyx (Shankar, scarlett & Abraham 2009).

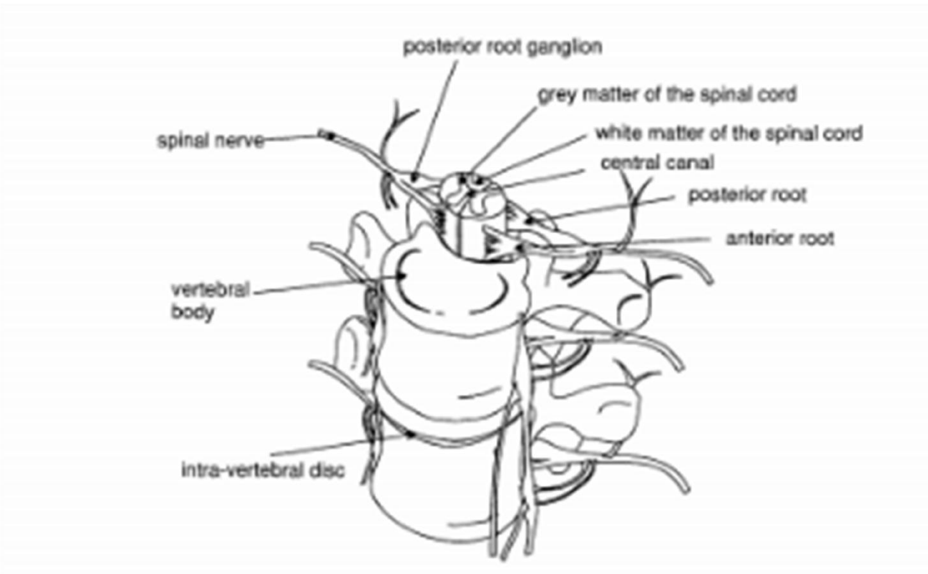


Fig. (2-6) The components of the spine and Spinal cord (Catherine w 2009)

2-8-5 Nerve roots

the cauda equina is a fanning bundle of lumbar and sacral nerve roots exiting of the spinal cord at the conus medullaris , this mass of nerve roots provides communication the lower extremities and control bowel, bladder, and sexual function The cauda equina is relatively resistant to neurologic insults, compared with the spinal cord the exiting nerve root in the lumbar spine is numbered according to the pedicle above it. For instance, the l5 nerve root passes below the L5 pedicle (Shankar, Scarlett, Abraharm 2009).

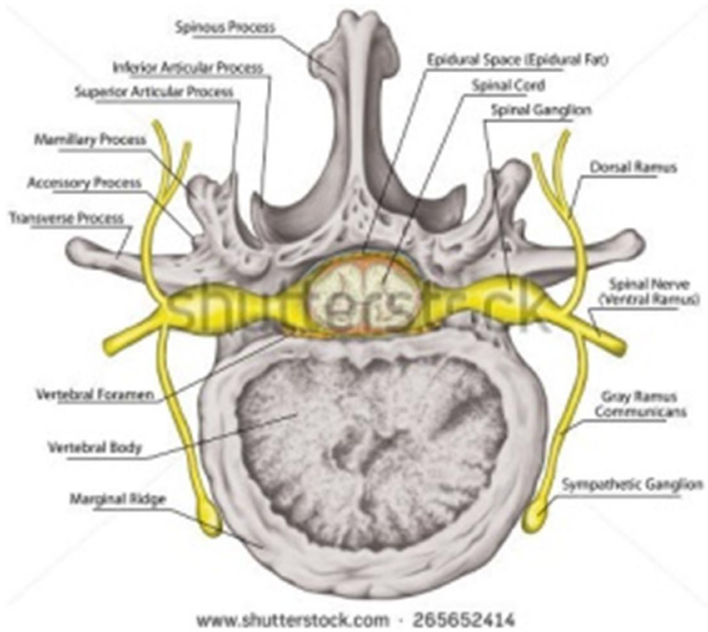


Fig. (2-7) Nerve roots of lumbar spine (www.shutterstock.com)

2-8-6 Vasculature

The abdominal aorta follow the left side of the spine until l4, where it bifurcates into the left and right common iliac arteries. The femoral arteries arise from the common iliac arteries. The middle sacral artery, iliolumbar artery, and internal iliac artery supply blood to L5 and the sacrum, Segmental arteries branch of the aorta and supply the vertebral body, posterior elements, and paraspinal muscles of the lumbar spine. Near the posterior wall of the vertebrae, each segmental artery bifurcates into a posterior branch and spinal branch. The spinal branch enters the vertebral canal through the intervertebral foramen and supplies portions of the posterior vertebral body. It joins other spinal branches at other levels to form the anterior spinal artery. the anterior spinal artery supplies the anterior two-thirds of the spinal cord. Segmental veins drain into the inferior vena cava, which originate at the convergence of the left and right common iliac veins at the l4 level the inferior vena cava terminates in the right atrium of the hear (Becske and Nelson, 2009).

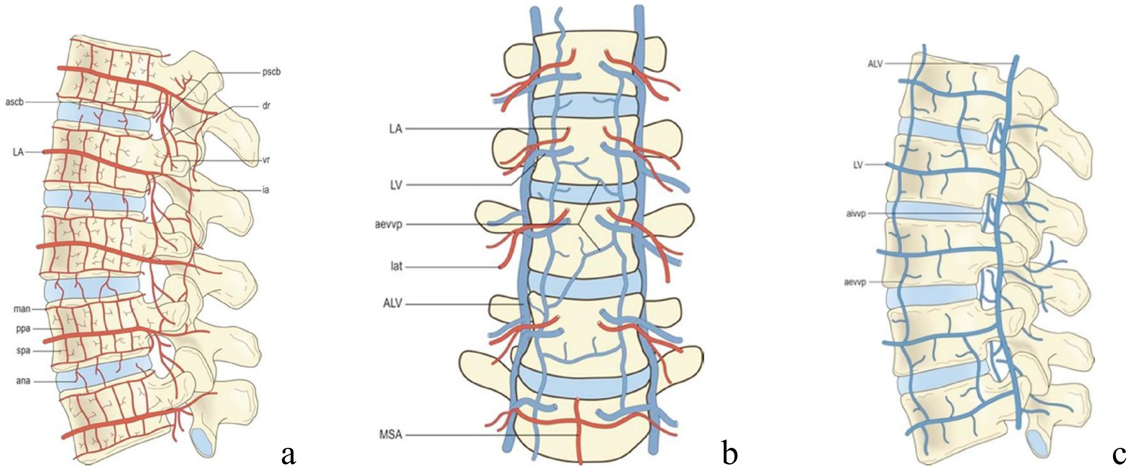


Fig. (2-8) (a,c) lateral view of the lumbar spine showing the lumber arteries ,veins and their branches.(b) an anterior view showing its intrinsic blood vessels.

(www.clinicalgate.com)

2-8-7 Imaging technique of the lumbar spine:

2-8-7-1 Conventional X-ray Studies

Plain films of the spine offer a quick and inexpensive evaluation of bony structures and are frequently used as an initial screening examination in, for instance suspected fractures, misalignment, and congenital spinal defects. Abnormal spinal curves can be assessed in scoliosis and the anatomy of individual vertebrae can be defined, although superimposition of anatomical structures is a problem. Spondylolysis and spondyloisthesis are well demonstrated. Spinal metastases can be detected on plain x-ray films, but only in a late stage, when cortical bony structure s of the vertebrae are affected, or vertebra is deformed or collapsed.

Contrast resolution in conventional, X-my images is limited: only four tissue densities, namely bone, water, fat, and air. Can be distinguished and soft tissue pathology such as a disc herniation cannot he visualized.

On the other hand, so-called degenerative features such as disc space narrowing. spondylosis, and spondylarthrosis can be demonstrated in asymptomatic as well as symptomatic individuals (Fullenlovc & Williams,1957).

The diagnostic yield of plain film studies in low back pain is very limited unless so-called red flags (indicators for specific disease conditions such-as neoplasm, disc himation or infectious disease) are present (Staiger et al. 1999). As mentioned above, however, the sensitivity for early detection of specific pathology by plain films is low, and in such cases alternative techniques with higher sensitivity, such as CT or MRI,

Are preferable, a plain film examination of the lumbar spine usually consists of a lateral and a postero-anterior view. Oblique views are sometimes performed of the isthmus region in case of spondylolysis, but these substantially increase the X-ray dose to the patient, and are not always necessary. Studies of the spine in flexion (kyphosis) and extension or retroflexion (lordosis) can be used in the assessment of post-traumatic or degenerative instability.

Fig. (2-9) Lumbar spine x-ray AP and lateral views (www.dreamstime.com)

2-8-7-2 Computed Tomography

Acquisition of sectional (tomographic) images by the use of an X-ray tube rotating around the patient. This made it possible to study spinal anatomic relationships in the axial plane which could not previously be visualized. A much better insight was obtained in the morphology and classification of, For instance, spinal stenosis. Detection of smaller differences in X-ray attenuation (tissue density) by using more sensitive scintillation detectors instead of an X-ray film, thus, greatly improving soft tissue contrast resolution. Image reconstruction by a computer algorithm permitting selection of window and level settings appropriate for viewing bony or soft tissue structures as required. The improved contrast resolution of CT made it possible to image disc herniations and other intraspinal normal and abnormal soft tissue features without the necessity of contrast injection into the dural sac. Visualization of intradural details by unconstructed CT is limited; the spinal cord can sometimes be seen faintly, and intradural nerve roots not at all. CT and myelography are complementary techniques: the first is more suitable for assessing the cause of radicular complaints, herniated disc, spinal stenosis etc, while the second is better for imaging the effect the compressed intradural nerve root (wilmink, 1989)

Fig. (2-10) Lumbar spine CT sagittal view (www.nursespot.com)

2-8-7-3 Magnetic Resonance

MR images can be acquired in any plane desired. And are superior tnreformatted sagittal or coronal CT images of the spine, especially for showing soft tissues. The largest single indication for spinal MR imaging is presently in degenerative spinal disease, usually performed to diagnose a possible disc herniation (ruggieri, 1999).

Phased array spine coils should be used for all spine imaging. Patients are

supine in the magnet. Both sagittal and axial images are acquired in the cervical, thoracic, and lumbar regions. In the axial imaging plane, we obtain stacked cuts that cover an entire block of the spine, as well as images angled with the disks when the indications are for pain, degenerative changes, or to rule out disk or radiculopathy. Some people obtain stacked images only and do not bother angling with the disks on any sequence; this is a matter of personal preference.

Conversely, acquiring images angled only through the disks (without obtaining stacked images) is considered inadequate, because portions of the spinal canal will not be imaged in the axial plane and sequestered disk fragments could be missed. Sagittal images alone are sometimes not adequate to detect a disk fragment that has migrated from the parent disk. Because sequestered disks are a cause of failed back surgery and persistent symptoms, it is important to identify them on MRI by obtaining stacked axial images in addition to sagittal images through the canal. In the unoperated lumbar spine, we obtain stacked axial images from the middle of the L3 vertebral body to the middle of the S1 vertebral body. In the postoperative spine, stacked axial images (matched images pre- and post-contrast) are obtained by centering at the level of the previous surgery.

Axial images are often better than sagittal for detecting lesions in the neural foramina. In general, we consider axial and sagittal planes of imaging to be complementary, and do not recommend doing without either. Coronal images may be useful to better define the anatomy in patients with scoliosis. (Phoebe A. Kaplan et al, 2001)

2-8-7-3-1 Pulse Sequences “Regions of Interest

The pulse sequences are determined by the clinical indications for the examination. basecl on the followine maior L, categories:

Degenerative disease (including radicular symptoms),

Trauma,

Cord compression bone metastases, and

Infection (disk or epidura1) intradural lesion.

T1W and fast T2W images are the standard for sagittal imaging in any segment of the spine. Graclient echo sagittal sequences are used when looking for blood in the cord after trauma to take advantage of the blooming effect. A fast STIR sagittal sequence also is useful in trauma patients when looking for ligamentous injury with changes of hemorrhage and edema. Gradient echo axials are used to detect disk disease in the cervical spine, whereas fast T2W axial images are used in the thoracic and lumbar spine for the same indications (Phoebe A. Kaplan et al, 2001).

Both TIW and some type of T2W images are selected in both the sagittal and axial planes for most indications. Details are given in the tables of spine protocols. Slice thickness in general is 3 or 4 mm. axial gradient echo images through the cervical disks are 2 mm thick. The fields of view are as small as possible; larger ones are required for sagittal than for the axial imaging planes. In the cervical, thoracic, and lumbar spine, the sagittal fields of view are usually 14 cm, 16 cm, and 16 cm, respectively; recommended fields of view for the axial images are " 11 cm, 12 cm, and 14 cm, respectively, Phase and frequency encoding gradients should be reversed for imaging the spine in the sagittal plane, so that chemical shift artifacts at the discovertebral interfaces do not obscure pathology in the vertebral body endplates or disks (Phoebe A. Kaplan et al, 2001).

2-8-7-3-2 Contrast

Contrast is always used for postoperative spine imaging, suspected infection, or intradural or non-traumatic cord lesions. If any abnormality is identified in the epidural space when evaluating for osseous metastases or cord compression, gadolinium is given to better demonstrate these lesions. (Phoebe A. Kaplan et al, 2001)

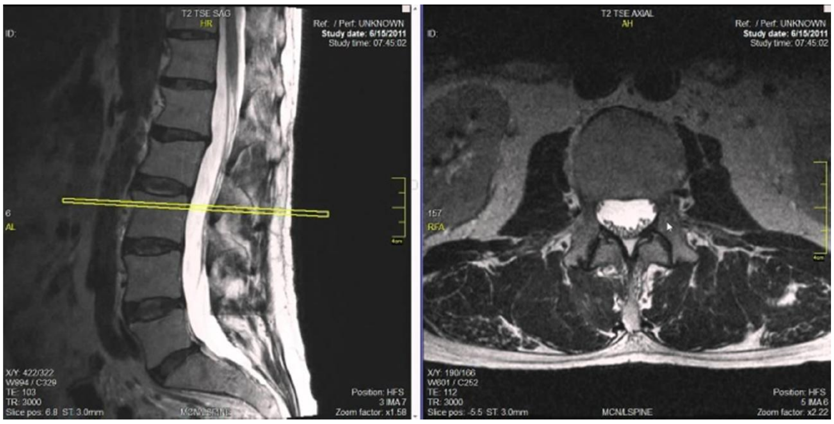


Fig. (2-11) Lumbar spine MRI sagittal and axial views (www.radiopaedia.org)

2-9 Sacrum:

The triangular sacrum, which shapes the posterior wall of the pelvis, is formed by five fused vertebrae (S1–S5) in adults . It articulates superiorly (via its superior articular processes) with L5 and inferiorly with the coccyx. Laterally, the sacrum articulates, via its auricular surfaces, with the two hip bones to form the sacroiliac joints of the pelvis. The sacral promontory (prom9on-tor0e; "high point of land projecting into the sea"), the anterosuperior margin of the first sacral vertebra, bulges anteriorly into the pelvic cavity. The body's center of gravity lies about 1 cm posterior to this landmark.

Four ridges, the transverse ridges, cross its concave anterior aspect, marking the lines of fusion of the sacral vertebrae. The anterior sacral foraminalie at the lateral ends of these ridges and transmit blood vessels and anterior rami of the sacral spinal nerves. The regions lateral to these foramina expands superiorly as the winglike alae. In its posterior midline the sacral surface is roughened by the median sacral crest (the fused spinous processes of the sacral vertebrae). This is flanked laterally by the posterior sacral foramina, which transmit the posterior rami of the sacral spinal nerves, and then the lateral sacral crests (remnants of the transverse processes of S1–S5).

The vertebral canal continues inside the sacrum as the sacral canal. Since the laminae of the fifth (and sometimes the fourth) sacral vertebrae fail to fuse medially, an enlarged external opening called the sacral hiatus (hi-a9tus; "gap") is obvious at the inferior end of the sacral canal. (Elaine n. marib, katja hoehn 2013)

2-10 Coccyx:

The coccyx, our tailbone, is a small triangular bone. It consists of four (or in some cases three or five) vertebrae fused together. The coccyx articulates superiorly with the sacrum. (The name coccyxis from the Greek word meaning "cuckoo" and was so named because of its fancied resemblance to a bird's beak.) Except for the slight support the coccyx affords the pelvic organs, it is a nearly useless bone. Occasionally, a baby is born with an unusually long coccyx, which may need to be removed surgically. (Elaine n. marib, katja hoehn 2013)

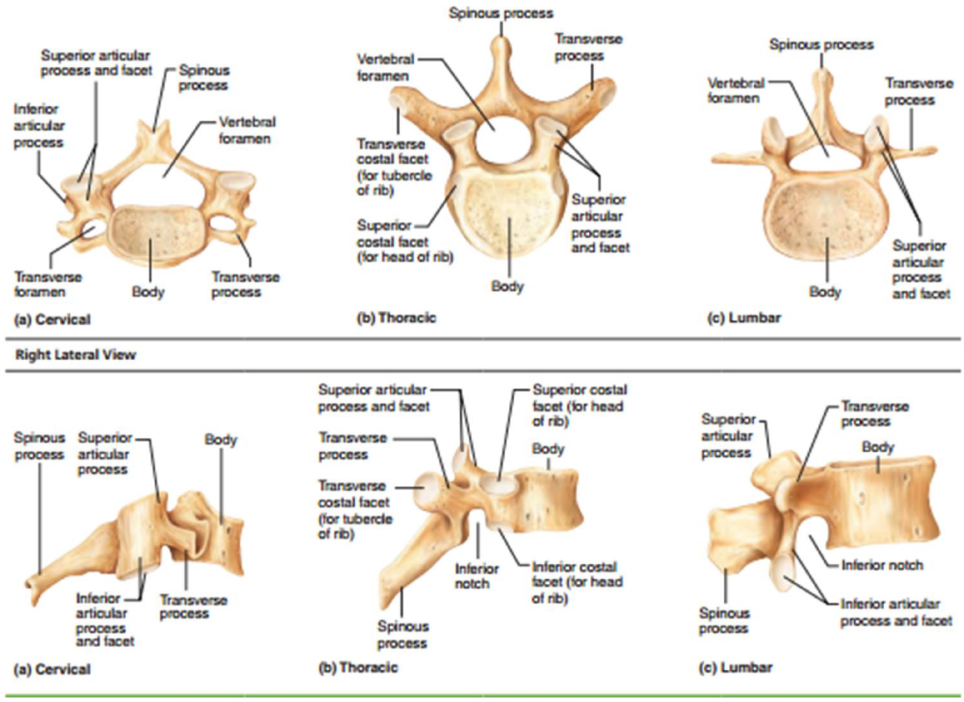


Fig. (2-12) Superior (upper) and lateral (lower) views at the cervical , thoracic, and lumbar vertebra (Elaine n. marib, katja hoehn 2013)

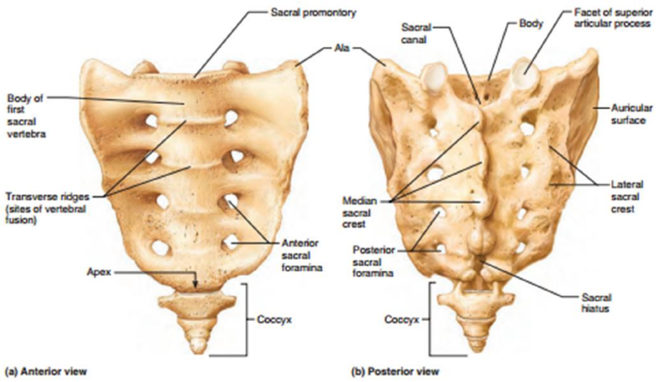


Fig. (2-13) The sacrum and coccyx (Elaine n. marib, katja hoehn 2013)

2-11 Normal and Abnormal Degenerative Changes:

Without a doubt, the most prevalent abnormalities of the spine are degenerative changes of the joints and osseous structures. Remember that, in the spine, the major joints consist of the paired, freely movable (diarthrodial) synovial facet joints running along the dorsal aspect of the spine and the minimally movable (amphiarthrodial) cartilaginous articulations formed by the intervertebral disks. Primary stability of the spine below C2 is provided by this three-joint complex, composed of the intervertebral disk and paired facet joints at each vertebral level. Anatomic and biochemical changes occur in these joints as the result of aging, but such changes may or may not cause symptoms. The major focus of spine imaging over the years has been on the mechanical effect that osseous, disk, and joint structures have on adjacent nerves. Although it is important to detect this mechanical effect with imaging, it must be remembered that most symptoms of back pain are not related to compression or stretching of an exciting or descending nerve. Pain may arise from the facet joints or disks, regardless of what these structures do to an adjacent spinal nerve root. It has been well established that asymptomatic individuals of all ages have disk abnormalities on imaging studies.' Defining the source of a patient's neck or back pain must be done very carefully by integrating the findings of clinical examination and MRI, often with the aid of diagnostic injections of anesthetic to different spinal structures for confirmation. (Phoebe A. Kaplan et al, 2001)

2-12 Disk Aging\Degeneration

Features of normal and abnormal disks discussed here apply to disks at any level in the spine, because they appear the same whether in the cervical, thoracic, or lumbar regions.

2-12-1 Normal Disk

Intervertebral disks consist of a central gelatinous nucleus pulposus composed of water and proteoglycans. The nucleus pulposus is surrounded by the annulus fibrosus. The inner portion of the annulus is composed of fibrocartilage, whereas the outer fibers are made of concentrically oriented lamellae of collagen fibers. The annulus is anchored to the adjacent vertebral bodies by Sharpey's fibers. On MRI, the itleal normal disk is low signal intensity on T1W images, being slightly lower signal than adjacent normal red marrow, and very similar to muscle. T2W images show diffuse high signal intensity throughout the disk, except for the outer fibers of the annulus, which are homogeneously low signal intensity. Distinctiol between the nucleus pulposus and the inner annulus fibrosus is not possible by MRI. Normal disks typically do not extend beyond the margins of the adjacent vertebral bodies; however, diffuse extension beyond the margins by 1 to 2 mm may certainly occur in some histologically normal disks.' The posterior margins of disks tend to be mildly concave in the upper lumbar spine, straight at the L4-5 level, and slightly convex at the lumbo- sacral junction. (Phoebe A. Kaplan et al, 2001)

2-12-2 Abnormal Nucleus

With aging and degeneration, the intervertebral disks lose hydration, lose proteo-glycans, and gain collagen as they become more fibrous. A horizontally oriented fibrous intranuclear cleft develops in the nucleus.

2-12-3 Abnormal Annulus

Aging and bio- chemical changes in the disks as described above are associated with the development of multiple, focal annular tears. Three types of annular tears have been described, but only one type is of practical interest, and that is the radial type of tear:' Radial tears (or fissures) involve either part or the entire thickness of the annulus from the nucleus to the outer annular fibers. Radial tears run perpendicular to the long axis of the annulus and occur more commonly in the posterior half of the disk, usually at L4-5 and L5-S1. The radial annular tear is considered by many to be responsible for pain. It may be a pain source because vascularized granulation tissue grows into the tear and causes painful stimulation of nerve endings that also extend into the defect from the surface of the disk: this would result in diskogenic pain. It also may be a pain source because of the instability of the disk that accompanies these fissures. And the chemical as well as mechanical irritation to the nocicleptive fibers that normally exist in the annulus. Radial fissures that cause diskogenic pain can be treated by minimally invasive intradiskal therapy (thermal or chemical) or by spinal fusion.

MRI of annular tears shows focal areas of high signal intensity on T2W images or on contrast enhances T1W images.' Radial tears may be seen on T2W sagittal images within the posterior annulus as globular or horizontal lines of high signal intensity. On axial images, radial tears may be seen as focal areas of high signal intensity that parallel the outer disk margin for a short distance. Radial tears or fissures on MRI also are referred to as high- intensity zones (HIZ)." (Phoebe A. Kaplan et al, 2001)

2-13 Abnormalities in Disk Morphology

The terminology for disk abnormalities is very confusing and inconsistent in the literature. Many physicians have referred to any and all disk abnormalities that extend beyond the margin of the vertebral body or disk as a herniated disk or herniated nucleus pulposus (HNP). The problem with this approach is that most of the abnormalities are of no consequence to the patient and are not associated with symptoms. This explains the high incidence of disk "herniations" reported in an asymptomatic popu1ation.l Analogies to this situation would be to call benign bone islands "sclerotic foci of undetermined etiology" or calcified granulomas in the lungs on a chest x-ray as "changes of infection." These latter statements are true, but of absolutely no help to the referring clinician or patient. They do not put the abnormality seen on the imaging study in proper perspective and indeed may be very misleading. Most surgeons dealing with spine disorders are starting to use a more standardized nomenclature that helps to distinguish what are likely to be clinically relevant lesions from those that probably are not. We use the same terminology as our surgeons to describe abnormalities in disk morphology: diffuse disk bulge, broad-based protrusion, focal disk protrusion, disk extrusion, and sequestered disk.

Focal disk abnormalities occur when material from the nucleus extends either partially or completely through radial tears in the annulus. Thus, focal disk abnormalities generally occur in a degenerated disk. The term "herniated disk" can be used as a general term to encompass all of the other more specific terms outlined here, but in our opinion it should never be the diagnosis in a report of a spine MRI examination. Once it has been determined that there is a diffuse or focal abnormality in disk contour, we generally try to quantify the abnormality as mild, moderate, or severe in extent. Unfortunately there are no aereed- i' upon definitions for what constitutes these different categories. Our method of quantifying the severity of disk disease is mild if the anterior epidural fat is not obliterated, moderate if the epidural fat is obliterated and the thecal sac is being displaced, or severe if the cord is being effaced or nerve root(s) displaced. This is not rocket science. The greatest difficulty is consistency and agreeing to the terms. All we are really evaluating when it comes to abnormalities in disk morphology is whether or not something is sticking out from the normal margin of a disk (like a wart from the skin surface), and by how far (how big the wart is). (Phoebe A. Kaplan et al, 2001)

2-13-1 Disk Bulge:

A diffusely bulging disk extends symmetrically and circumferentially by more than 2 mm beyond the margins of the adjacent vertebral bodies. This diagnosis is based on axial and sagittal images by comparing the size of the disk with the size of the adjacent vertebral bodies and determining if the central canal and neural foramina are narrowed by the disk. Identifying disk material protruding beyond the vertebral body margins on sagittal images does not clearly define if it is a diffuse or focal disk abnormality. The annulus can be considered as lax, and a decrease in disk height and disk signal usually is present on MRI. There are tears in the annulus when there is disk bulging, although they may not be evident on MRI.

Along segment of disk tissue that projects beyond the margin of the vertebral body but that does not involve the entire circumference of the disk can be called either a focal bulge or a broad-based protrusion. (Phoebe A. Kaplan et al, 2001)

2-13-2 Disk Protrusion:

This is a focal, asymmetric extension of disk tissue beyond the vertebral body margin, usually into the spinal canal or neural foramen that often does not cause symptoms. The base (the mediolateral dimension along the posterior margin of the disk) is broader than any other dimension. Some of the outer annular fibers remain intact, and some people refer to this as a contained disk. The protruded disk does not extend in a cranial or caudal direction from the parent disk. MRI shows most disk protrusions and their parent disks to have low signal intensity on both T1W and T2 W images. (Phoebe A. Kaplan et al, 2001)

2-13-3 Disk Extrusion:

An extruded disk is a more pronounced version of a protrusion and often is responsible for symptoms. There is disruption of the outer fibers of the annulus, and the disk abnormality usually is greater in its anteroposterior dimension than it is at its base (mediolateral dimension). The extruded disk may migrate up or down behind the adjacent vertebral bodies, but maintains continuity with the parent disk. These also may be referred to as non-contained disks. MRI shows the described contour abnormalities and, because of a significant inflammatory reaction that may occur in response to the extruded disk material, there may be high signal intensity on T2W and contrast-enhanced T1W images in or surrounding the disk. The typical appearance, however, is the same signal intensity as the parent disk on all pulse sequences. Lumbar disk extrusions that cause radiculopathy but that are managed non-operatively have been shown to do well about 90% of the time.7 Spontaneous reduction in size of disk extrusion and protsions that were managed conservatively has been well documented with imaging. The larger the disk extrusion, the greater the amount of regression in size of the extruded fragment with time. The regression in disk size may not be the reason for reduction in pain. Again, much of the pain from extruded disks is probable from the inflammatory response to them, rather than from compression of neural elements from the mass effect. (Phoebe A. Kaplan et al, 2001)

2-13-4 Sequestered Disk

When extruded disk material loses its attachment to the parent disk, it is called a sequestered fragment. These may migrate in a cranial or caudal direction with equal frequency and generally remain within about 5 mm of the arent disk. They may be located between the posterior longitudinal ligament and the osseous spine or extend through the posterior ligament into the epidural mass. They almost always remain in the anterior epidural space, but occasionally the fragment may migrate into the posterior epidural space. Rarely, sequestered fragments may enter the dural sac or migrate into the paraspinous soft tissues. It is extremely important to recognize these fragments, because they may be overlooked at surgery and are a contraindication to chymopapain, percutaneous discectomy, and other limited disk procedures. The fragment of disk material that mi- grates from the parent disk often shows peripheral or diffuse high signal intensity on T2W and contrast enhanced T1W images, caused by the inflammatory reaction within or surrounding it. Otherwise, a low signal intensity mass resembling the signal of the parent disk is seen. (Phoebe A. Kaplan et al, 2001)

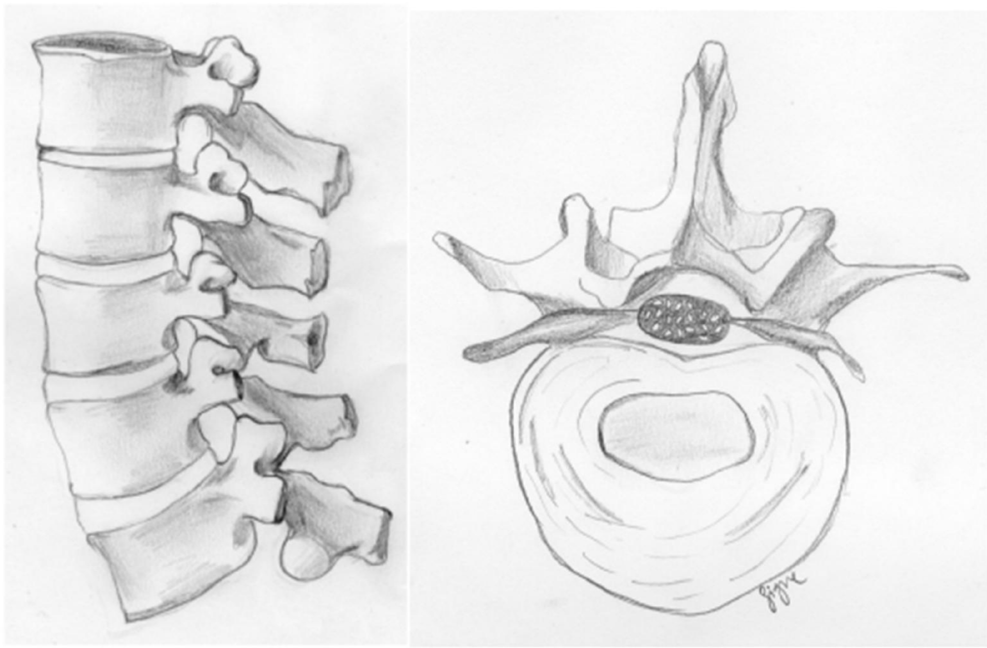


Fig. (2-13) The spine includes five lumbar vertebrae with discs. A healthy disc with the nucleus pulposus and annulus fibrosus. (Gunilla L. S, 2013)

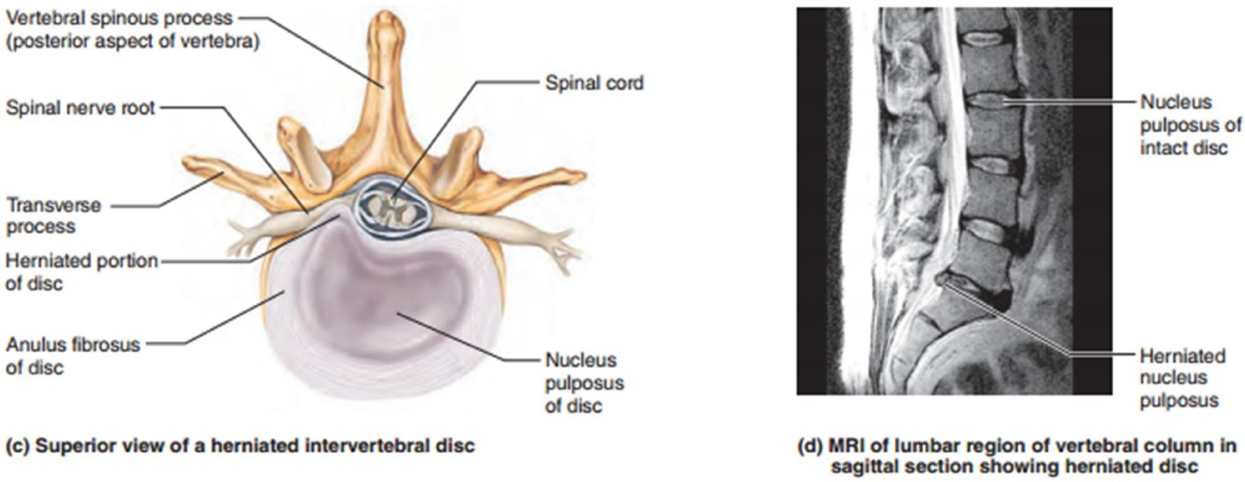


Fig. (2-15) axial and sagittal views showing a herniated intervertebral disc (human anatomy, page 220)

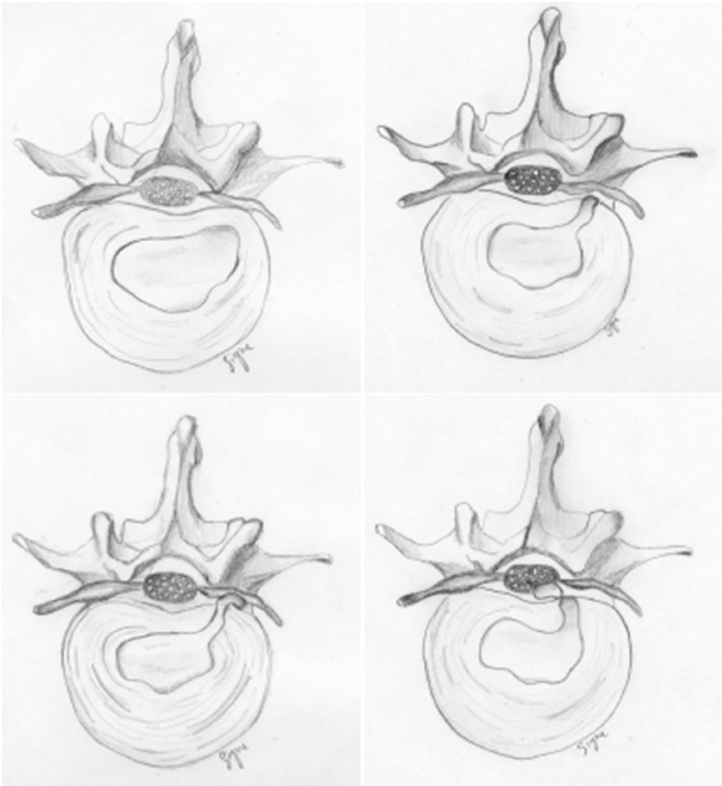


Fig. (2-16) Different severities of disc herniation from upper left: Disc bulge, protrusion, extrusion, and sequestration (Gunilla L. S, 2013)

2-14 Imaging the Intervertebral Disc:-

2-14-1 Discography is a radiographic technique in which contrast medium is injected percutaneous into the central part of the intervertebral disc. The method allows eva luation of disc disease in two ways, *First*, the injection of contrast medium into t he nucleus pulposus may provoke a pain sensation which reproduces(or aggrava tes) the original pain pattern experienced by the patient (Vanharantaet al. 1988a; Mon eta et al. 1994; Tehranzadeh1998).

Second, Pain provocation suggests disruption of the outer annulus fibross, and may provide the specificity missing from the purely morphologic information that CT and MR imaging provides (Jarvikand Deyo2000). The contrast medium injec ted into the nucleus pulposus can reveal the exact location of fissures and defects i n the annulus fibrosus (Vanharanta et al. 1988b; Tehranzadeh1998).

Despite its merits, discography is an invasive and discussion (Bogduk and Modic199

6; Weishaupt et al. 2001). Proponents argue that discography is the only method that directly relates a radiographic image to the patient's pain, and that it is the only moda lity that can detect the internal disc disruption syndrome (Guyer and Ohnmeiss1 995; Guye ret al. 2003).

Some investigators use discography as a preoperative diagnostic test to identify pai nful discs (Bini et al. 2002) or before performing intradiscal electrothermal annulopl asty (IDET) (KarasekandBogduk2000).

Many authors recommend the procedure to be limited to a strictly scientific an d prospective evaluation, and argue that there is no basis for the performance of disc ography in clinical medicine (Nachemson1989; Bogduk and Modic1996).

Abnormal discography examinations have been reported in normal asymptomatic sub jects (Walsh et al. 1990; Carragee et al. 2006).

Discography has many disadvantages: it is invasive and time-consuming; it includes a potential risk of infection; and it involves a moderate dose of radiation (especially wh en combined with CT). Subjects with signifycant emotional and chronic pain problem s may have long-term back symptoms after discography, and patients may present a f alse-positive pain provocation (Carragee and Alamin2001).

Discography is therefore not recommendable as a screening technique and the resul ts should be interpreted with great caution.

2-14-2 MRI:

Is the most sensitive imaging method for evaluating the intervertebral disc and has be come the primary imaging modality for investigation of the spine (Parizeland Wilmi nk1998). In addition for distinguishing recurrent disc herniation from epidural scar tis sue in the postoperative spine (Bradley1999). MRI yields exquisitely detailed i mages of disc herniation and root compression, but fails to distinguish clinically sym ptomatic findings from those that are incidental (Haughton 2004). This limitation has led to the development of newer MR-based techniques, such as:

Serial post-gadolinium MRI scans to assess the diffusion characteristics of lumbar in tervertebral discs (Rajasekaran et al. 2004). The status of the end plate influences diff usion of a contrast agent to the center of the disc. Endplate cartilage damage increases with age and produces considerable changes in diffusion.

Diffusion-weighted imaging with calculation of apparent diffusion coefficient maps to evaluate disc disease in an early phase (Kerttula et al.2000). Diffusion tensor microscopy imaging has been utilized to study the integrity of the fibers in the annulus fibrosus (Hsu and Setton1999). Measuring changes in T2-relaxation values as a means to assess the water content and structure of intervertebral discs (Kerttulaet al. 2001).

2-14-3 Magnetic resonance spectroscopy (MRS) of intervertebral discs to detect lactic acid, which increases in degenerative disc disease (Haughton2004). Dynamic imaging of the spine (e.g. during flexion-extension or by using axial loading) to increase the sensitivity of MRI. The application of axial compression can cause narrowing of the spinal canal or the neural foramina (Saifuddinetal. 2003a).

High intensity zones have been shown to develop on axial-loaded images of the lumbar spine (Saifuddinet al. 2003).

2-14-4 Neurography

This term is used to describe signal intensity changes in spinal nerves and spinal nerve roots on T2-weighted images obtained with high resolution phased array surface coils (Grant et al. 2004).

diculopathy (Mixter and Barr 1934), the terminology to report and grade degenerative diseases of the spine has been surrounded by controversy and confusion (Milette19 97).

In a recently published literature review study based on a Medline search, the authors found as many as 42 different grading systems for assessing cervical or lumbar disc and facet degeneration (Kettlerand Wilke2006).

Different terminology is used by pathologists, neuro surgeons, orthopedic surgeons, radiologists, and neuro radiologists.

The same terms are used with different definitions, which is highly confusing. Some nomenclature systems describe disc pathology based on the observed morphology of the disc contour, whereas others take into account anatomical, clinical and pathological findings.

Definitions and concepts based on cross sectional imaging studies are different from those based on discography or myelography (Bogdukand Modic1996).
The lack of standardization in terminology contributes to a substantial interobserver variability in the interpretation of imaging studies (Jarviket al. 1996).
In one study evaluating reader consistency in the interpretation of lumbar disc abnormalities, authors compared two different nomenclatures ("normal/bulge/herniation " *Versus* "normal/bulge/protrusion/extrusion"); they commonly found disagreements for normal versus bulge and between bulge versus herniation or protrusion (Brant-Zawadzkiet al. 1995).
There is dire need for a reliable and unambiguous terminology to describe normal and pathologic conditions of intervertebral discs. In 2001, the Combined Task Forces of the North American Spine Society, American Society of Spine Radiology, and American Society of Neuroradiology proposed a new nomenclature and consistent classifyaction system, intended for the reporting of imaging studies (Fardon and Milette2001; Milette2001).
The focus of this document is on the lumbar spine, though certain terms and definitions can be extrapolated to the cervical and thoracic spine. The diagnostic categories and subcategories are based on pathology. (Milette2000).
There are, however, other classification systems in use which are based on the three-joint complex: the intervertebral Disc (anterior column of the spine) and the two facet joints (posterior column) (Thalgottet al.2004).
In this chapter, we shall follow the general classification of disc lesions as proposed by the Combined Task Forces.

2-14-5 Diffusion tensor microscopy imaging

Has been utilized to study the integrity of the fibers in the annulus fibrosis (Hsu and Setton1999).Measuring changes in T2-relaxation values as a means to assess the water content and structure of intervertebral discs (Kerttulaet al. 2001).

2-15 Nomenclature and Classification of Degenerative Disc Disease:-

The lack of standardization in terminology contributes to a substantial interobserver

variability in the interpretation of imaging studies (Jarviket al. 1996).
since the initial description in 1934 by Mixterand Barr of a “ruptured disc” with monora-diculopathy(Mixterand Barr 1934), the terminology to report and grade degenerative diseases of the spine has been surrounded by controversy and confusion (Milette1997).
In a recently published literature review study based on a Medline search, the authors found as many as 42 different grading systems for assessing cervical or lumbar disc and facet degeneration (Kettlerand Wilke2006).
Different terminology is used by pathologists, neurosurgeons, orthopedic surgeons, radiologists, and neuroradiologists. The same terms are used with different definitions, which is highly confusing. Some nomenclature systems describe disc pathology based on the observed morphology of the disc contour, whereas others take into account anatomical, clinical and pathological findings. Definitions and concepts based on cross-sectional imaging studies are different from those based on discography or myelography (Bogduk and Modic1996).
In one study evaluating reader consistency in the interpretation of lumbar disc abnormalities, authors compared two different nomenclatures (“normal/bulge/herniation *“versus* “normal/bulge/protrusion/extrusion”); they commonly found disagreements for normal versus bulge and between bulge versus herniation or protrusion (Brant-Zawadzkiet al. 1995).
So there is a dire need for a reliable and unambiguous terminology to describe normal and pathologic conditions of intervertebral discs.
In 2001, the Combined Task Forces of the North American Spine Society, American Society of Spine Radiology, and American Society of Neuroradiology proposed a new nomenclature and consistent classify action system, intended for the reporting of imaging studies (Fardon and Milette2001; Milette2001).
The focus of this document is on the lumbar spine, though certain terms and definitions can be extrapolated to the cervical and thoracic spine. The diagnostic categories and subcategories are based on pathology.
There are, however, other classification systems in use which are based on the Three

-joint complex: the intervertebral disc (anterior column of the spine) and the two facet joints (posterior column) (Thalgottet al. 2004).

General classification of disc lesions:-

- Normal (excluding aging changes)
- Congenital/developmental variant
- Degenerative/traumatic lesion:
    - Annular tear
    - Herniation
        - Protrusion/extrusion
        - Intervertebral
- Degeneration
    - Spondylosisdeformans.
    - Intervertebral osteochondrosis.
- Inflammation/infection.
- Neoplasia.

Morphologic variant of unknown significance

2-16 Measurements of lumbar lordosis

Measurement of lumbar lordosis can be difficult. Obliteration of vertebral end-plate landmarks by inter body fusion may make the(raditional measurement of segmental lumbar lordosis more difficult, Because the L4-L5 and L5-S1 levels are most commonly involved infusion procedures, or arthrodesis, and contribute to normal lumbar lordosis, it is helpful to identify a reproducible and accurate means of measuring segmental lordosis at these levels. (Babai.E et al, 2012)

Considering the prevalence of spinal anomalies in general, and lumbar lordosis in particular, among adults and young adults, and negative effects on spinal movement and preparing for waist ache and back ache, it seems essential to diagnose these anomalies in the right time and right way to decrease their harmful effects.

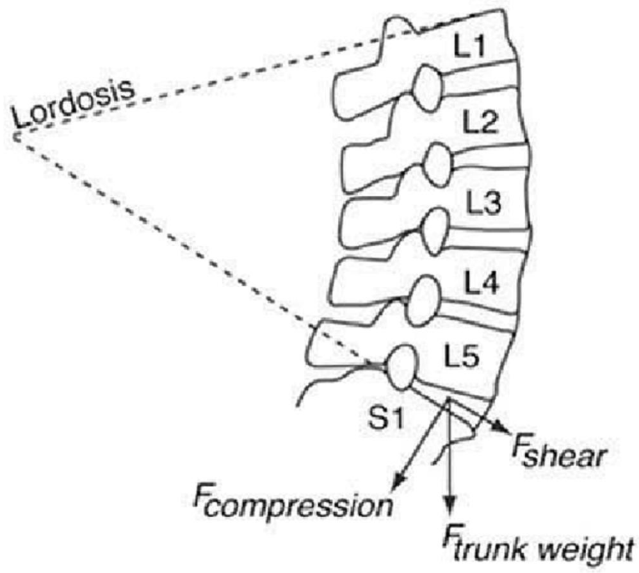


Fig. (2-17) Degree of lumbar lordosis (www.researchgate.net)

There are different methods for diagnosing spinal column anomalies

2-16-1 Methods of measurement

Many methods are used to evaluate lumbar lordosis. We divided the methods into clinical and imaging evaluation. Clinical examination evaluates the degree of lordosis directly on the individual's body. Radiologic evaluation uses two dimensional radiographs, three-dimensional (3D) computed tomography and MRI. Each method of evaluation has its advantages and disadvantages, but the major problem is that it is difficult to compare the measurements when performed by different methodologies. Clinical methods for evaluating lordosis angles include various 3D posture analysis systems and surface topography systems. Most of these methods use the spinous processes of the lumbar vertebrae to evaluate the degree of lordosis. The main advantage of these measurements is the lack of radiation, thus allowing frequent evaluation of the spinal curves, and better monitoring of the changes in the lordosis angle. The reproducibility of clinical methods is relatively high (interobserver intraclass correlation coefficient [ICC] is 0.70–0.85, however, it is not as high as with radiologic methods (interobserver ICC is 0.87).On the other hand, because clinical methods use surface anatomy to evaluate the lordosis angle, only moderate correlations with radiologic measurements were found. Comparisons between the patients are also problematic because of different paraspinal muscle development, thickness of subcutaneous fat, and anatomic variations in spinous processes length and orientation. Recently, a few articles have suggested the use of electronic or laser lordosis angle measurements. (Ella. Been and L. Kalichman 2013)

2-17 Radiographic method

Which are: Cobb's method, TRALL, centroid, and Harrison posterior tangent methods. Among them, Lumbar Lateral X-ray radiography stands out as the "gold standard" for such evaluations. This method is also the most requested by medical professionals. However, its application is not very common in the physical therapy clinical practice, either because the equipment is not available to the physical therapist or because not all health plans cover radiographic examinations. The most common procedure for measuring the angles of the spinal curvatures is Cobb's method, carried out by means of radiographic studies. But TRALL, centroid, and Harrison posterior tangent methods are not as commonly performed (Harrison et al, 2001).

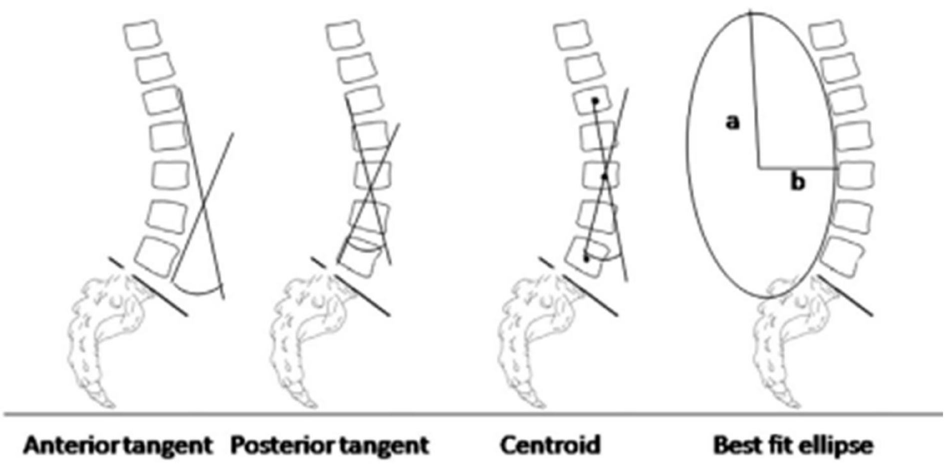


Fig. (2-18) Measurements of lumbar lordosis: anterior tangent, posterior tangent, and centroid (Ella. Been and L. Kalichman 2013)

2-17-1 Cobb's method

The most common evaluation of lumbar lordosis uses the angle formed by all five lumbar segments (L1–L5). When employing Cobb's method, the upper line is drawn at the superior endplate of L1, and the lower line at the superior endplate of the sacrum (S1). However, some researchers measure lordosis starting as high as T10*, others finish at L3. Some researchers do not include the lower lumbar segment (L5) or only do not include the last intervertebral disk L5–S1 in their measurements. Significant differences occur between lordosis angles when different numbers of vertebral segments are measured. Therefore, we believe that it is crucial to measure exactly the same number of segments to compare the different studies. We suggest that measurements should include the vertebral bodies and intervertebral disks of L1–L5; in other words, measurements (Cobb's method) should be performed between the superior endplate of the first lumbar vertebra and the superior endplate of the sacrum. The logic behind our suggestion is based on anatomic considerations, including all of the lumbar segments in the lumbar lordosis measurements. In addition, this is the most popular measurement of lumbar lordosis used today; functionally, the five lumbar segments share a fundamental role in upright functions such as walking and running (Ella. Been and L. Kalichman 2013).

The Cobb angle was originally used to measure coronal plane deformity on antero-posterior plain radiographs in the classification of scoliosis. It has subsequently been adapted to classify sagittal plane deformity, especially in the setting of traumatic thoracolumbar spine fractures. (www.wikipedia.com).

In the setting between a line drawn parallel to the superior endplate of one vertebra above the fracture and a line drawn parallel to the inferior endplate of the vertebra one level below the fracture .the Cobb angle is the preferred method of measuring post-kyphosis in a recent meta-analysis of traumatic spine fracture lordotic angle (LLA) is measured from the sagittal plane by perpendicular line to a line drawn across the superior endplate the upper-end (most tilted) vertebra (L1) and the inferior endplate of end vertebra (L5); the angle formed by the intersection of the tow perpendicular lines is the Cobb angle or lumbar lordotic angle, which is the measure of magnitude of the curve. (www.wikipedia.com).

2-18 Literature review

Zohreh Habibi1, et al. (2014) had studied (Lumbosacral Sagittal Alignment in Association to Intervertebral Disc Diseases to evaluate the correlation between lumbosacral sagittal alignment and disc degeneration), their Results showed that Lumbar lordosis based on Cobb’s method was lower in group with discopathy (20°–67°; mean, 40.48°±9.89°) than control group (30°–62°; mean, 44.96°±7.68°), although it was not statistically significant. The proposed global lumbosacral angle in subject group (53°–103°; mean, 76.5°±11.018°) was less than control group (52°–101°; mean, 80.18°±9.95°), with the difference being statistically significant ($p=0.002$).

C.E.A et.al (2013) had studied (Evaluation of Lumber Lordotic Angle in Patients with Inter Vertebral Disc Prolapse using Cobb's Method) during the period from November 2012 up to March 2013, they concluded that Cobb angle and Disc prolapse levels have no significant relation with job, height, weight, age and BMI, no significant difference was detected between Cobb angle of the normal subjects and patients with prolapsed disc and the results did not differ among male and female patients.

Judith R Meakin et al. had study (Characterizing the Shape of the Lumbar Spine Using an Active Shape Model: Reliability and Precision of the Method) .the outcome of the study showed that the shape model identified two modes of variation to describe the shape of the lumbar spine (mode 1 described curvature and mode 2 described evenness of curvature). Significant correlations were found between mode 1 and total lordosis ($R = 0.97$, $P < 0.001$) and between mode 2 and mean absolute deviation of segmental lordosis ($R = 0.80$, $P < 0.001$). Intra- and inter-observer reliability was higher for the shape model (ICCs 0.98 – 1.00) than for the Modelling the lumbar spine shape3 lordosis angle measurements (ICCs 0.68 – 0.99). The relative error of the shape model (mode 1 = 4 %; mode 2 = 9 %) was lower than the conventional measurements (total lordosis = 10 %).

Caroline E.A et al. (2011) had studied (Defining normal vertebral end plates Cobb angle from T12 to L4 using computerized tomography in Sudanese populations) The study concluded that the mean Cobb angle end plate differs significantly from males and females Sudanese subjects and it has relation with age and the values differs from what was mentioned in the previous studies, the knowledge of the normal end plates angle allows better characterization and diagnosis for vertebra from T12 to L4.

Luizh Enrique fonsecadamascenoi, et al,(2006), had studied (lumbar lordosis: a study of angle values and of vertebral bodies and intervertebral discs role) their result showed that The values obtained for lumbosacral curvature measurements (L1S1) ranged from –33.0° to –89.0° (average –60.9° ± 10.65). The values for lumbolumbar curvature (L1L5) ranged from –15.0° to –78.0° (average –45.1° ± 10.8). Vertebral bodies showed kyphotic bent in L1, tended to neural in L2, and then showed progressive lordotic bent, with a statistically significant difference between measurements. Intervertebral discs showed progressive lordotic bent from L1-L2 to L5-S1, also showing statistically significant differences between values. Vertebral bodies, as well as intervertebral discs, presented a progressively more lordotic participation on head-tail direction of the lumbosacral curvature. The only lumbar curvature element presenting medium kyphotic participation was the vertebral body L1 (negative percent participation). It was observed that the percent participation range for vertebral bodies L1 to L4, as well as for intervertebral disc L1-L2 showed negative percent values in some individuals.

That observation is attributed to the finding of individuals presenting kyphotic bent in those vertebral bodies and intervertebral discs. It was observed that only vertebral body L5 and intervertebral discs L2-L3 to L5-S1 showed lordotic bent in all individuals. The comparison of both subjects groups according to age group showed a statistically significant difference between lumbosacral curvature measurements ($p<0.01$) and lumbolumbar curvature measurements ($p<0.001$). Only the angle values for vertebral bodies L2 and L5 and for intervertebral disc L2-L3 showed a statistically significant difference.

Lumbosacral and lumbolumbar curvatures measurements Showed statistically significant differences between male and female subjects. A statistically significant difference was also seen between the measurements for vertebral bodies L2 and L4. No statistically significant difference was found between angle values for intervertebral discs.

The assessment of male subjects as a separate subgroup showed no statistically significant difference between values for lumbosacral curvature, lumbolumbar curvature, vertebral bodies, or intervertebral discs among individuals within both age groups studied. The assessment of female subjects divided into both age groups showed a statistically significant difference between measurements for lumbosacral curvature, lumbolumbar curvature and vertebral body L5. There was no significant difference between values for other vertebral bodies and intervertebral discs. The results of reliability tests showed a good reliability between intra- and inter-observer measurements for studied parameters, showing an acceptable consistency between measurements.

Another method employed for assessing the reliability of performed measurements was the comparison between angle values measured on lumbosacral curvature (L1S1) and values found by the sum of angle measurements for vertebral bodies and intervertebral discs, which are integral part of the lumbosacral curvature.

Measurements found for lumbosacral curvature ranged from –33° to –89° (average –60.9° ± 10.65) for measurements of the sum of vertebral bodies and intervertebral discs ranged from –31° to –89° (average –60.9° ± 10.78), with a correlation of 0.98 (Pearson $p<0.0001$), showing an almost perfect correlation.

V.L. murrie, et al had study (Lumbar Lordosis: Study of Patients With and Without Low Back Pain) 2003 Wiley-Liss, Inc. used magnetic resonance imaging (MRI) to assess lumbar lordosis in 27 patients with low back pain and 19 patients and 10 volunteers with no known back pain. Their study aimed to investigate whether lordosis changes with age and is reduced in those with low back pain.

Although their results confirm known observations that lumbar lordosis is more prominent in women (P>0.01) and those with a higher body mass index (P>0.04), we were unable to demonstrate any significant variation in lordosis with age. Nor could we demonstrate any difference in the degree of lordosis among women with or without back pain. Men with low back pain tended to have a less prominent lordosis, but this difference did not reach statistical significance. Therefore, a reduced lumbar lordosis should be regarded as a very weak clinical sign.

Chapter three

Chapter three

Material and method

3-1 Study design

This is analytical descriptive; case-control study.

3-2 Study Population

3-2-1 Inclusion & exclusion criteria

Study was include patient come to radiology department to do lumbosacral MRI scan and it's complain of low back pain, when images finding all patients with vertebral column congenital or traumatic will be excluded.

3-2-2 Duration and place of the study

This study will be conducted in the period from Aug 2015 to Aug 2018 in Sudan University of science & technology; data well is collecting by using a special design collection sheet, From Advanced Diagnostic Center by machine 0.35 Tesla, and Baraha Medical City by machine 1.5 Tesla.

3-3 Study sample size and type

The sample of this study consists of 140 adults Sudanese individuals male (55) Female (85) with different ages, weight, gender, height and BMI that referred to do Lumbosacral MRI exam.

3-4 Method of data collection

3-4-1 Tools and Technique

3-4-1-1 Equipment's

- Machine type: Philips & Superstar Neusoft medical system 0.35 Tesla.
- Machine type: Siemens, symphony, mastro class 1.5 Tesla.

3-4-1-2 L\S Exam Technique:-

The patient lies supine on the examination couch with their knee elevated over a foam pad, the coil should extend from the xiphisternum to the bottom of the sacrum. The longitudinal alignment light lies in the midline, and the horizontal alignment light passes just below the lower costal margin, which corresponds to the third lumbar vertebra.

3-4-1-3 Protocol of MRI scan

The lumbar spine was examined with the use of a 1.5 Tesla scanner. T1- T2 weighted images in the sagittal plane

-T1 se-sag 03:28.TR 400, TE 16.0 ms.

-T2 Tse-sag 02:54.TR 4000, TE 118.0 ms.

-T1 Tirm-sag 03:09.

0.35 Tesla scanners:

-T1 Tse sag.. TR 484.8,, TE 11.0 ms.

-T2 Tse sag .. TR 3752.8,, TE 144.0 ms.

Slice thickness was 5.5 mm.

The field of view (FOV) used was 340 x 340 ml , which readily contained the lumbar spine with the last thoracic vertebra and a part of the sacrum

3-5 Variables used for data collection

3-5-1 Measurements

All MRIs were examined in the midsagittal plane. Confirmation that the resulting images were truly midline for all lumbar segments was determined from the presence of the spinous processes and clear demarcation of the spinal cord.

Data sheet include

3-5-1-1 Sagittal view measurements

Age, gender, weight, height, BMI

Intervertebral disc space (Middle height) (mm)

Herniated disc (Length, Width) (mm)

Angle of lumbar lordosis (Cobb angle)

Body (Middle height) (mm)

Lumbosacral angle

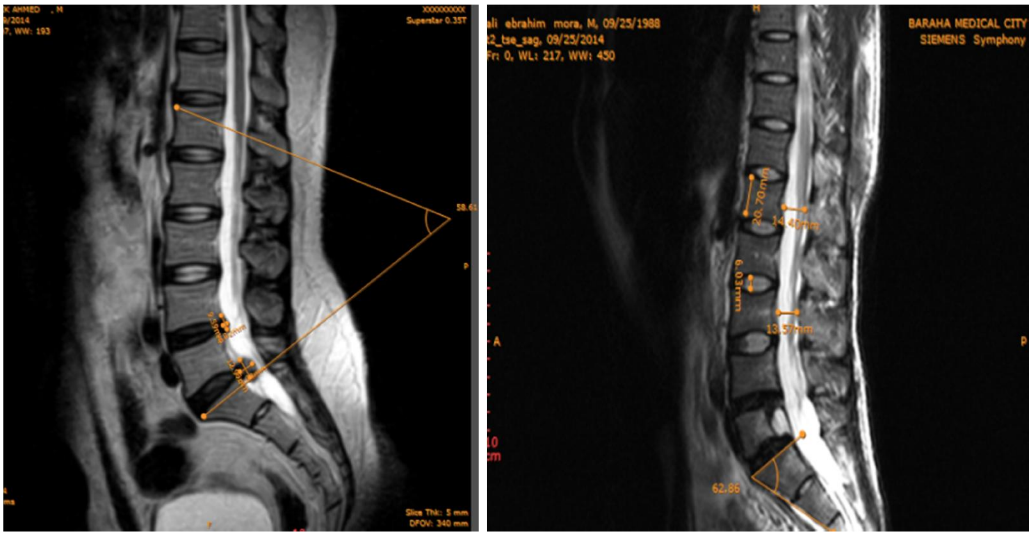


Fig (3-1) MRI sagittal T2 W images showed measurement of Cobb angle, bo dy diameter, IVD space diameter, LS angle and disc bulge

3-6 Method of data analysis

The data were analyzed using computerized Statistics Package for Social Sciences (SPSS version 21) and Microsoft offices excel, using T. test and ANOVA test. A *p*-value of less than 0.05 was considered to indicate a statistically significant difference. Using correlation to estimate the association between the Cobb angle and variables which collected from patients (vertebral body diameter. IVDS diameter, patient weight and height). Descriptive statistics (frequencies, percentages, Bars chart, Scatter plot, means and standard deviation**.**

3-7 Ethical Issue

*the study candidate are selected randomly, no patient identifications or individual patient details will be published,

* All patients in this study are referred as usual to do lumbosacral MRI scan aft er permission taken from them all their images will be under the study to do all measurements.

* Also permission will be taken from the head of the Radiology department in th e hospital.

Chapter four

Chapter four

The results

The flowing results represent the research study population data after had been comprehensively analyzed.

Table (4-1): Distribution of sample study according to demographic data

Group		Age	Height	Weight	BMI
ABN	Mean ± SD	47.3 ± 15.7	167.2 ± 10.4	77.9 ±15.1	46.6 ± 8.7
	Minimum	17	146	47	29.9
	Maximum	90	191	115	69.3
Control	Mean ± SD	37.8 ± 13	169.8 ± 10	71.5 ± 15.7	42.1 ± 9
	Minimum	13	148	48	28.9
	Maximum	74	191	130	79.8

SD= Standard Deviation

Table (4-2) the mean and stander deviation of Cobb angle, diameter of vertebral body and IVD space of lumber spine for normal and abnormal patients

Group Statistics

Status		Mean	SD
Cobb angle	Abnormal	50.087	8.1589
	Normal	57.183	4.1096
BodyL5	Abnormal	18.811	2.1374
	Normal	19.045	1.9025
IVDspaceL5	Abnormal	10.810	2.4570
	Normal	10.085	1.4795
BodyL4	Abnormal	19.477	1.7751
	Normal	19.398	1.7952
IVDspaceL4	Abnormal	11.153	2.0577
	Normal	10.633	1.4457
BodyL3	Abnormal	19.738	1.7180
	Normal	19.708	1.5986
IVDspaceL3	Abnormal	10.570	2.1815
	Normal	9.628	1.1554
BodyL2	Abnormal	19.974	2.1509
	Normal	19.950	1.6787
IVDspaceL2	Abnormal	9.613	2.2464
	Normal	8.938	1.2939
BodyL1	Abnormal	19.553	1.9896
	Normal	19.300	1.8425
IVDspaceL1	Abnormal	8.163	1.7035
	Normal	7.653	1.5302
Lumbosacral angle	Abnormal	54.96	4.95
	Normal	56.40	4.44

Table (4-3) independent t-test show the significance difference in means according to p-values between the normal and abnormal values of Cobb angle, vertebral body diameter and IVD space of lumber spine.

Independent Samples Test		
	t-test for Equality of Means	
	T	P-value
Cobb angle	-5.233	**0.000**
BodyL5	-0.603	0.547
IVDspaceL5	1.742	0.084
BodyL4	0.239	0.812
IVDspaceL4	1.461	0.146
BodyL3	0.097	0.923
IVDspaceL3	2.587	**0.011**
BodyL2	0.063	0.950
IVDspaceL2	1.785	0.077
BodyL1	0.694	0.489
IVDspaceL1	1.647	0.102

Table (4-4): Distribution of sample study according to Gender

Group		Male	Female	Total
ABN	Count	45	55	100
	% within Group	45.0%	55.0%	100.0%
Control	Count	10	30	40
	% within Group	25.0%	75.0%	100.0%
Total	Count	55	85	140
	% within Group	39.3%	60.7%	100.0%

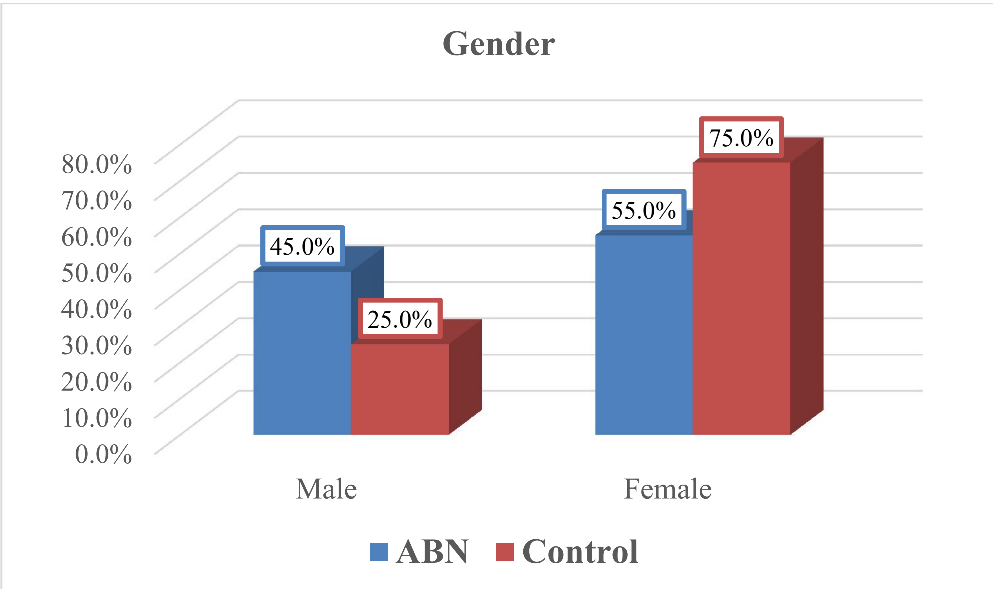


Figure (4-1): Distribution of sample study according to Gender

Classification results

To classify the cases into normal or abnormal using linear discriminant analysis and the measured values (vertebral data body diameter L1 to L5 as well as the IV disc) and body characteristics 7 variables were selected as the most discriminant features between the normal and abnormal, the classification accuracy was 93.3% sensitivity = 92.8% and specificity = 94.6%

Table (4-5): Classification results

Classification Results [a]					
		Status	Predicted Group Membership		Total
			Abnormal	Normal	
Original					
	%	Abnormal	92.8	7.2	100.0
		Normal	5.4	94.6	100.0
93.3% of original grouped cases correctly classified.					

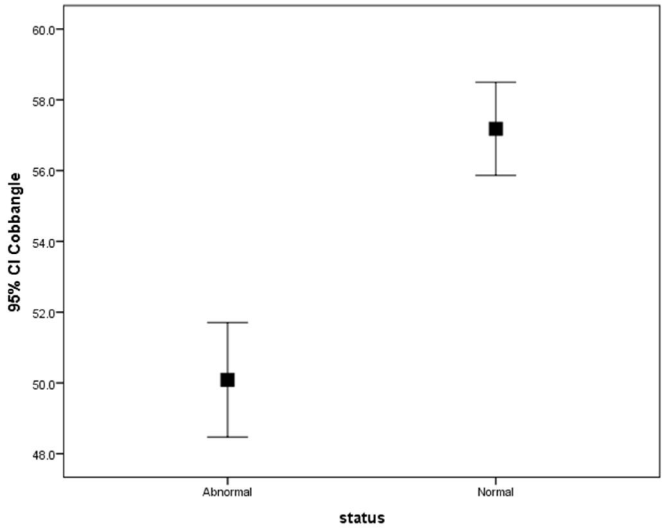


Figure (4-2) error bar plot show the average distribution of Cobb angle for normal and abnormal patients

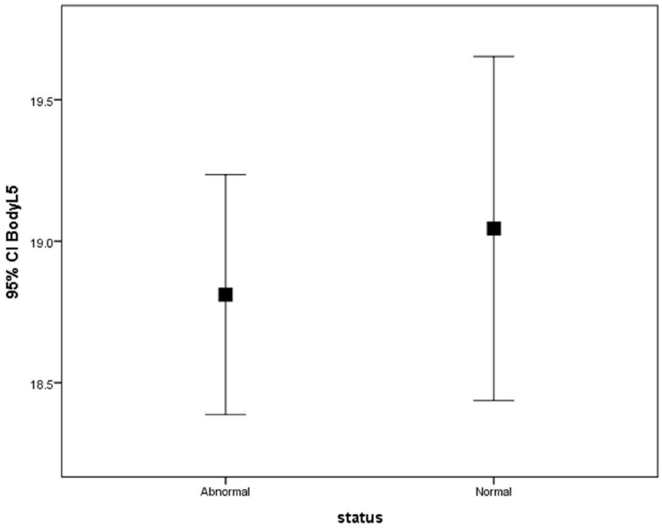


Figure (4-3) error bar plot show the average distribution of vertebral body diameter of L5 for normal and abnormal patients

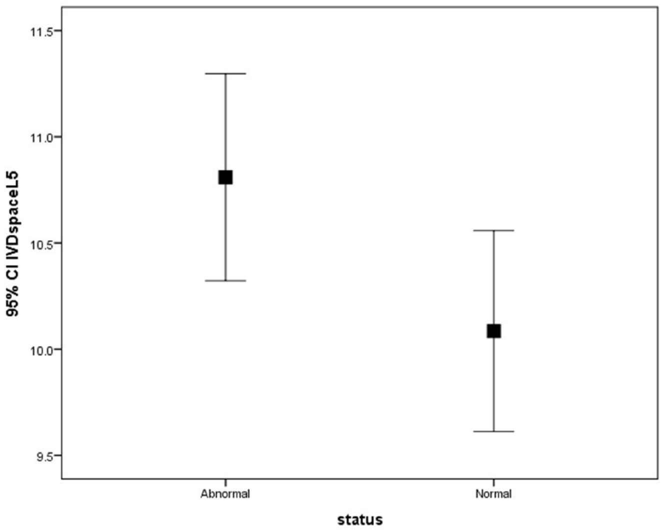


Figure (4-4) error bar plot show the average distribution of inter vertebral disc space diameter of L5 for normal and abnormal patients

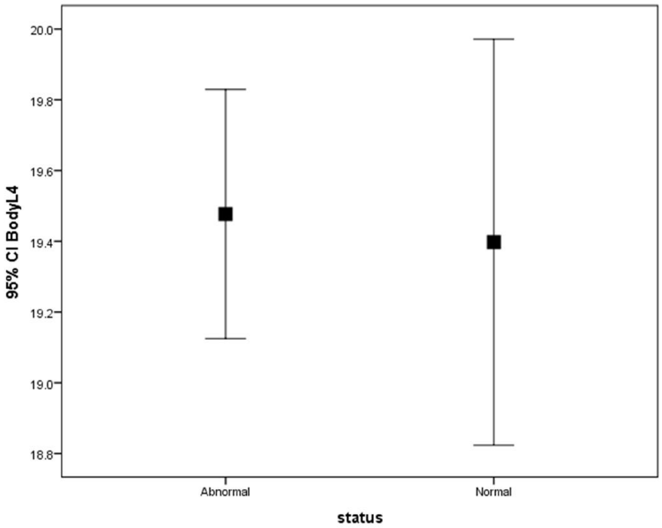


Figure (4-5) error bar plot show the average distribution of vertebral body diameter of L4 for normal and abnormal patients

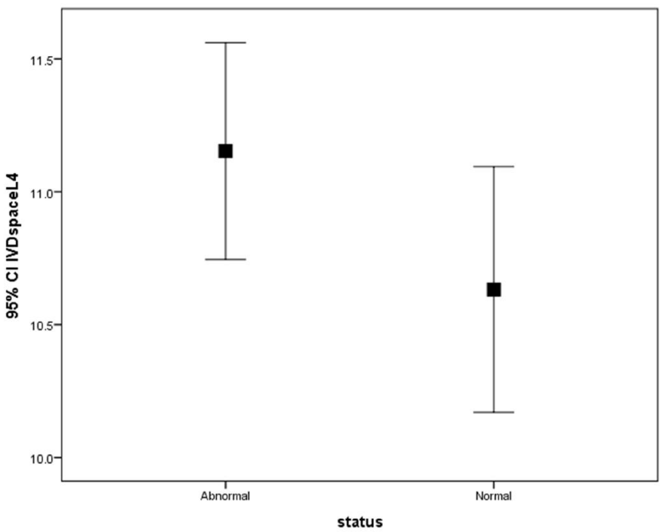


Figure (4-6) error bar plot show the average distribution of inter vertebral disc space diameter of L4 for normal and abnormal patients

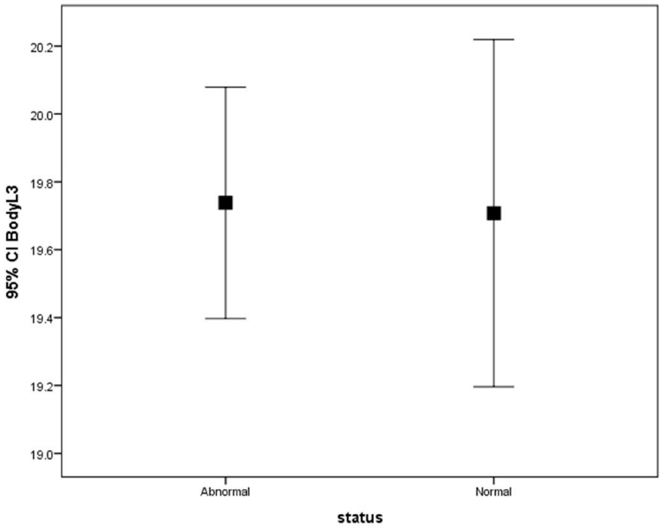


Figure (4-7) error bar plot show the average distribution of vertebral body diameter of L3 for normal and abnormal patients

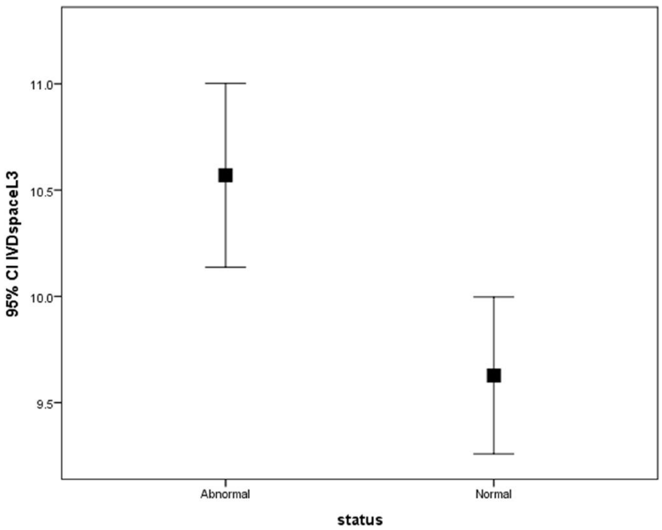


Figure (4-8) error bar plot show the average distribution of inter vertebral disc space diameter of L3 for normal and abnormal patients

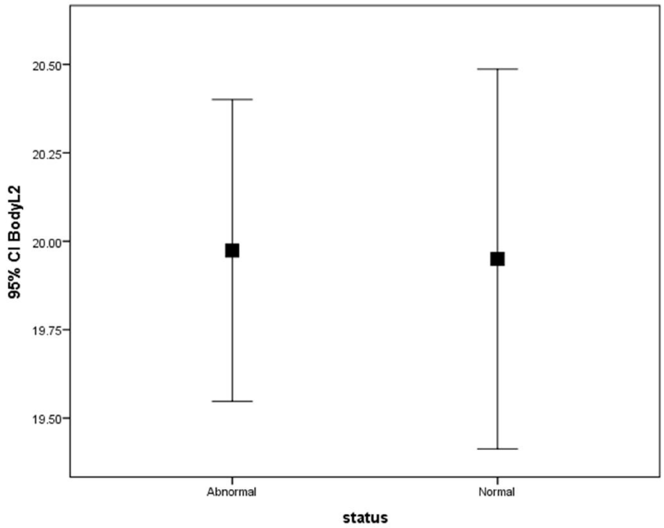


Figure (4-9) error bar plot show the average distribution of vertebral body diameter of L2 for normal and abnormal patients

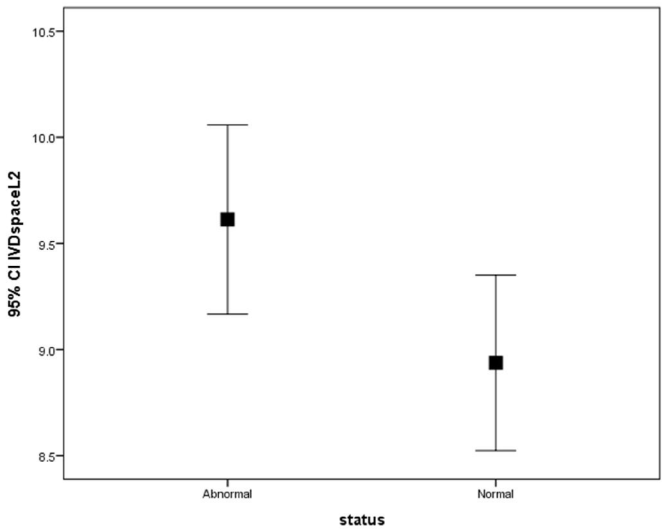


Figure (4-10) error bar plot show the average distribution of inter vertebral disc space diameter of L2 for normal and abnormal patients

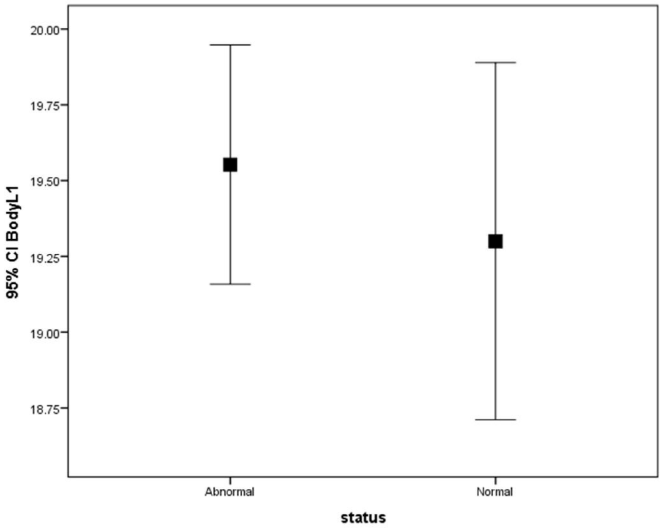


Figure (4-11) error bar plot show the average distribution of vertebral body diameter of L1 for normal and abnormal patients

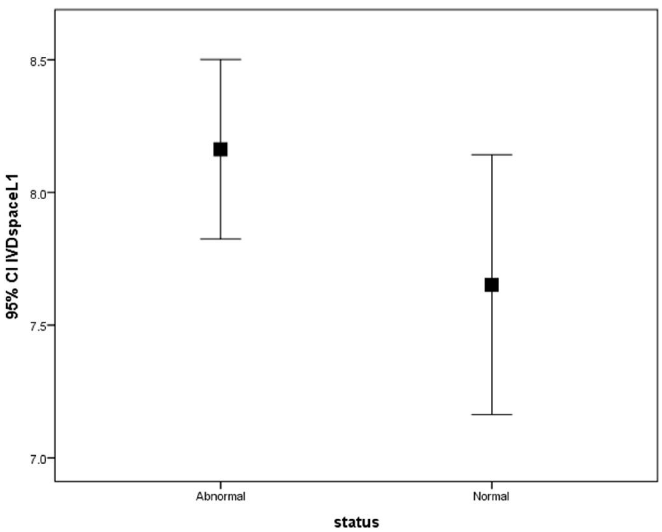


Figure (4-12) error bar plot show the average distribution of inter vertebral disc space diameter of L1 for normal and abnormal patients

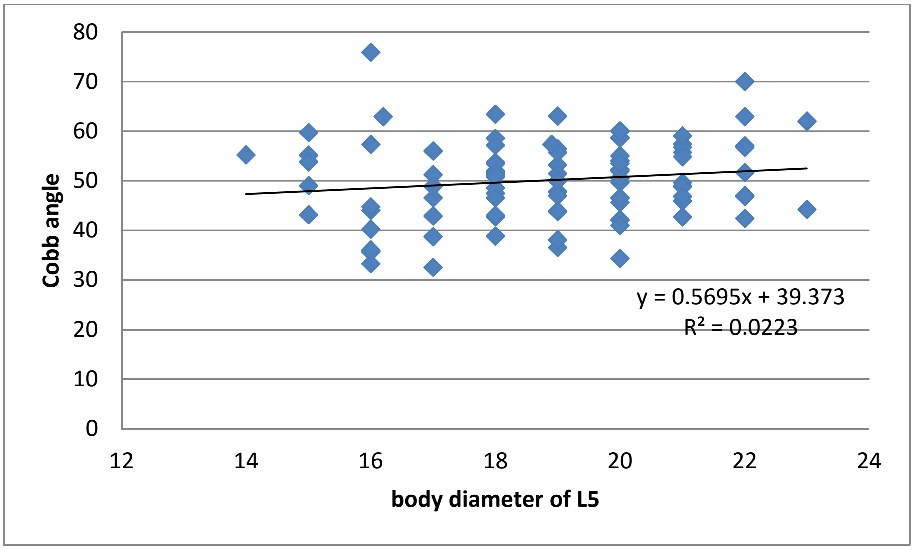


Figure (4-13):Scatter plot show Cobb angle increases linearly by 0.57 versus 1mm of L5 vertebral body starting from 39.4 for abnormal

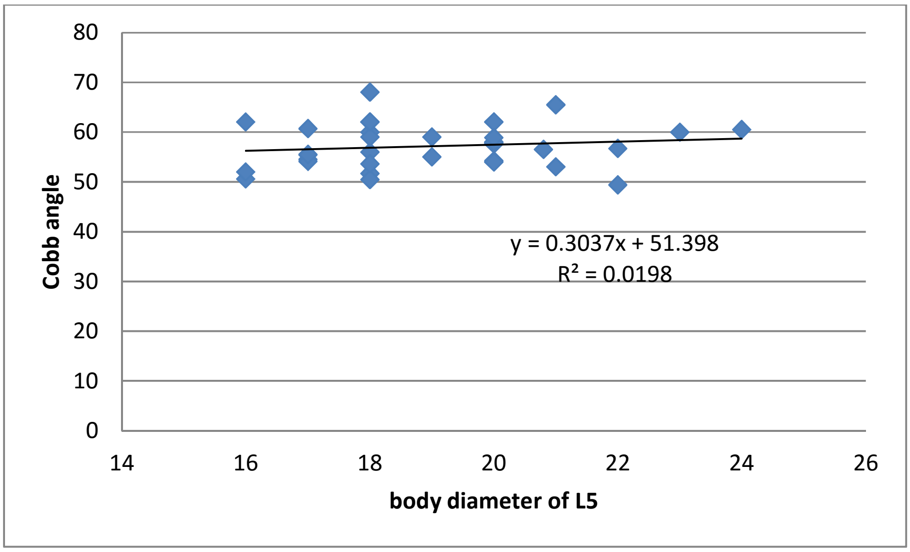


Figure (4-14) Scatter plot show Cobb angle increases linearly by 0.30 versus 1mm of L5 vertebral body starting from 51.4 for normal (control).

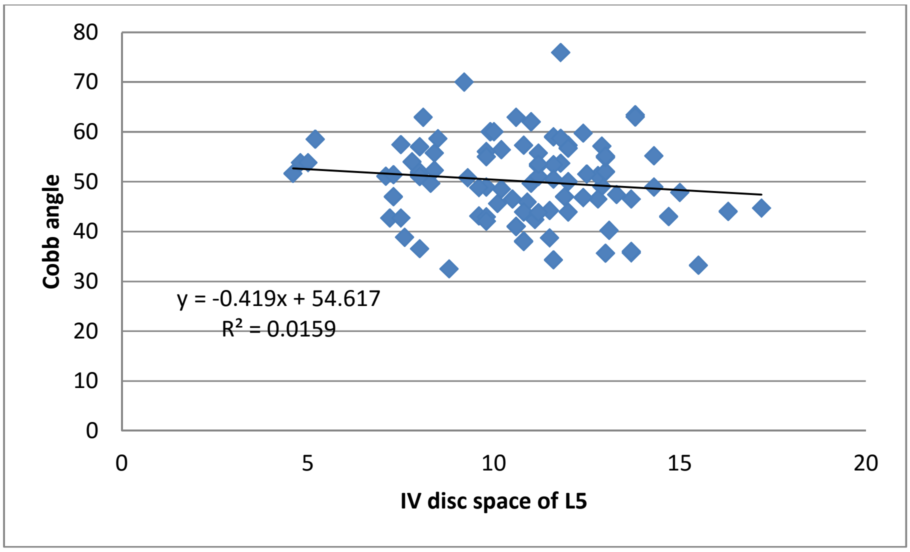


Figure (4-15) Scatter plot show Cobb angle decreases linearly by 0.42 versus 1mm of IV disc space of L5 starting from 54.6 for abnormal .

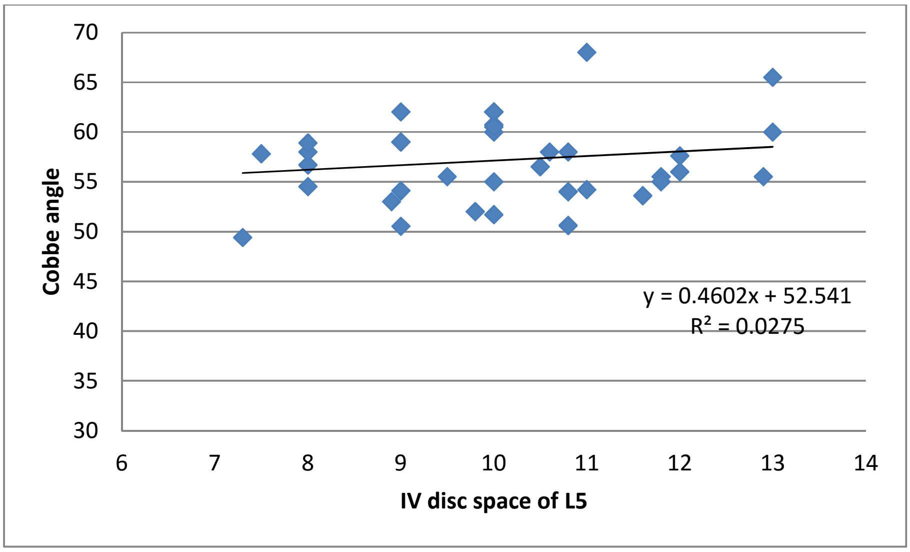


Figure (4-16) Scatter plot show Cobb angle increases linearly by 0.46 versus 1mm of IV disc space of L5 starting from 58.2 for normal (control).

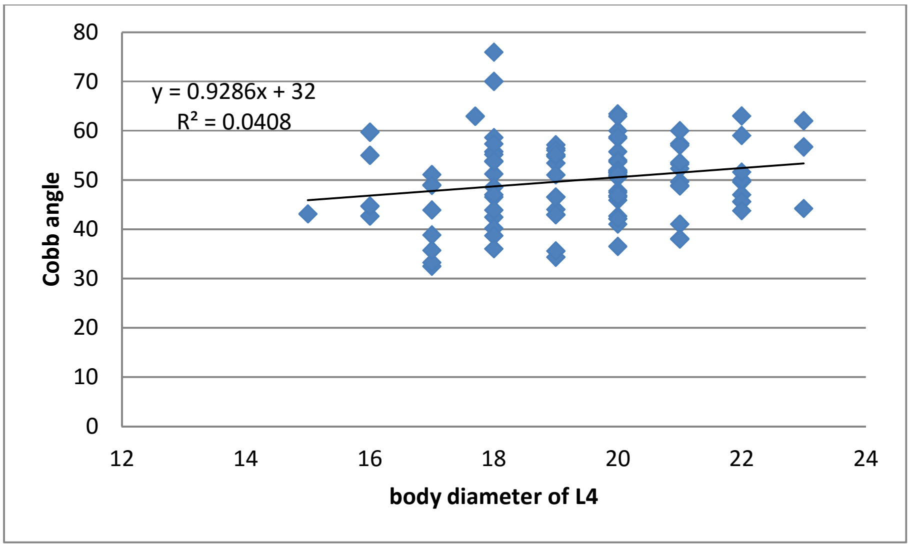


Figure (4-17) Scatter plot show Cobb angle increases linearly by 0.93 versus 1mm of L4 vertebral body starting from 32.0 for abnormal

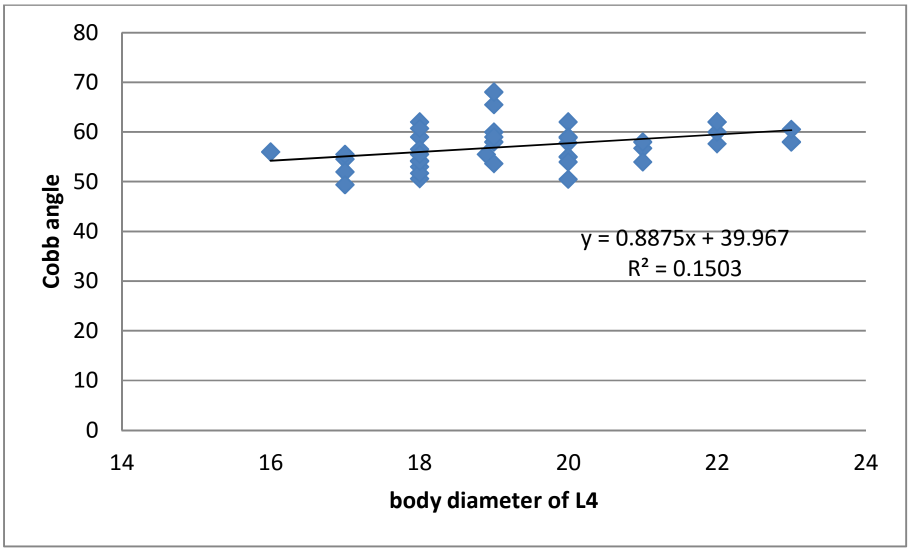


Figure (4-18) Scatter plot show Cobb angle increases linearly by 0.88 versus 1mm of L4 vertebral body starting from 40.0 for normal (control).

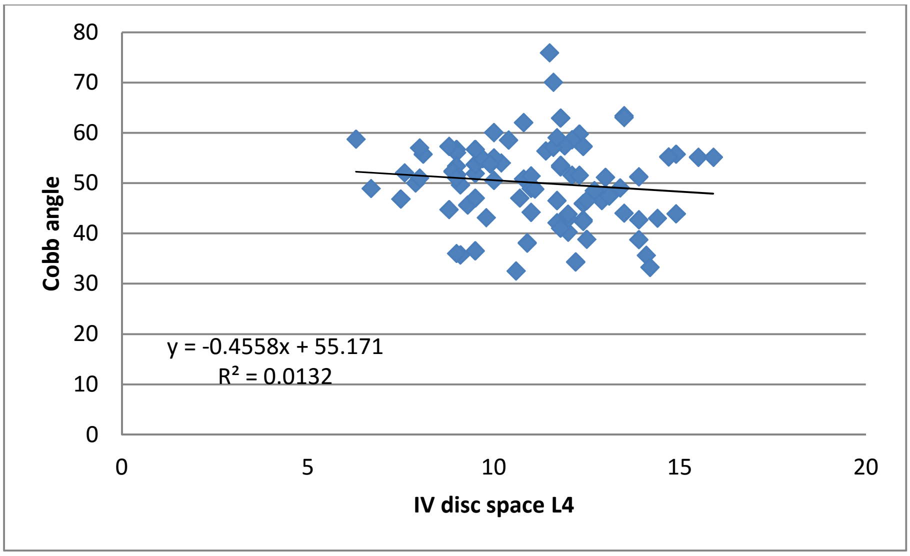


Figure (4-19) Scatter plot show Cobb angle decreases linearly by 0.46 versus 1mm of IV disc space of L4 starting from 55.2 for abnormal .

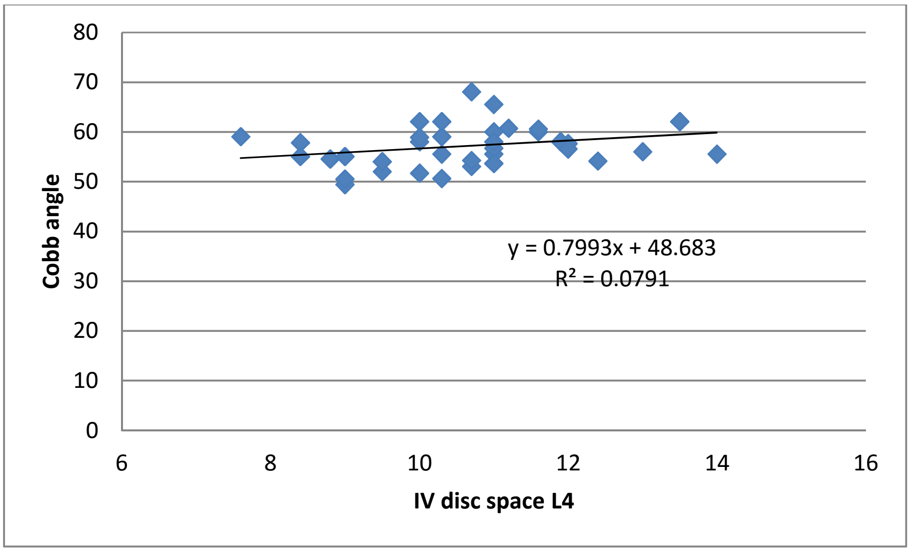


Figure (4-20) Scatter plot show Cobb angle increases linearly by 0.8 versus 1mm of IV disc space of L4 starting from 48.7 for normal (control).

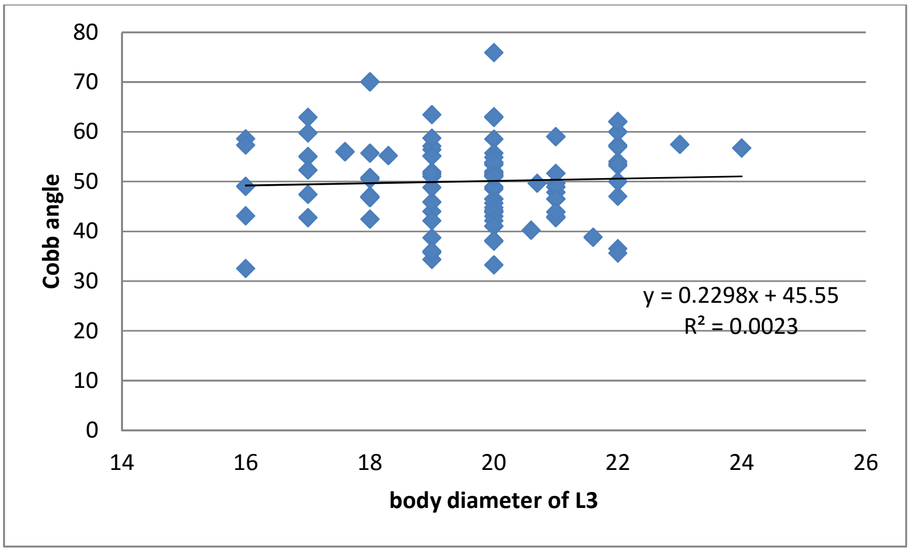


Figure (4-21) Scatter plot show Cobb angle increases linearly by 0.23 versus 1mm of L3 vertebral body starting from 45.6 for abnormal

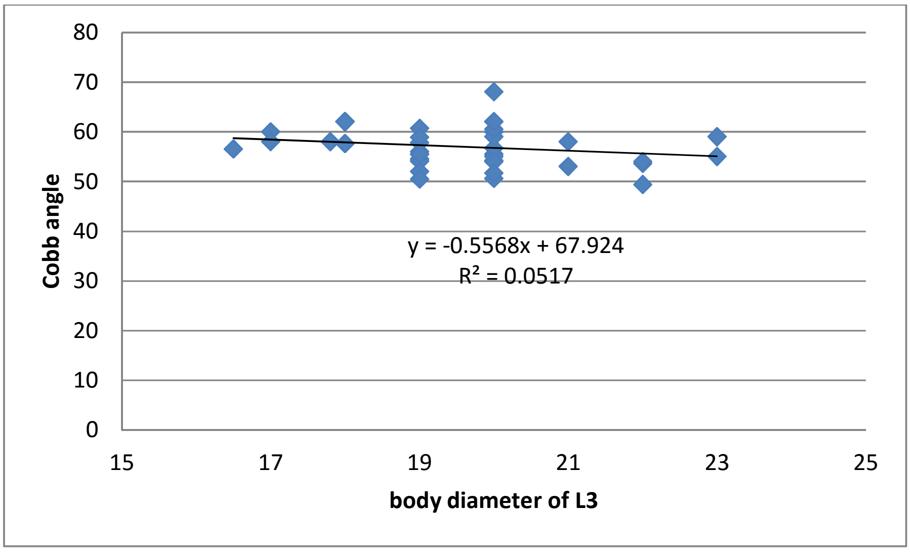


Figure (4-22) Scatter plot show Cobb angle decreases linearly by 0.56 versus 1mm of L3 vertebral body starting from 67.9 for normal (control).

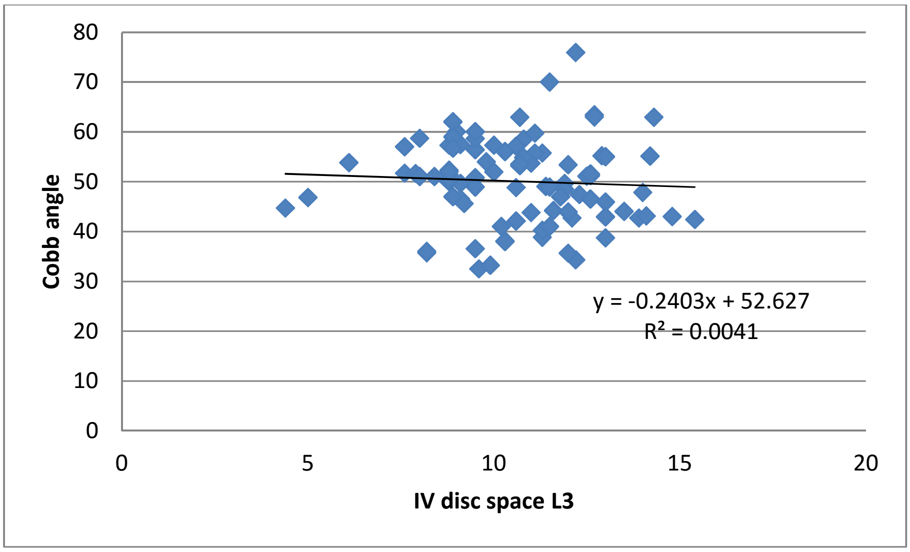


Figure (4-23) Scatter plot show Cobb angle decreases linearly by 0.24 versus 1mm of IV disc space of L3 starting from 52.6 for abnormal .

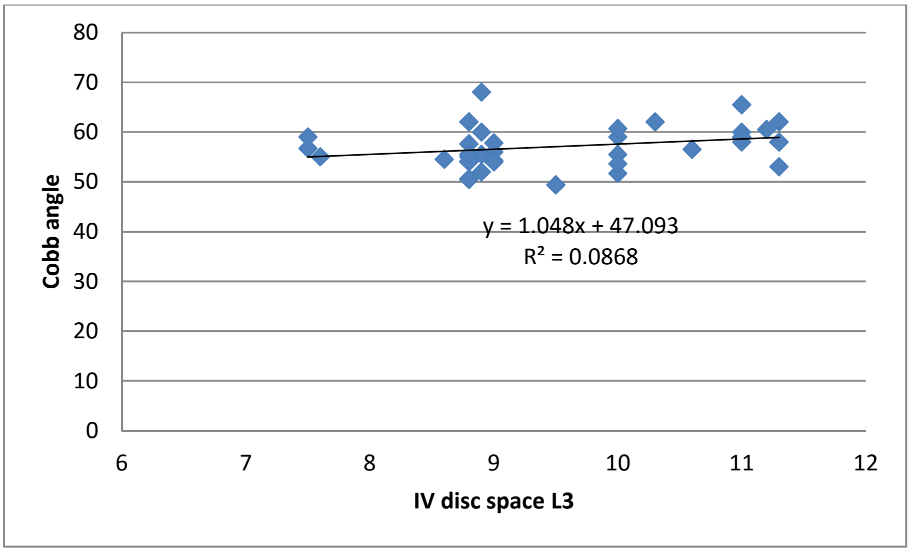


Figure (4-24) Scatter plot show Cobb angle increases linearly by 1.05 versus 1mm of IV disc space of L3 starting from 47.1 for normal (control).

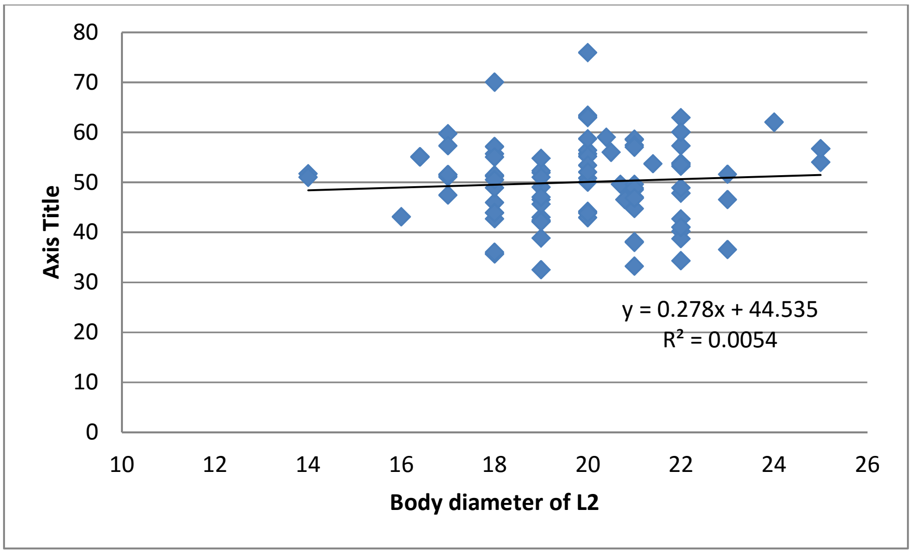


Figure (4-25) Scatter plot show Cobb angle increases linearly by 0.28 versus 1mm of L2 vertebral body starting from 44.5 for abnormal.

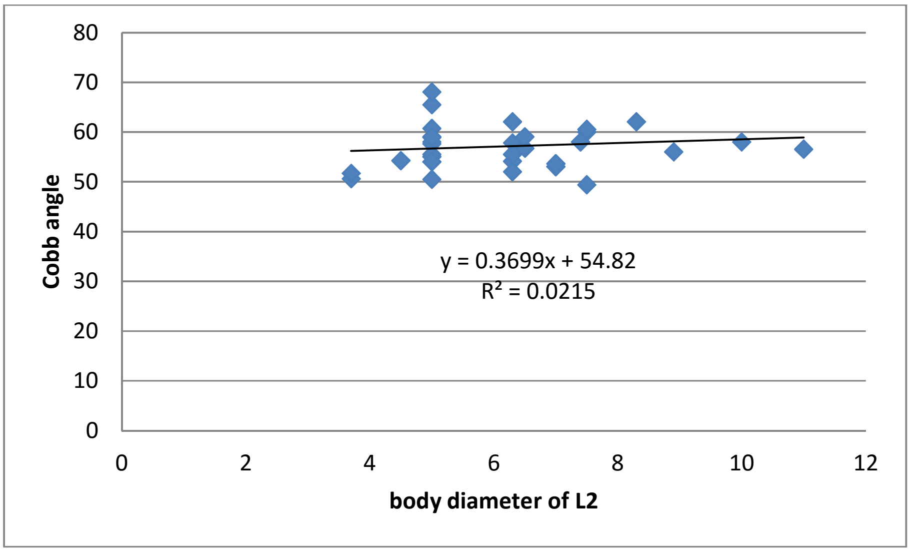


Figure (4-26) Scatter plot show Cobb angle increases linearly by 0.37 versus 1mm of L2 vertebral body starting from 54.8 for normal (control)

.

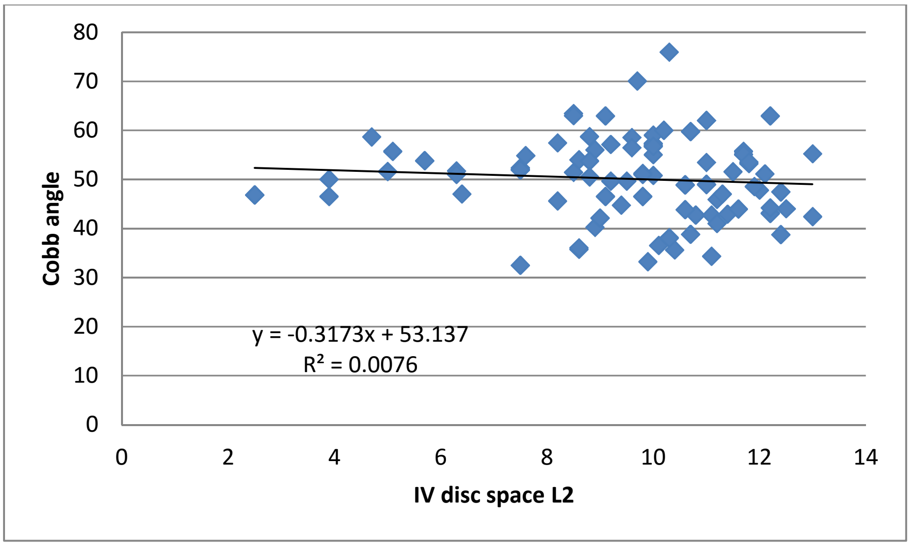


Figure (4-27) Scatter plot show Cobb angle decreases linearly by 0.32 versus 1mm of IV disc space of L2 starting from 53.1 for abnormal .

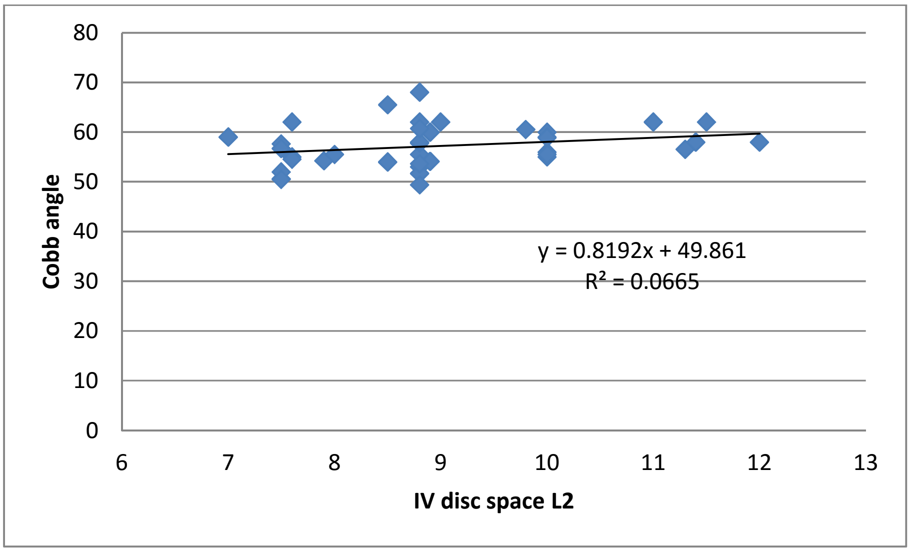


Figure (4-28) Scatter plot show Cobb angle increases linearly by 0.82 versus 1mm of IV disc space of L2 starting from 58.2 for normal (control).

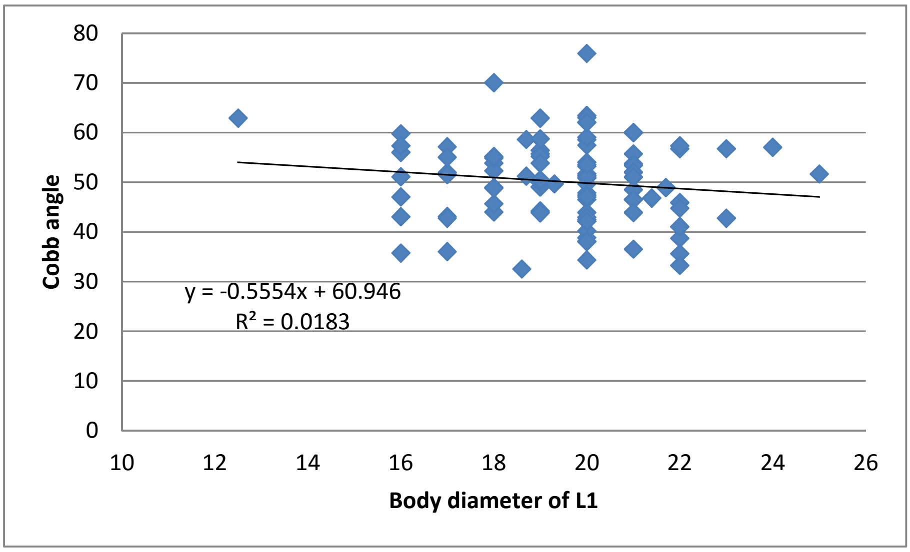


Figure (4-29) Scatter plot show Cobb angle decrease linearly by 0.55 versus 1mm of L1 vertebral body starting from 60.9 for abnormal.

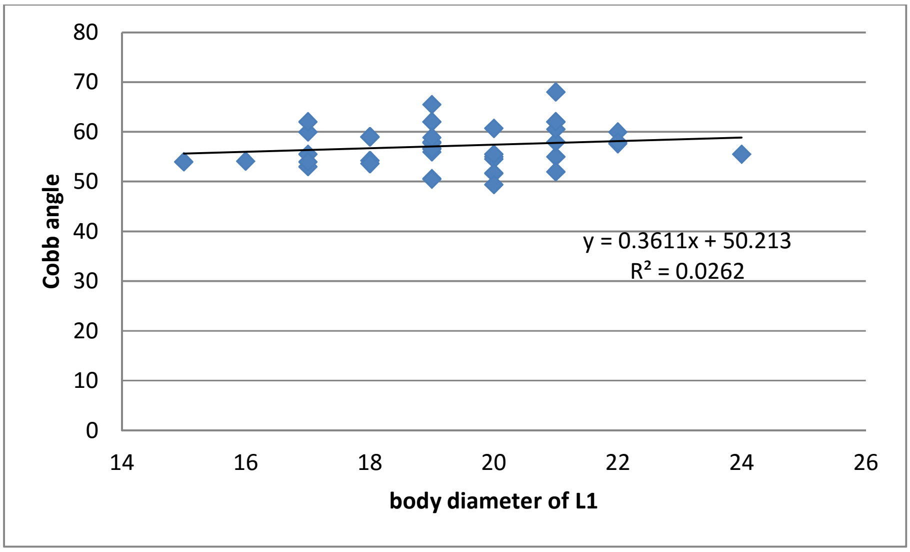


Figure (4-30) Scatter plot show Cobb angle increases linearly by 0.36 versus 1mm of L1 vertebral body starting from 50.2 for normal (control).

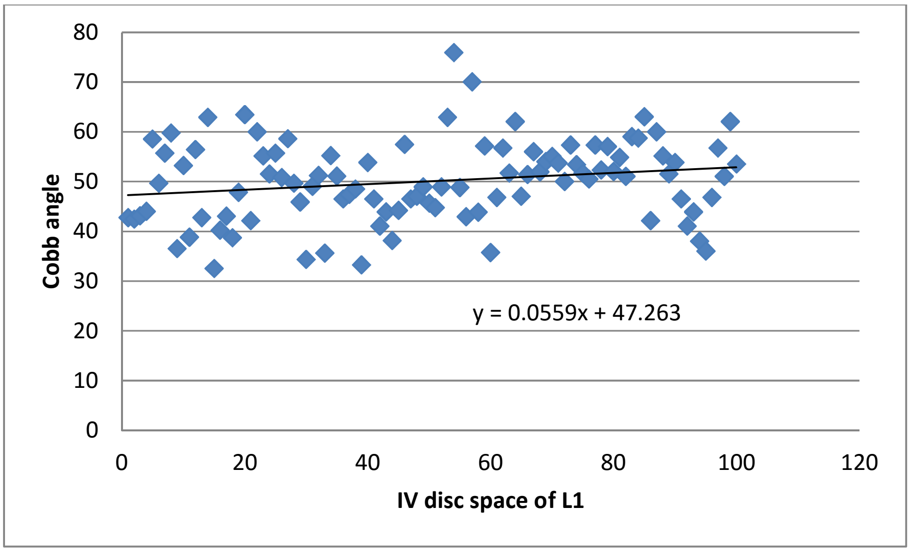


Figure (4-31) Scatter plot show Cobb angle increases linearly by 0.06 versus 1mm of IV disc space of L1 starting from 58.2 for abnormal .

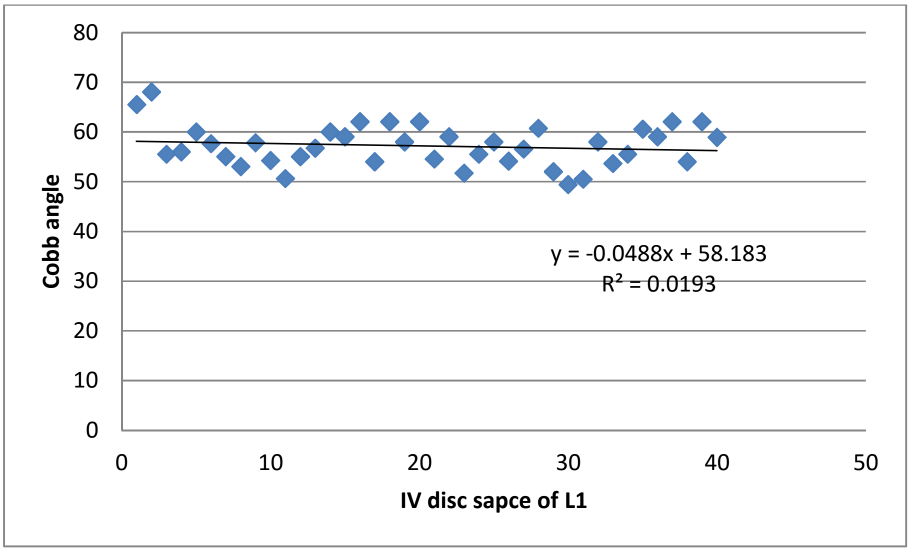


Figure (4-32) Scatter plot show Cobb angle decreases linearly by 0.05 versus 1mm of IV disc space of L1 starting from 58.2 for normal (control).

Disc bulge

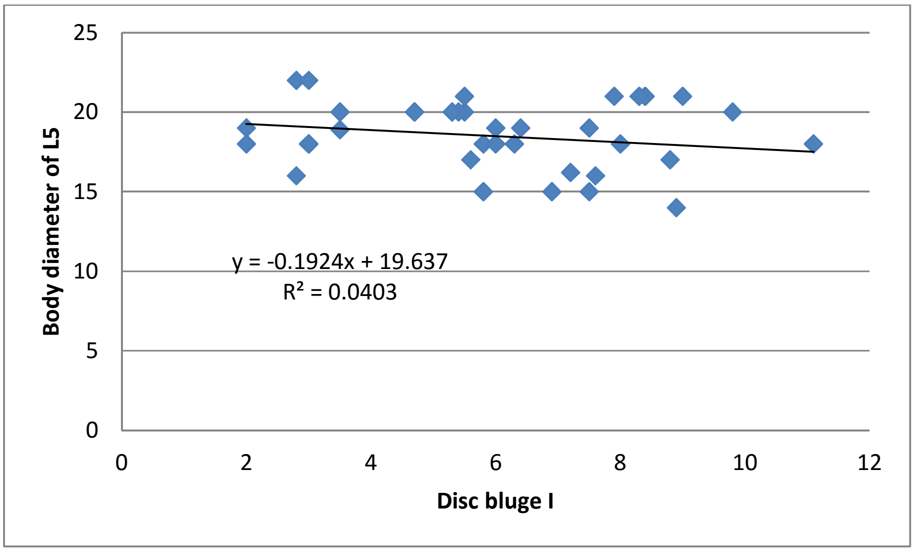


Figure (4-33) Scatter plot show that; the body diameter of L5 decreases linearly by 0.20 versus 1mm of disc bulge starting from 19.6.

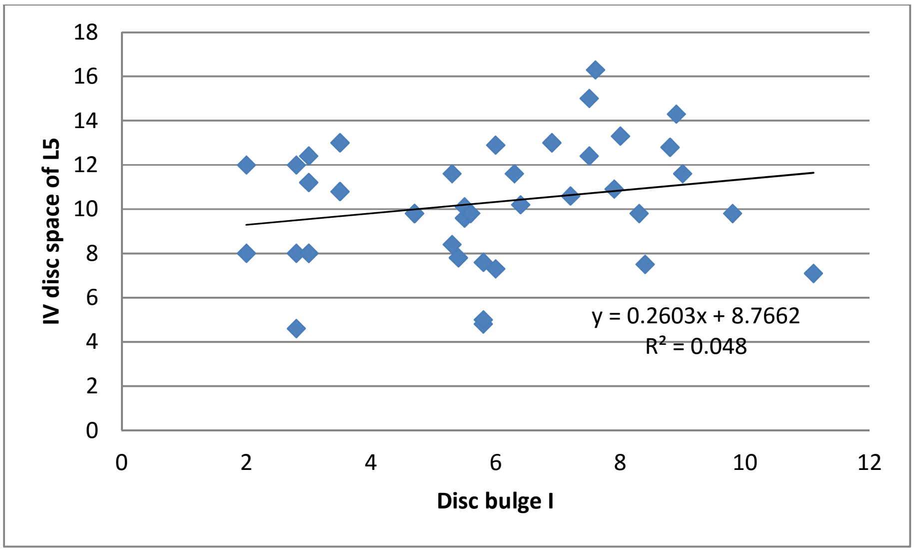


Figure (4-34) Scatter plot show that; the IV disc space of L5 increases linearly by 0.26 versus 1mm of disc bulge starting from 8.7.

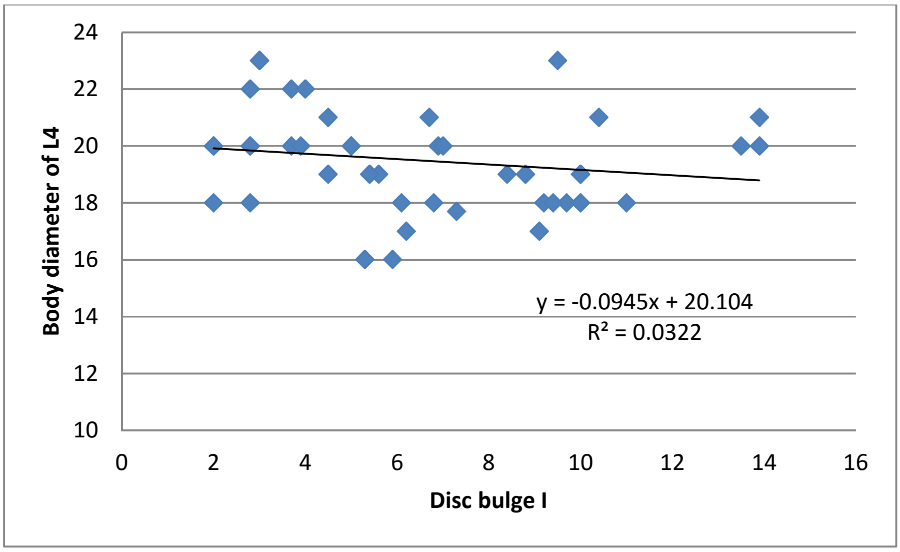


Figure (4-35) Scatter plot show that; the body diameter of L4 decreases linearly by 0.1 versus 1mm of disc bulge starting from 20.1.

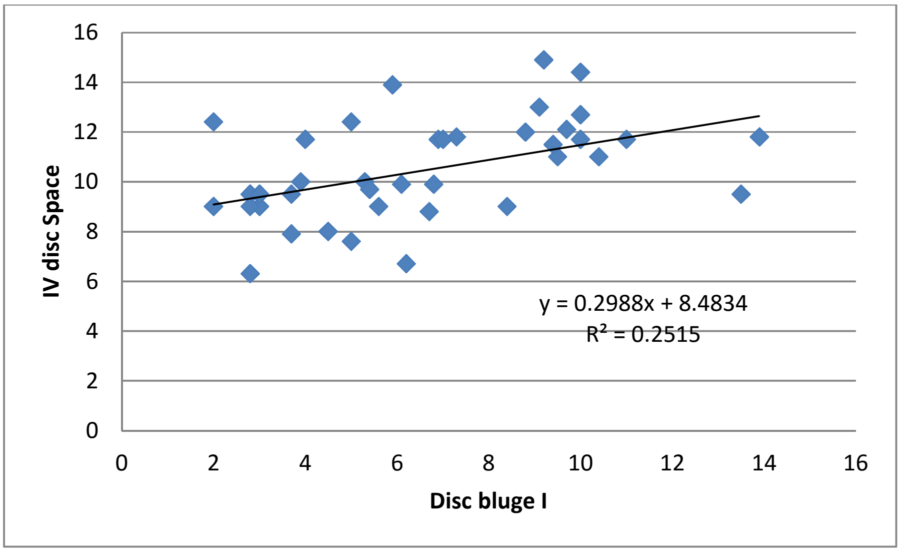


Figure (4-36) Scatter plot show that; the body diameter of L4 increases linearly by 0.30 versus 1mm of disc bulge starting from 22.3.

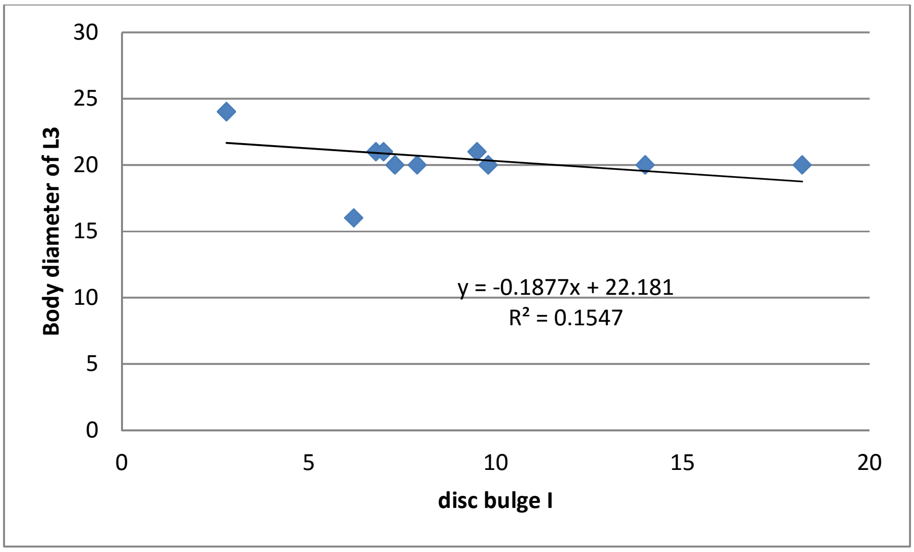


Figure (4-37) Scatter plot show that; the body diameter of L3 decreases linearly by 0.20 versus 1mm of disc bulge starting from 22.1.

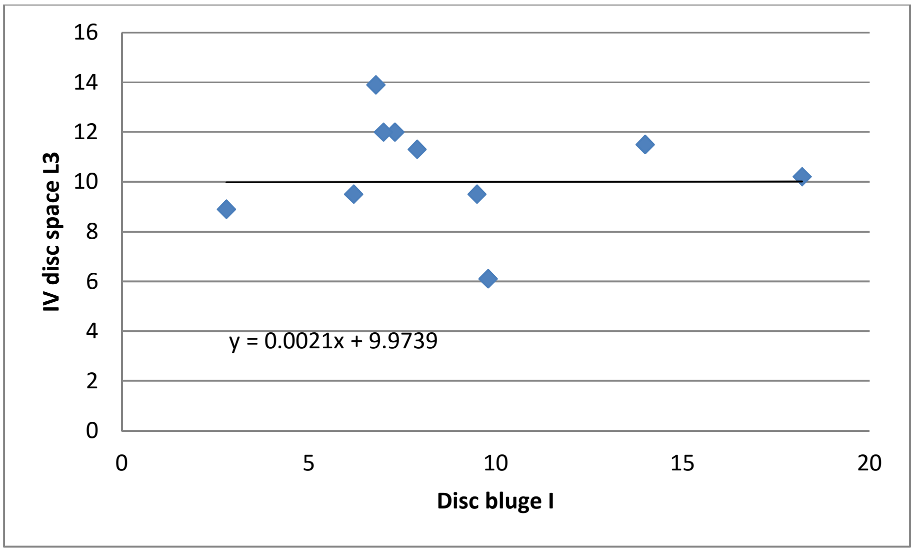


Figure (4-38) Scatter plot show that; the body diameter of L3 increases linearly by 0.002 versus 1mm of disc bulge starting from 9.9.

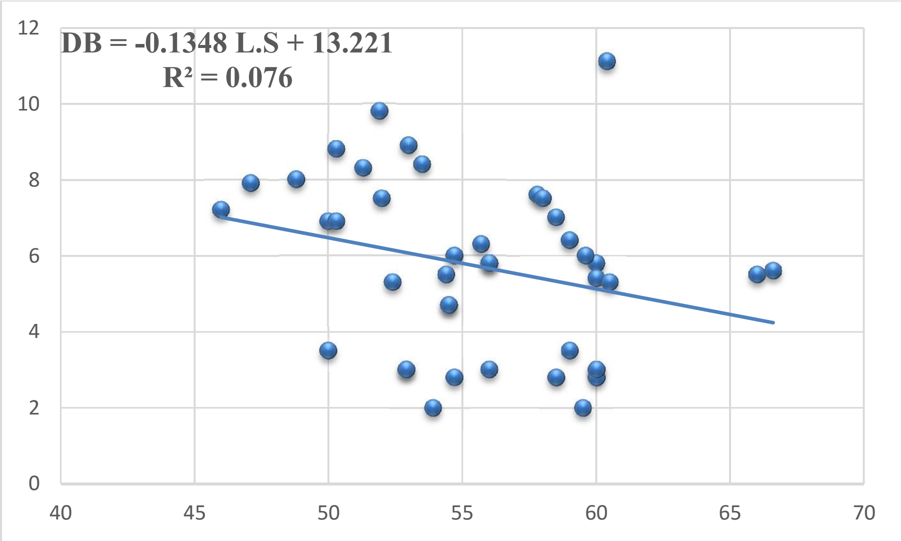


Figure (4-39) Scatter plot show disc bulge decreases linearly by 0.13 versus 1unit of LS angle starting from 13.2. **(*P*-value = 0.077)**

Table (4-6) Association between gender and L.S angle in Abnormal & control groups

Group	Gender	Mean ± SD	*P*-value
Control	Male	58.14 ± 3.08	0.155
	Female	55.82 ± 4.71	
Abnormal	Male	54.64 ± 4.87	0.564
	Female	55.22 ± 5.05	

Table (4-7): Association between Cobb angles with LS angle

Correlations			LS. Angle
Abnormal	Cobb Angle	Pearson Correlation	0.201
		P-value	0.045*
Control	Cobb Angle	Pearson Correlation	0.065
		P-value	0.691

*.Correlation is significant at the 0.05 level.

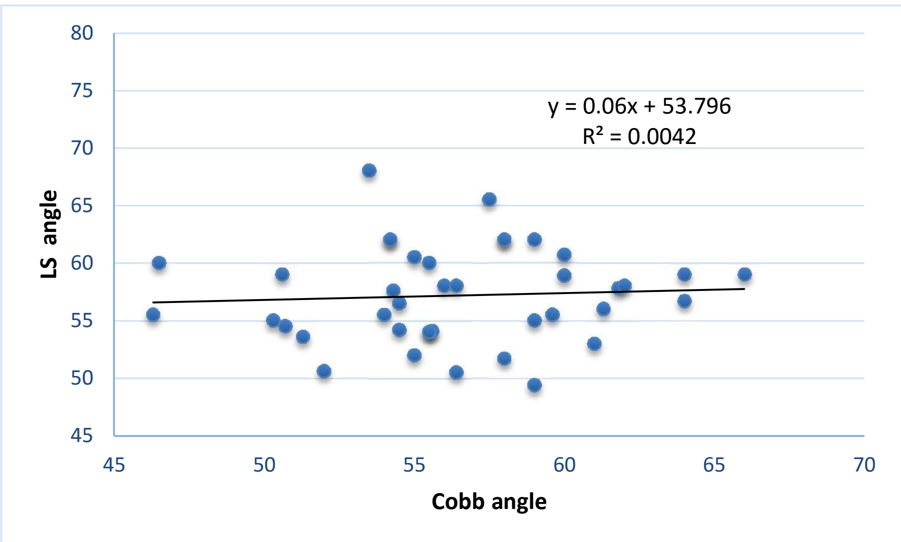


Figure (4-40) Scatter plot show LS angle increases linearly by 0.06 versus 1unit of Cobb angle starting from 53.79 (control).

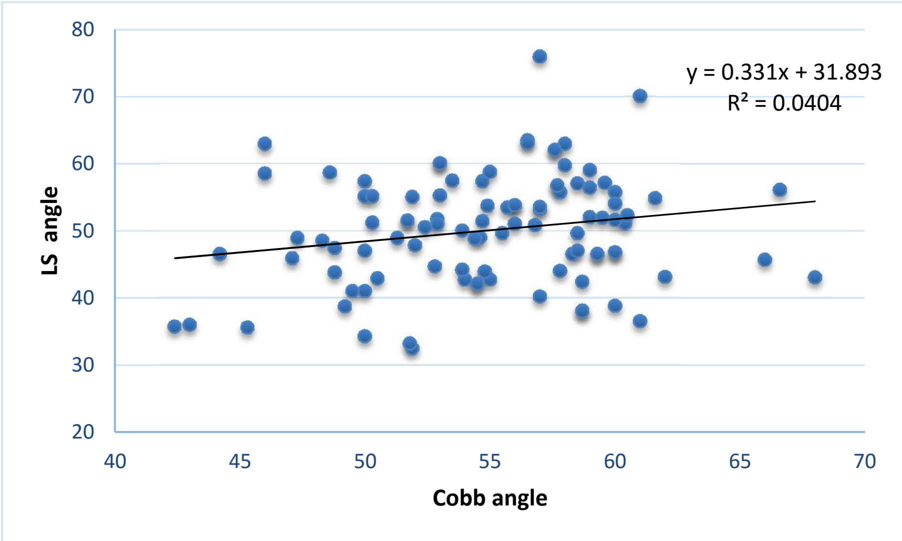


Figure (4-41) Scatter plot show LS angle increases linearly by 0.33 versus 1unit of Cobb angle starting from 31.8 in abnormal.

Chapter five

Chapter five

Discussion, Conclusion & Recommendation

5-1 Discussion

The aim of this study is to evaluate the lumbar spine using cobb's method in Sudanese subjects, MRI sagittal T2 W images were done using two different MRI Machines with 1.5 Tesla and 0.35 Tesla. Cobb method for all subjects was measured from superior end plate of L1 to superior end plat of S1.

This study was conducted on 140 patients; their ages ranged from 13-90 years. There were 85 female patients and 55 male subjects, Normal population (control) included 40 patients (10 males and 30 females), their mean age was (37.8 ± 13 years) with (minimum 13years) and (maximum 74 years), as seen in (Table 4-1)

One hundred patients have pathological discs (disc herniation) at different levels. They included (55 females and 45 males), their mean age was (47.3 ± 15.7 years) with (minimum 17 and maximum 90 years), table (2-4) , which are the mean weight, height and BMI are77.9 ±15.1, 167.2 ± 10.4, 46.6 ± 8.7 respectively in abnormal patient and 71.5 ± 15.7, 169.8 ± 10, 42.1 ± 9 respectively in control cases as seen in table (4-1), Also in normal subjects; the mean Cobb angles were (57.183 ± 4.109) table (4-2), In patients with disc herniation; the mean cobb angles were (50.1 ± 8.156) (Table 4-2).

The study results showed that was statistically significant difference between normal population and patients with disc herniation as regards the cobb angle (p-value 0.000) and IVD space of L3 (p-value 0.011) table (4-3); while there was a no statistically significant difference ($p > 0.05$) between control subjects and abnormal patient at L1-L5 body vertebrae and L1, L2, L4 and L5 IVD levels and Lumbosacral angle (p-value 0.112) (Table 4-3), Also there was statistically significant different between Cobb angle and LS angle at abnormal group (p- value 0.045) while no significant different in control cases (p-value 0.691) (Table 4-7). In male and female groups there was no statistically significant deferent regarding the L.S angle in Abnormal & control groups (Table 4-6).

The results revealed that in abnormal subjects (patient with disc herniation at different levels) Cobb angle direct linear relationship with the vertebral body of L5, L4, L3 and L2 where it increases by 0.57, 0.93, 0.23 and 0.28 degree per mm respectively (Fig 4-13, 4-17, 4-21 and 4-25) with mean vertebral bodies of 18.8±2.1, 19.5±1.8, 19.7 ±1.7 and 9.6± 2.2 mm respectively (Table 4-2). This means the Cobb angle increases more concerning the diameter of L4 which almost one degree for each mm of the body diameter and less in L3.

The result also indicate that there is indirect linear relationship between Cobb angle and inter vertebral disc spaces for L5, L4, L3 and L2; where the angle decreases by 0.42, 0.46, 0.24 and 0.32 degree per mm respectively of intervertebral disc space; which means Cobb angle mostly decrease as a result of increase in intervertebral disc of L4 and less for L2 (Fig. 4-15, 4-19, 4-23 and4-27), with mean intervertebral disc of 10.8±2.5, 11.2±2.1, 10.6±2.2 and 9.6±2.2 mm respectively (Table 4-2).

The results revealed that in control subjects Cobb angle direct linear relationship with the vertebral bodies of L5, L4, and L2 where it increases by 0.30, 0.88, and 0.37 degree per mm respectively (Fig 4-14, 4-18and 4-26) with mean vertebral bodies of 19±2, 19.3 ±1.7 and 19.9± 1.6 mm respectively (Table 4-2). This means the Cobb angle increases more concerning the diameter of L4 which almost one degree for each mm of the body diameter. Regarding the vertebral body of L3 there is an indirect linear relationship with Cobb angle it decrease by 0.56 mm (Fig 4-22)with mean vertebral body of 19.7± 1.6 mm (Table 4-2)

Also the result indicate that there is direct linear relationship between Cobb angle and inter vertebral disc spaces for L5, L4, L3 and L2; where the angle increases by 0.46, 0.80, 1.05 and 0.82 degree per mm respectively of intervertebral disc space; (Fig. 4-

16, 4-20, 4-24 and 4-28), with mean intervertebral disc of 10±1.5, 10.6±1.4, 9.6 ±1.2 and 9.6 ±1.2 mm respectively (Table 4-2).

The results also revealed that LSA direct linear relationship with cobb angle where it increases linearly by 0.06 and 0.33 versus 1 unit of cobb angle in control and abnormal groups respectively (Fig 4-40,4-41) with mean cobb angle 57.2±4.1, 50.1±8.1 and LS mean angles 56.4 ±4.4, 54.9 ±4.9 degree respectively (Table 4-2).

Most of the patient suffers from disc bulge at L5, L4 and L3 as a result of this there is an indirect linear relationship between the body diameter and disc bulge measurement s in mm where the body diameter decreases by linearly 0.20, 0.1 and 0.20 per mm r espectively of disc bulge starting from 19.6, 20.1 and 22.1 mm, (Fig 4-33, 4-35, 4-37).

While there is direct linear relationship between the intervertebral disc space diame ter and disc bulge measurements in mm where the IVD space diameter increases linea rly by 0.26, 0.29 and 0.002 per mm respectively of disc bulge starting from 8.7, 8.5 a nd 9.9 mm, (Fig 4-34, 4-36, 4-38).

This dictates that with reduction in disc bulge caliber the caliber of vertebral bo dy increases while the IVD space diameter increases in respect to increase in dis c bulge diameter.

Most of the patient suffers from disc bulge at L5-S1 as a result of this there is an indirect linear relationship between the lumbosacral and disc bulge where disc bulge decreases linearly by 0.13 versus 1unit of LS angle starting from 13.2 (Fig 4-39).

5-2 Conclusion

This study was intended to evaluate the lumbar spine using cobb's method in Sudanese subjects, MRI sagittal T2 W images were done using two different MRI Machines Philips & Superstar Neusoft medical system 0.35 Tesla and Machine ty pe Siemens, symphony, mastro class 1.5 Tesla.

The study results showed that There was statistically significant difference between normal population and patients with disc herniation as regards the cobb angle (p-value 0.000) and IVD space of L3 (p-value 0.011) table (4-3); while there was a no statistically significant difference ($p > 0.05$) between control subjects and abnormal patient at LSA, L1-L5 body vertebrae and L1, L2, L4 and L5 IVD levels.

In abnormal subjects (patient with disc herniation at different levels) we find there is direct linear relationship between the vertebral body L5-L2 with the Cobb angle; and indirect linear relationship between the intervertebral disc spaces L5-L2 with the Cobb angle.

Regarding the control cases results find there is direct linear relationship between the vertebral body and intervertebral disc spaces with the Cobb angle; except at L3 vertebral body level find indirect linear relationship.

The results also revealed that LSA direct linear relationship with cobb angle where it increases linearly by 0.06 and 0.33 versus 1 unit of cobb angle in control and abnormal groups respectively with mean cobb angle 57.2±4.1, 50.1±8.1 and LS mean angles 56.4 ±4.4, 54.9 ±4.9 degree respectively.

Also an indirect linear relationship between the body diameter L5-L3and disc bulge; and direct linear relationship between the intervertebral discs apace diameter and disc bulge at same levels. While there is an indirect linear relationship between the lumbosacral and disc bulge where disc bulge decreases linearly by 0.13 versus 1unit of LS angle starting from 13.2.

Cobb angle can be estimated by using vertebral body diameter, inter vertebral disc and body characteristics as follows:

Cobb angle = (Age × 0.151) + (VBL4 × 1.137) + (Gender × 3.930) + 14.724 (see appendix A)

Where gender = 1 for male and 2 for female.

Also to know whether the patient were normal or abnormal the data concerning the Cobb angle, VBL4, IVDL3, gender, age, height and BMI can be entered in the two equation below an the vote will be to the higher value.

Abnormal =
(Cobb angle × 0.57) + (VBL4 × 4.36) + (IVDL3 × 2.35) + (Gender × 56.99) + (Age × 0.26) + (Height × 3.35) + (BMI × 0.76) -408.997

(see Table A-1)

Normal =
(Cobb angle × 1.02) + (VBL4 × 3.94) + (IVDL3 × 1.61) + (Gender × 60.37) + (Age × 0.078) + (Height × 3.51) + (BMI × 0.56) -435.102

(see Table A-2)

Where gender = 1 for male and 2 for female: the vote will be to the higher score.

5-3 Recommendation

-Using MRI in the detection of vertebral morphological changes is recommended since it involves no ionizing radiation and has excellent demarcation of disc prolapse. The dependence upon the Cobb angle in diagnoses of disc prolapse is of significant value.

- Correlation of Cobb angle with patient age, weight and gender should take place in our general farm of radiological report.

-Achievement of proper representative sample the study should test wide areas and many medical MRI centers.

-Proper evaluation of lumber spine should test larger sample of the population for more accurate results.

-Further studies should examine whether there is a correlation between the patient job and the duration conducting it and Cobb's angle.

References and Appendix

References

A. Stewart hitley, Charles Sloan, Graham Hoadley Adrian D. Moore, Chrissie W. Alsop (2005) CLARK'S POSITIONING IN RADIOGRAPHY.12th edition Page 167

Andreasen ML. Langhoff L, Jensen TS. (2007) reproduction of the lumbar lordosis: A comparison of standing radiographs versus supine magnetic resonance imaging obtained with straightened lower extremities J Manipulative Physiol Ther, 30:26-30

Becske, T., & Nelson, P. (2009). The vascular anatomy of the vertebrospinal axis. Neurosurgery Ckinics of North America, 20(3), 259-264

Benneker LM, Heini PF, Alini M, Anderson SE, Ito K (2005) 2004 Young Investigator Award Winner: vertebral endplate marrow contact channel occlusions and intervertebral disc degeneration. Spine 30:167–173

Boos N, Weissbach S, Rohrbach H, Weiler C, Spratt KF, Nerlich AG (2002) Classification of age-related changes in lumbar intervertebral discs: 2002 Volvo award in basic science. Spine 27:2631–2644

Catherine Westbrook (2009) Handbook of MRI Technique 2nd edition page134-135

Chou, R., Baisden, J., Carragee, E., J., Resnick, D. K., Shaffer, W. O., Loeser, J. D., (2009). Surgery for Low Back Pain: A Review of the Evidence for an American Pain Society Clinical Practice Guideline. Spine, 34(10), 1094-1109

Deyo RA and Weinsteim JN , Low Back Pain. Nengl J med (2001) Feb 344 (5): 363-70

DOI: 10.1007/978-3-540-93830-9_2, © Springer- Verlag Berlin Heidelberg 2010

Elaine n.marib,,katja hoehn(2013) Human Anatomy & Physiology 9th edition page 218-224

Ella Been, PT, PhD,(, Leonid Kalichman, PT, PhD 21 July 2013, medical paper Lumbar lordosis,The Spine Journal, http://dx.doi.org/10.1016/j.spinee.2013.07.464

Fullenlove TM, Williams AJ (1957) Comparetive roentegen findings in symptomatic and asymptomatic backs. Radiology 68:572-574

Gunilla Limbäck Svensson ,Ineko AB, Bangårdsvägen Kållered,(2013), medical paper Evaluation of a structured physiotherapy treatment model for patients with Lumbar disc herniation, 8, 428 35, http://hdl.handle.net/2077/31996

Hicks, G.E, Morone, N, & Weiner, D,K. (2009). Degenerative Lumber disc and facet disease in older adults: Prevalence and correlates. Spine, 34(12), 1301-1306

Metwally, MYM: Textbook of neuroima ging, A CD-ROM publication, (Metwally, MYM editor) WEB-CD agency for electronic publishing, version – McGill, S., & Karpowicz, A. (2009). Exercises for spinal stabilization: 9.1a January 2008

Modic, MT and Ross, JS, (2007) Oct Lumbar Degenerative Disk Disease. Radiology,245 (1): 43-57

Phoebe A. Kaplan Clydea. Helms, M.D. Robert Dussactl T, M.D. Mark W. Anderso n, M.D. Nancy M. Major, M.D.(2001). Musculoskeletal MRI 1st edition page 279-2 84

Ruggieri PM (1999) Pulse sequence in lumbar spine imaging. Magnetic Resonance Imaging Clin N Am 7:425-37, vii

Shankar H., Scarlett, J., & Abram, S. (2009). Anatomy and pathophysiology of intervertebral disc disease. Technique in Regional Anasthesia and Pain Management, 13(2), 67-75.

SHUTTERSTOCK (2003) nerve roots of lumbar spine. http, \\ www. Shutterstock.com\ fr\category \nature.14 July 2018

Sphen kishner, MD (2017). Lumbar Spine Aatomy. http,\\ www.medscape.com updated :novembar 09,2017.

Stadnik TW, Lee RR, Coen HL, Neirynck EC, Buisseret TS, Osteaux MJ (1998) Annular tears and disk herniation: prevalence and contrast enhancement on MR images in the absence of low back pain or sciatica. Radiology 206:49–55

Staiger TO, Paauw DS, Deyo RA (1999) Imaging studies for acute low back pain. When and when not to order them. Postgard Med 105:161-162. 165-166, 171-172

Torsten B. Moeller, M.D, Emil Reif, M.D (2003) MRI Parameters and Positioning page 157-159

WIKIPEDIA. (2013) intervertebral disc 19 April 2013 30:04.35, http:// en.m.wikipedia.org\ wiki\ intervertebral disc. 14 July 2018.

Wilmink, Lumbar Spinal Imaging in Radicular Pain and related Conditions

www.ainsworthinstitute.com \14 July 2018.

www.clinicalgate.com \14 July 2018.

www.dreamstime.com \14July 2018.

www.nursespot.com \14 July 2018.

www.radiopaedia.org \ 14 July 2018.

www.spineunverse.com \14 July 2018.

Appendix A:

Table (A-1) Estimation of Cobb angle (using vertebral body diameter, inter vertebral disc and body characteristics) using stepwise method using multiple regression equation (abnormal)

Coefficients [a]

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	14.724	9.401		1.566	.121	-3.937	33.385
Age	.151	.048	.289	3.131	.002	.055	.246
BodyL4	1.137	.429	.247	2.649	.009	.285	1.990
Gender	3.930	1.523	.241	2.580	.011	.907	6.953

a. Dependent Variable: Cobb angle

Table (A-2): Estimation of Cobb angle (using vertebral body diameter, inter vertebral disc and body characteristics) using stepwise method using multiple regression equation (normal)

Coefficients [a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	36.309	6.651		5.459	.000	22.832	49.787
BodyL4	.790	.332	.345	2.378	.023	.117	1.463
Weight	.078	.038	.296	2.042	.048	.001	.155

a. Dependent Variable: Cobb angle

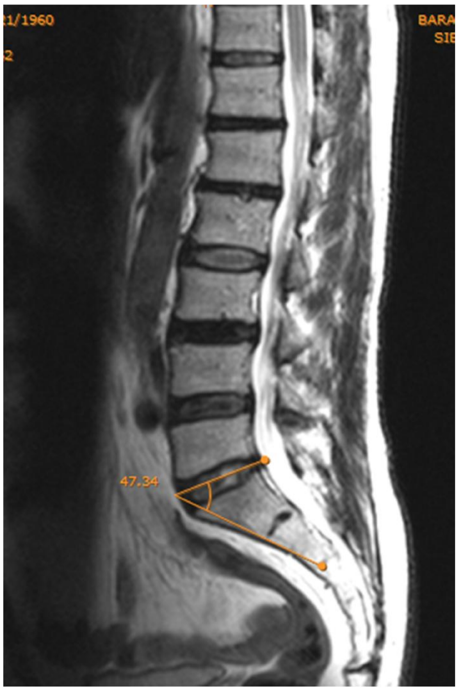
Table (A-3): Classification Function Coefficients

	Status	
	Abnormal	Normal
Cobb angle	.570	1.017
BodyL4	4.364	3.942
IVDspaceL3	2.346	1.612
Gender	56.986	60.372
Age	.261	.078
Height	3.353	3.506
BMI	.755	.556
(Constant)	-408.997	-435.102

Fisher's linear discriminant functions

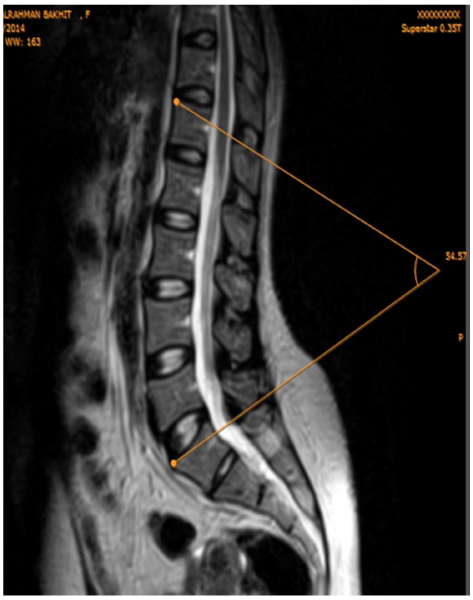
Appendix B:

Measurements:



Lumbosacral Angle

V.B height of L3 and IVD height L4-L5

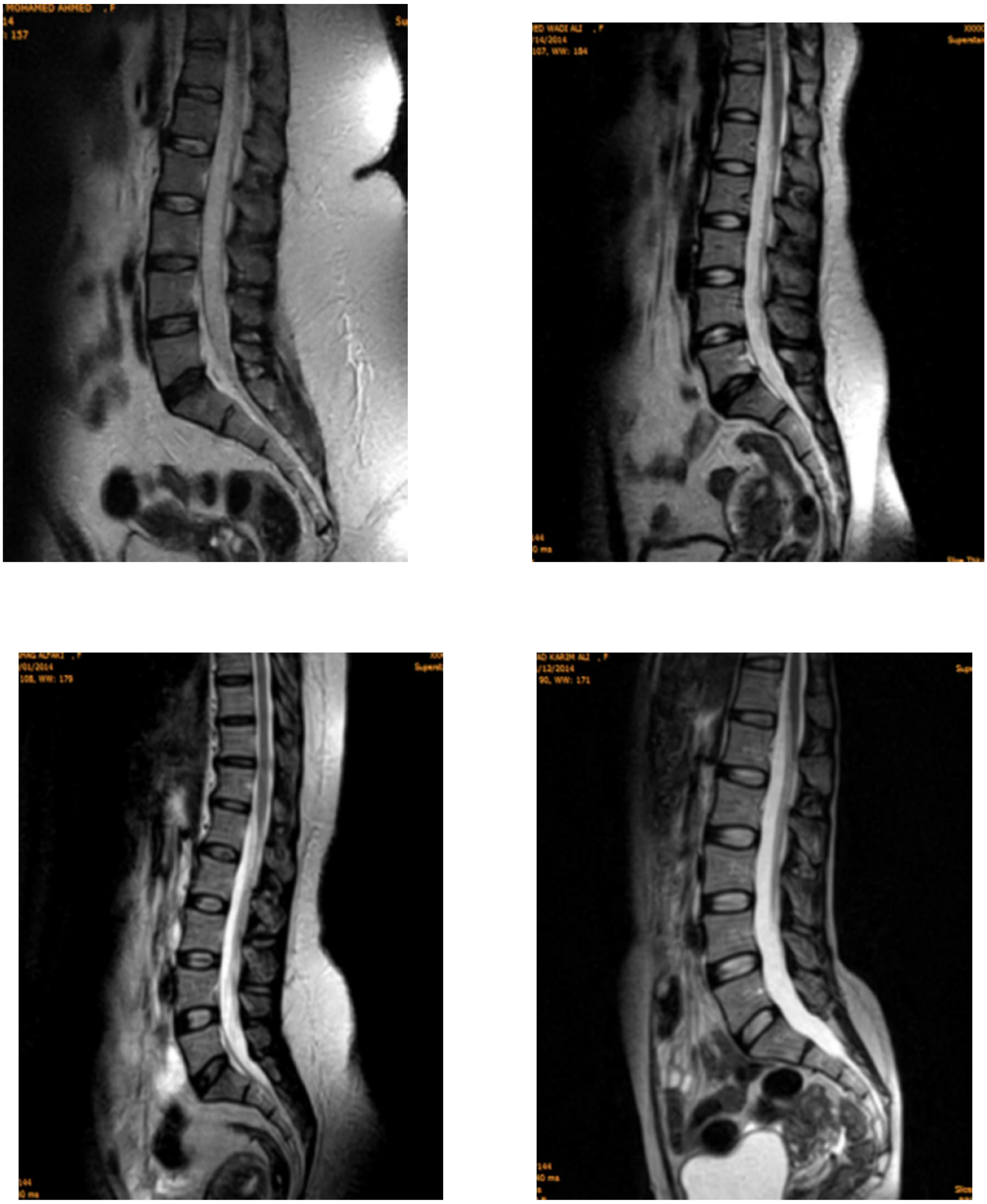


Cobb Angle

disc bulge at L5-S1 level

Appendix C:

Normal MRI lumbar spine sagittal T2 W images



Appendix D:

MRI lumbar spine sagittal T2W images with disc bulge at different levels


, 09/30/1969
/2014
WW: 344
BARAHA MEDI
SIEMENS S


mohamad, F, 09/23/1977
9/23/2014
4, WW: 632
BARAHA ME
SIEMENS


ALSHAIKH ALI , F
11/05/2014
L: 96, WW: 165
Sup
2/144


, 09/30/1969
/2014
WW: 344
BARAHA MEDIC
SIEMENS Sy
Slice Thi

Appendix E:
Table (E-1) Patient data sheet

Age	Height	Gender	Weight	Name	Case No.
					1
					2
					3
					4
					5
					6
					7
					8
					9
					10
					11
					12
					13
					14
					15
					16